Groundwater quality assessment using nitrate pollution index (NPI): Case study in Doukkala-Abda Region, Morocco

EL-Haji Sarra*, Imane Bedoui* , Nadia Aghrib*, Mustapha Lebkiri, Dounia Challi*, Hefdhallah Alaizari***, Mohamed Fadli*.**

[*]Laboratory of Plant, Animal and Agro-Industry Productions, Faculty of Sciences Kenitra, Ibn Tofail University, Kenitra, Morocco.

[**]Laboratoire des matériaux avancés et génie des procédés Faculté des sciences de kenitra

[***] Department of Chemistry, Faculty of Education, University of Dhamar, Yemen.

Abstract

Nitrate is among the most important elements in water that play a vital role in its quality. The current research was proposed to evaluate the groundwater quality for drinking purposes in region of Doukkala, Morocco. This study aimed to identify the pollution level of nitrate compounds using Nitrate Pollution Index (NPI) method for 97 groundwater samples. The result of the NPI showed the following: 24.8% of the sample sites was very good, 21.6% of the sample sites was good, 12.4% of the sample sites was moderate status, 13.4% of the sample sites was poor status, and 27.8 % of sample locations was bad status type of pollution. It shows from this study that it is necessary to implement strategies to protect groundwater resources against nitrate pollution in region of Doukkala. And also educating farmers about the excessive use of fertilizers and their components, and their dire consequences for humans.

Key words: NPI, Groundwater Quality, Region of Doukkala, Morocco.

I. Introduction

Water covers nearly 70% of the Earth's surface and fresh water contains 3%. However, this resource is not evenly distributed throughout the world, as is the case with demand [1]. The problem of water pollution is one of the most important problems in the world and must be dealt with very seriously because this problem is related to human health, development and economy. It is a great blessing from God and must be preserved because it is very important for life [2]. Many technological changes have taken place in the agricultural sector in Morocco. The side effect of these technological efforts is manifest in the nitrate pollution of groundwater and its severe adverse effects on human health. The groundwater resources contaminated with high levels of nitrate (>50 $mg1^{-l}$ as NO_3^-) are an environmental hazard. The high concentration of nitrate ions in water has negative effects on humans and animals, as the accumulation of nitrate in plant tissues and consequently its transfer to animals increases their health risks and potential for humans [2]–[4]. Drinking water is contaminated with nitrate, converting nitrate in the microbial gut into nitrite, which reacts with the iron hemoglobin in red blood cells, leading to the formation of methemoglobin, which leads to a condition known as methegs lob in emia (So-called blue baby syndrome), in which the capacity of the blood decreases To carry enough oxygen to the cells of the body. Especially children under the age of one year, who are most susceptible to methemoglobinemia (Met Hb). Reduction of nitrate ions to nitrite by elevated gastric bacteria can affect the elderly, some patients and infants due to low gastric acidity [5], [6]. In recent years, excessive use of nitrogen fertilizers i inwater bodies increase with the increase of human activity, industrial production, domestic sewage discharge are the main source of high nitrate concentration in groundwater[3], [7]–[10]. The aim of this study is to evaluate of drinking suitability of groundwater by method of nitrate pollution index (NPI) in Doukkala-Abda, Morocco.

Study area

The Doukkala-Abda region located between the governorates of Safi and El Jadida, a coastal region that is divided into two large regions on the coast and Doukkala, located latitudes 33°2.451' and 33°15.798' N and longitudes 8°29.150' and 8°39.082' W. ' covers an area of about 7,700 km 2 and a length of 150 km of coastline (Figure 1). It is bordered on the west by the Atlantic Ocean, on the north and east by Wadi Umm al-Rabi, the south, and southwest of Al-Abdah, West Atlantic, and to the south-east, the Rehamna massifs [11], [12]. The altitude range of the study area is comprise between 120-300 m from the coast and the foot of Rihamna Mountain. The climate is coastal and has continental influences and maritime in the hinterland. Rainfall, concentrated in autumn and winter, decreases slightly from the coast to the interior with an average annual 380 mm in 2016-2018. Temperatures are moderate with monthly averages between 18 ° C and 23 ° C and an annual average of 21.5 ° C for the entire basin of the Sahel-Doukkala. The main outlets for runoff temporary superficial are the Oued "Faregh" andthe Wadi "Fel Fel"[11]. The geology of the study area belongs to the Moroccan coastal mesita and consists of secondary and tertiary sediments that settle on the primary layer strongly folded by the Hercynian[1], [13]–[15].

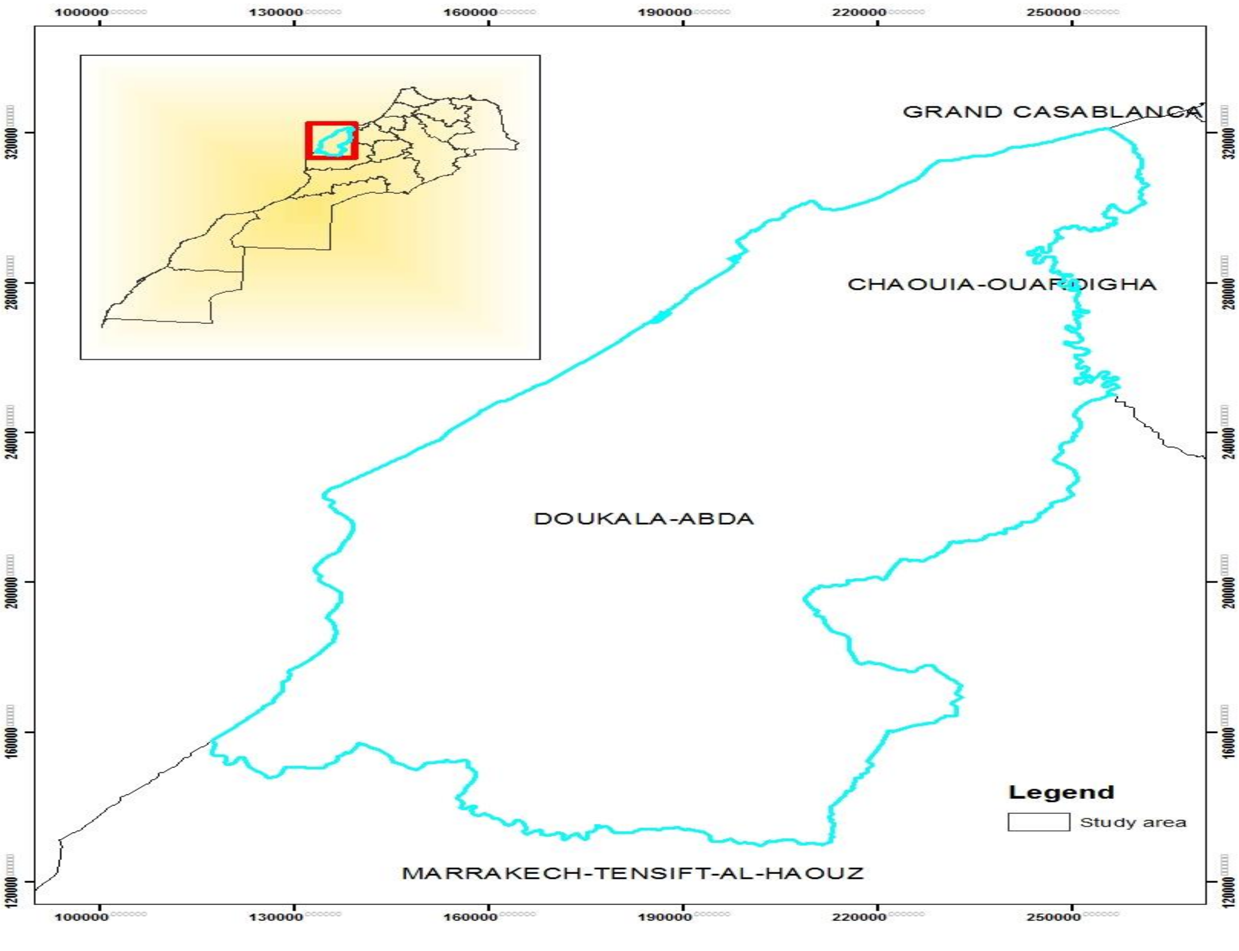

Figure1: Study area

II. Method and materiel

1. Sample collection and processing

The study samples were taken in 2018 in the Doukkala Coast region, where 97 samples of groundwater were collected, and the selected samples represented the spatial variation of the quality of groundwater in the study area. (Fig. 1). Water levels were measured using a 100 m pressure gauge. At the site, the electrical conductivity (EC), temperature, and pH of the groundwater were measured using multipurpose portable meters (CON 150. The samples were transported into polyethylene bottles with a capacity of 250 ml, according to Rodier's protocol, and stored at 4 ° C and in the lab were analyzed the groundwater samples for the required elements. Where, Cl^- was analyzed using titration methods, while $NO3^-$ was determined using a visible UV absorption spectrophotometer. [16]–[19]

2. Nitrate Pollution Index (NPI) methodology.

Nitrate is one of the most important elements in water, which plays a vital role in its quality. It is important and necessary to check and evaluate the percentage of nitrates in the water.it can the NPI be measured using the following equation 1 in order to investigate groundwater pollution by nitrate.[20]

$$NPI = \frac{Cs - HAF}{HAF} \quad \ldots\ldots 1$$

Where, C_s is the concentration of nitrate and HAF is the human acceptable value of nitrate and is taken as 20 mg/L.

Table1: The results of water samples

Variable	Max(mg/l)	Min(mg/l)
Cl^-	1409	14
$NO3^-$	227	2.3
CI/NO3	87.8	0.2
NPI	69.5	-0.3

III. Results and discussion

The results of groundwater analysis in the study area showed significant variation in nitrate concentration in the samples taken. Where the concentration of nitrate (NO_3^-) ranges from 1.5 ppm to 227 ppm (Table 1), and it was the lowest value for nitrate concentration (1.5 ppm) for well sample W-30. Interestingly, well samples contained higher concentrations of nitrate; The highest concentration of 227ppm was for sample W-10, (Figure 2). Where the concentration of chloride in the study samples ranged between 14 and 1409mg/l, and the lowest concentration of chloride was in well 2 and the highest concentration of chloride in well 94, and this indicates that the water source is Hilt (Figure 3).

The results showed 5 samples with higher values of nitrogen dioxide and a higher concentration of Cl^-, which indicates compost as a possible source. While other samples contain a high concentration of chlorine compared to the concentrations of NO_3^-, which indicates the source of chloride may be a geological source where the effect of groundwater can be attributed to high concentrations of chlorine in the surface water or it may be the most likely sources are unidentified sources of fertilizers (KC1).

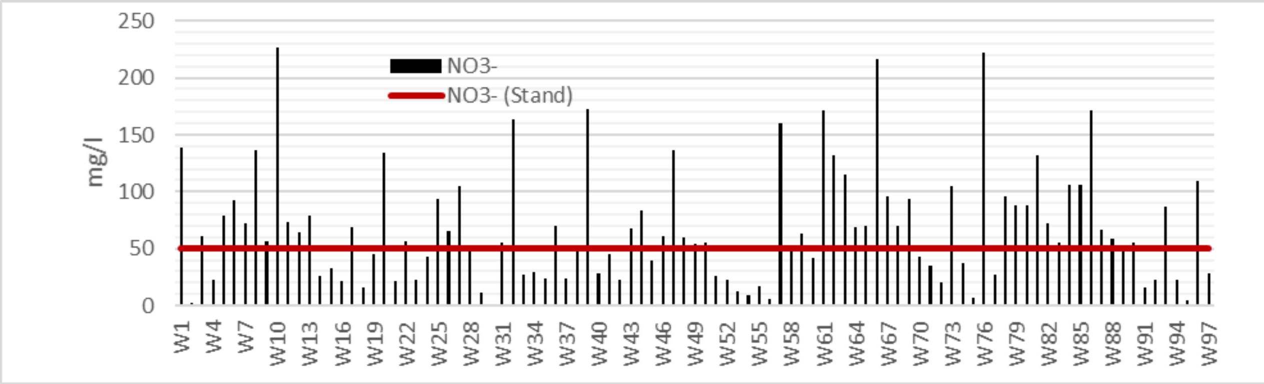

Figure 2: Concentration of nitrate

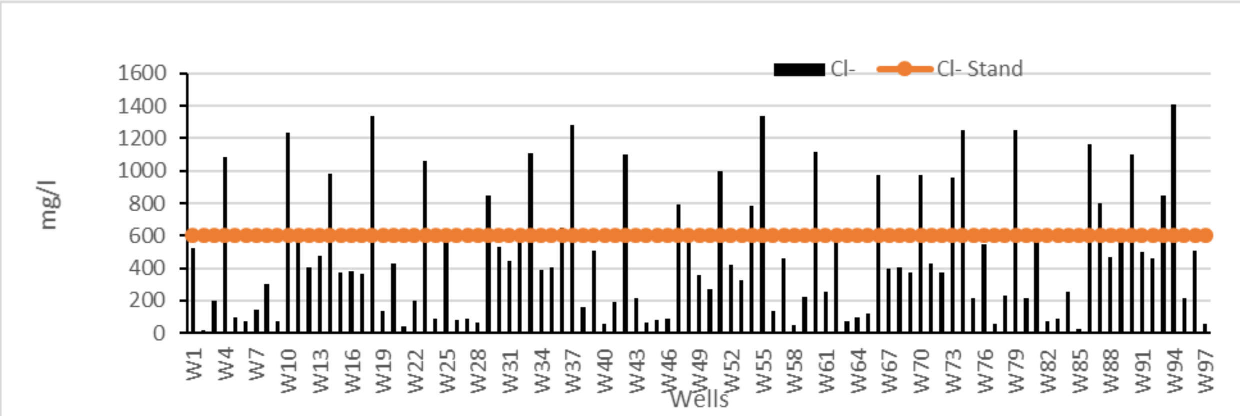

Figure 3: Concentration of Chloride

The $C1^-/NO_3^-$ ratio of the study samples in the region shows a variance between 0.2 to 87.8 (Figure. 4). Groundwater samples collected near deep wells have very high $C1^-/NO_3^-$ ratios, indicating chloride inputs from geologic sources or saline surface waters. Where, it represent the high $C1^-/NO_3^-$ ratios the majority of wells. In general, the well samples in the study area show a large variation in the $C1^-/NO_3$- ratio. Nitrogen loss is due to uneven use of fertilizers due to denitrification, removal of more nitrogen than chlorides by harvested crops and fertilizers, affecting the use of shallow wells in adjacent land, and different types of fertilizes.

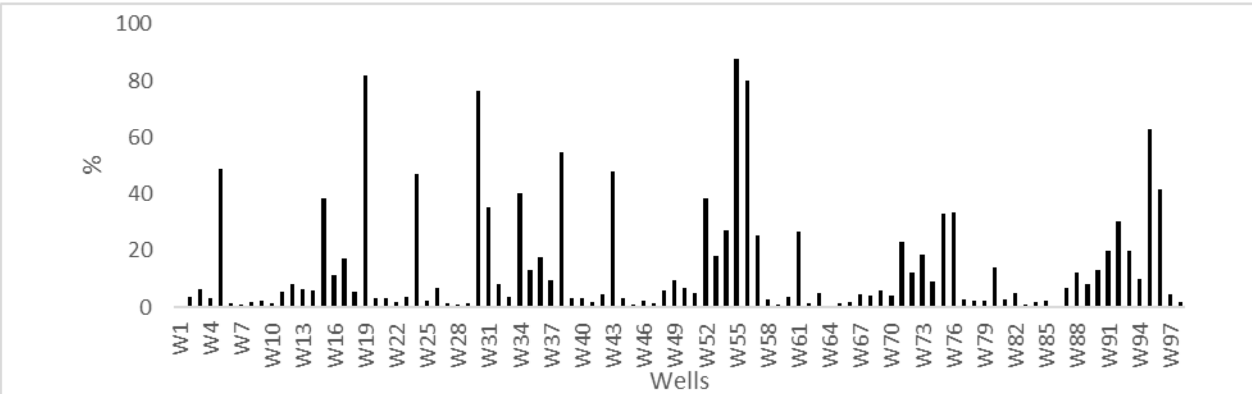

Figure 4: The rate of Cl^-/NO_3^-

Nitrate Pollution Index (NPI)

NPI is an indicator for assessing the level of pollution in water caused by high concentration.

Table3. NPI classification of groundwater.

Classification of NPI	Type of pollution	Number of wells	%
<0	Very good	24	24.8
0-1	good	21	21.6
1-2	Moderate status	12	12.4
2-3	Poor status	13	13.4
>3	Bad stats	27	27.8

Groundwater is classified in Table 3, according to the nitrate pollution index. In the study area, where NPI values range from -0.9 to 10.35, with a mean of 2.4. About 24.8% of the sample sites was very good, 21.6% of the sample sites was good, 12.4% of the sample sites was moderate status, 13.4% of the sample sites was poor status, and 27.8 % of sample locations was bad status type of pollution (Figure 5).

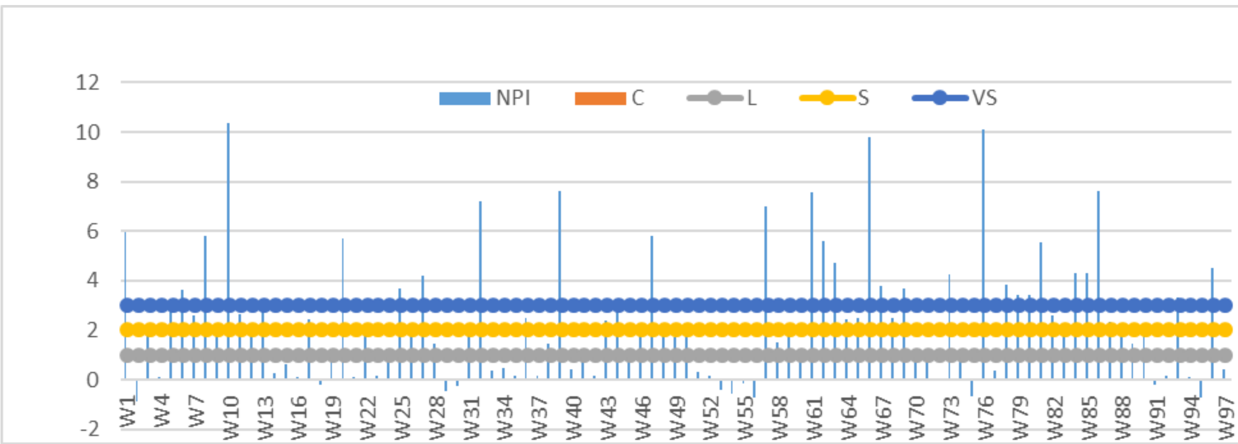

Figure 5: value of NPI

Sources of nitrate in groundwater

Shallow aquifer limestone-dominated formations are the most important groundwater in the Doukkala areas. However, the upper parts of these aquifers are highly susceptible to pollution from land-use practices. In some irrigated areas in Doukkala, due to excessive use of fertilizers and water, and the potential for contamination of groundwater by agricultural chemicals is high. Studies performed in 2005, and 2016 have shown higher concentrations of nitrate in the groundwater from the areas with heavily fertilized crops such as potatoes, corn, etc in the same study area. [12].

There are studies in a number of countries conducted on groundwater pollution with nitrates as studies by There are some types of fertilizers: urea, CO (N**H**$_2$**), KC1 potash and phosphate** [21]–[23]. The solubility of urea and potash is very high in water and soil, which in turn affects the quality of groundwater. It can appear as follows:

$CO(NH_2)2 + H_2O \rightarrow (NH_4) + 2CO_3$

$NH_4 + H_2O \rightarrow NH_4 + O_2$

$NH4 + 3O_2 \rightarrow 2NO_2^- + 4H^+ + H2O$

$NO_2^- + O2 \rightarrow NO3^-$

From this interaction it is clarified that urea is soluble in water and in soil and converted to ammonium carbonate and then to nitrate. While the solubility of phosphate fertilizers is low.

Avad Hill and Starr & Gilham [24], [25].Higher concentrations of NO_3^- are attributed to sandy aquifers for fertilizers, it was observed that most of the aquifers are distinguished by higher concentrations of nitrates emitted from composting [26]. Report NO_3^- concentrations for limestone aquifers range from 9 to 36 ppm and are comparable. With the values obtained from the current work. Other studies on the pollution of aquifers with nitrates from india includes phyllite - dolomite - quartzite aquifer system.

IV. Conclusion

This study investigated groundwater quality for nitrate in 2018 that varied spatially in a part of the Sahel in Doukkala, Morocco. The strata of this area consist mostly of fractured rock and karst limestone in the Cenomanian period. The results of the samples taken showed high concentrations of NO3- in groundwater, which suggests that fertilizers are the main source of nitrates. Adequate data must be created on water quality, especially on the concentration of nitrates in water to avoid the dangerous health effects of nitrates NO3-. Therefore, it is necessary to pay attention and protect groundwater from such problems. Therefore, the current study confirms this and recommends decision-makers take the necessary measures to protect groundwater in the study area and to raise awareness among farmers of the excessive use of fertilizers and their serious consequences for human.

References

V. R. E. Mbaki, A. Boukdir, P. M. Okandza, A. Elissami, A. Zitouni, And E. Sabri, "Estimation Of The Recharge Potential Of Aquifers In The Sahel-Doukkala Region (Morocco)," *J. Water Sci. Environ. Technol.*, Vol. 2, No. 1, 2017.

[2] N. Al-Hamdany, Y. Alshaker, And A. Al-Saffawi, "APPLICATION OF NITRATE POLLUTION INDEX (NPI) TO EVALUATE THE HEALTH SAFETY OF WELLS WATER FOR SOME QUARTERS OF THE LEFTSIDE OF MOSUL CITY, IRAQ," Pp. 6063–6068, Jan. 2020.

[3] M. Nujić And M. Habuda-Stanić, "Nitrates And Nitrites, Metabolism And Toxicity," *HRANA U Zdr. Boles. FOOD Health Dis.*, P. 63, 2017.

[4] M. Parvizishad, A. Dalvand, A. H. Mahvi, And F. Goodarzi, "A Review Of Adverse Effects And Benefits Of Nitrate And Nitrite In Drinking Water And Food On Human Health," Vol. 6, No. 3, *Health Scope*, 2017, Pp.48-89.

[5] A. A. Al-Safawi And A. Al-Maadidi, "Use Aluminum Plates As Reflectors In Sewage Treatment By Solar Radiation," Vol. 27, No. 3, *J. Educ. Sci.*, 2018, Pp. 1–18.
Doi: 10.33899/Edusj.2018.159316.

[6] D. M. Manassaram, L. C. Backer, R. Messing, L. E. Fleming, B. Luke, And C. P. Monteilh, "Nitrates In Drinking Water And Methemoglobin Levels In Pregnancy: A Longitudinal Study," Vol. 9, No. 1, *Environ. Health*, 2010, Pp. 1–12.

[7] M. S. Aulakh, M. P. S. Khurana, And D. Singh, "Water Pollution Related To Agricultural, Industrial, And Urban Activities, And Its Effects On The Food Chain: Case Studies From Punjab," Vol. 10, No. 2,*J. New Seeds*, 2009, Pp. 112–137.

[8] A. Dawood, "Using Of Nemerow's Pollution Index (NPI) For Water Quality Assessment Of Some Basrah Marshes, South Of Iraq," Vol. 25,*J. Babylon Univ. Sci*, 2017, Pp. 1708–1720.

[9] N. Khatri And S. Tyagi, "Influences Of Natural And Anthropogenic Factors On Surface And

Groundwater Quality In Rural And Urban Areas," Vol. 8, No. 1, *Front. Life Sci,* 2015, Pp. 23–39.

[10] Y. Yang, Z. Meng, And W. Jiao, "Hydrological And Pollution Processes In Mining Area Of Fenhe River Basin In China," Vol. 234, *Environ. Pollut,*2018, Pp. 743–750.

[11] I. E. Adnani, A. Younsi, K. I. Namr, A. El Achheb, And E. M. Irzan, "Assessment Of Seasonal And Spatial Variation Of Groundwater Quality In The Coastal Sahel Of Doukkala, Morocco.," Vol. 19, No. 1, *Nat. Environ. Pollut. Technol.*, 2020.

[12] I. El Adnani, A. Younsi, K. Ibno Namr, A. El Achheb, And E. M. Irzan, "The Influence Of Anthropogenic Activities On Groundwater Quality Of Southwest Region Of El Jadida City (Sahel Of Doukkala, Morocco)," Vol. 151, *Eur. J. Sci. Res.*, 2018, Pp. 96–111.

[13] N.-E. Laftouhi *Et Al.*, "Groundwater Nitrate Pollution In The Essaouira Basin (Morocco)," Vol. 335, No. 3, *Comptes Rendus Geosci,* 2003, Pp. 307–317.

[14] A. H. Mahvi, J. Nouri, A. A. Babaei, And R. Nabizadeh, "Agricultural Activities Impact On Groundwater Nitrate Pollution," Vol. 2, No. 1, *Int. J. Environ. Sci. Technol,* 2005, Pp. 41–47.

[15] B. Panneerselvam, S. Karuppannan, And K. Muniraj, "Evaluation Of Drinking And Irrigation Suitability Of Groundwater With Special Emphasizing The Health Risk Posed By Nitrate Contamination Using Nitrate Pollution Index (NPI) And Human Health Risk Assessment (HHRA)," Vol. 27, No. 5, *Hum. Ecol. Risk Assess. Int. J,*2020, Pp. 1324–1348.

[16] W. G. Walter, "Standard Methods For The Examination Of Water And Wastewater." American Public Health Association, 1961, Pp.152.

[17] G. Miner, "Standard Methods For The Examination Of Water And Wastewater," Vol. 98, No. 1*Am. Water Works Assoc. J.*, 2006, Pp. 130.

[18] J. Rodier, B. Legube, And N. Merlet, "L'Analyse De L'eau 9e Edition," *Entièrement Mise À Jour Dunod Paris*, 2009.

[19] R. B. Baird, "Standard Methods For The Examination Of Water And Wastewater, 23rd." Water Environment Federation, American Public Health Association, American, 2017,Pp.350-420.

[20] B. Panneerselvam, S. Karuppannan, And K. Muniraj, "Evaluation Of Drinking And Irrigation Suitability Of Groundwater With Special Emphasizing The Health Risk Posed By Nitrate Contamination Using Nitrate Pollution Index (NPI) And Human Health Risk Assessment (HHRA)," Vol. 27, No. 5*Hum. Ecol. Risk Assess. Int. J,*2021, Pp. 1324–1348.

[21] G. Houben, T. Tünnermeier, N. Eqrar, And T. Himmelsbach, "Hydrogeology Of The Kabul Basin (Afghanistan), Part II: Groundwater Geochemistry," Vol. 17, No. 4, ,*Hydrogeol. J,* 2009, Pp. 935–948,. Doi: 10.1007/S10040-008-0375-1.

[22] V. Houzim, J. Fuksa, V. Pekny, J. Vrba, And J. Stibral, "Impact Of Fertilizers And Pesticides On Groundwater Quality," Vol. 5,*Impact Agric. Act. Ground Water Int. Contrib. Hydrogeol.*, 1986, Pp250.

[23] D. Murgulet And G. R. Tick, "Assessing The Extent And Sources Of Nitrate Contamination In The Aquifer System Of Southern Baldwin

County, Alabama," Vol. 58, No. 5, *Environ. Geol*, 2009, Pp. 1051–1065.

[24] A. R. Hill, "Nitrate Distribution In The Ground Water Of The Alliston Region Of Ontario, Canada," Vol. 20, No. 6,*Groundwater*, 1982, Pp. 696–702.

[25] R. C. Starr And R. W. Gillham, "Denitrification And Organic Carbon Availability In Two Aquifers," Vol. 31, No. 6,*Groundwater*, 1993, Pp. 934–947.

[26] B. R. Pearce And P. BR, "Fractured Rock Aquifers In Central Queensland," 1982, Pp. 95-120.

AUTHORS

EL-Haji Sarra (PhD Candidate)

sarraelhaji@gmail.com

Laboratory of Plant, Animal and Agro-Industry Productions, Faculty of Sciences Kenitra, Ibn Tofail University, Kenitra, Morocco

Imane Bedoui (PhD Candidate)

bedouiimane@gmail.com

Laboratory of Plant, Animal and Agro-Industry Productions, Faculty of Sciences Kenitra, Ibn Tofail University, Kenitra, Morocco

Nadia Aghrib(PhD Candidate)

aghribnadia1@gmail.com

Laboratory of Plant, Animal and Agro-Industry Productions, Faculty of Sciences Kenitra, Ibn Tofail University, Kenitra, Morocco

Mustapha Lebkiri (PhD)

maamoun2008@h**rocco**otmail.fr

Laboratoire des matériaux avancés et génie des procédés Faculté des sciences de kenitra

, Dounia Challi(PhD Candidate)

challidounia6@gmail.com

Laboratory of Plant, Animal and Agro-Industry Productions, Faculty of Sciences Kenitra, Ibn Tofail University, Kenitra, Morocco.

Hefdhallah Alaizari(PhD)

Alaizari2@gmail.com

Department of Chemistry, Faculty of Education, University of Dhamar, Yemen.