International Research Journal of Environmental Sciences ISSN 2319–1414
Vol. **15(1),** 1-6, January **(2026)** *Int. Res. J. Environmental Sci.*

Evaluation of the physico-chemical and bacteriological parameters of groundwater consumed in the rural areas of the commune of save

AÏSSEKOU Carbegie Djidémi Jaël[1], KOUMOLOU Luc Babatoundé[1], YESSOUFOU Arouna[2*], GOUETI Basile[4], ADANLOKONON Elias[1], ELEGBEDE Manou Bernadin[3] and SINA Haziz[4]
[1]Laboratory of Research in Biochemistry and Environmental Toxicology, Department of Biochemistry and Cell Biology, University of Abomey-Calavi, Benin
[2]Laboratory of Applied Hydrology, National Water Institute, University of Abomey-Calavi, Benin
[3]Department of water and Sanitation, National Water Institute, University of Abomey-Calavi, Benin
[4]Laboratory of Biology and Molecular Typing in Microbiology, Department of Biochemistry and Cell Biology, University of Abomey-Calavi, Benin
arouna.yessoufou@gmail.com

Available online at: www.isca.in, www.isca.me
Received 16th September 2025, revised 29th October 2025, accepted 24th November 2025

Abstract

This work focused on the study of the physicochemical and bacteriological quality of water from some boreholes used for drinking water in certain areas located in the commune of Savè (Alafia, Igbodja and Oké-owo) to determine whether they represent a public health risk for these populations. The samples were analyzed at the laboratory of the production department of SONEB in Gobé. The analyses concerned physical parameters such as temperature and electrical conductivity which were measured with a HANNA type conductivity meter, turbidity measured using a HANNA type turbidimeter and pH measured with a HANNA type pH meter; the chemical parameters concerned are, the Total Alkalimetric Title (TAC); Total Hardness (TH); chloride ions (Cl^-); free CO_2; Oxidability; aggressive CO_2 which are volumetric dosages and the dosage of total Iron (Fe^{2+}); Total manganese (Mn^{2+}); Ammonium (NH_4^+); Nitrates; Nitrites (NO^-_3); Sulfates (SO_4^{2-}), which are colorimetric assays. Bacteriological analyses consisted of counting germs and performing a presumptive test. The chemical quality of the sampled borehole waters revealed average mineralization, with average concentrations of calcium, magnesium, chlorides, sulfates, and nitrates of 58.73mg/L, 37.33mg/L, 60.11mg/L, 53.66 mg/L, and 54.66 mg/L, respectively. Furthermore, the hydrometric titration results revealed that all the waters were hard, particularly those from the villages of Alafia and Oké-owo. As for the village of Igbodja, it has a high nitrate level (120 mg/L), so its water poses a risk of methemoglobin for infants and fetuses. The village of Oké-owo, for its part, has a high electrical conductivity level (1091 µs/cm). The other elements present concentrations that meet the WHO and Beninese standards. Iron in the water does not present a worrying level (0.1 mg/L). Furthermore, microbiological analyses reveal results ranging from "0" to "countless" for the detection of common germs, and a "positive" result for the presumptive detection of total coliforms for most of the water analyzed, meaning it is not suitable for consumption. This water therefore poses a risk to consumer health. To protect consumer health, it is urgent that the ANAEPMR expand its activities.

Keywords: Bacteriological analysis, Borehole water, physicochemical analysis, rural environment, Save.

Introduction

Water also known as blue gold, is an essential resource that covers more than 71% of planet Earth[1]. It is the only naturally occurring substance that is present in all three states of matter: solid, liquid, and gas. It is extremely important for all life on Earth, especially human beings, who are made up of 70% of this substance[2]. Water is a part of everyday life, and it is so familiar that we often forget its role, importance, and absolute necessity[1].

After the gold rush and the oil boom, humans learned the importance of this odorless, transparent, and tasteless resource. Humans have recently realized that water resources are deteriorating and will be insufficient for human consumption due to population growth, which is leading to intensive water withdrawal for consumption and also for use in various areas such as industry, irrigation, etc[3]. Natural water resources consist of groundwater and surface water. They are taken for human consumption, agriculture or industry[1].

The quality of water depends largely on its origin. Indeed, surface water, in addition to the substances it naturally contains, is exposed to solid contaminants such as plastics and chemical contaminants such as molecules released by industries or pesticides used in agriculture. On the other hand, groundwater is much less exposed because it is located in depth in the ground. The cost of treating surface water is therefore higher than that of groundwater due to pollution. Aware of this risk, rural populations are implementing drinking water supply systems from boreholes, individually, collectively, or through municipal authorities.

In some cases, no treatment is performed before consumption of the groundwater, although it may be contaminated by undesirable chemicals or microorganisms requiring adequate treatment. The use of raw groundwater as drinking water can therefore pose public health risks in rural areas.

In Benin, the supply of drinking water in urban and peri-urban areas is provided by SONEB, while in rural areas, this responsibility is assumed by the ANAEPMR (National Agency for Drinking Water Supply in Rural Areas). The Beninese government is making efforts to ensure access to drinking water for the entire population by 2030[4]. In rural areas, thanks to the activities of the ANAEPMR, the coverage rate is close to 80%[4]. However, rural areas do not offer favorable conditions for the installation and maintenance of complete raw groundwater treatment systems, as is the case in urban areas[5]. Under these conditions, compliance with drinking water potability standards in these rural areas is not guaranteed. It is in this context that this study aims to assess the physicochemical and bacteriological parameters of groundwater consumed in rural areas of the commune of Savè.

The overall objective is to assess the quality of groundwater treatment prior to consumption in the villages of Alafia, IgboDja, and Oké-Owo in the commune of Savè. More specifically, the aim was to analyze the physicochemical and bacteriological parameters of drinking water; to identify the unsafe drinking water parameters of the analyzed groundwater in accordance with Beninese standards and WHO guidelines; and finally, to identify the causes and consequences related to the quality of drinking water in the villages of Alafia, Igbodja, and Oké-owo in the commune of Savè. To conduct this study, we visited one of the branches of the National Water Company of Benin (SONEB), specifically the Gobe treatment plant.

Materials and Methods

Geographic Location of the Study Area: The commune of Savè is located in the Collines department, covering an area of 222,800 hectares (2,228 km²). According to the results of the RGPH4 (Regional Regional Planning and Statistics), conducted in 2013, the commune's population is 87,177. It comprises eight districts subdivided into 60 villages and neighborhoods. Save, the capital of the commune, is approximately 255 km from Cotonou. It is crossed by the RNIE 2 and RNIE 5 (Savè-Oké-Owo). Its coordinates are 8° 01’ 59’’ north latitude, 2° 29’ 01’’ east longitude with an average altitude of 250 m above sea level. The village of Alafia is located in the district of Kaboua, that of Igbodja in that of Bessé and finally that of Oké-owo in that of Okpara[6].

This commune has a subequatorial climate characterized by two rainy seasons and two dry seasons. However, recently, this climate has given way to a tropical Sudanese climate characterized by one rainy season and one dry season. Average rainfall is 1,100 mm per Year[6].

The commune's hydrographic network is approximately 147 km long and consists of numerous rivers that collect water towards the Ouémé River and its main tributary, the Okpara. In addition, numerous streams flow through the commune.

The population of this commune is estimated at 87,177 inhabitants according to the RGPH (Regional Regional Planning and Statistics) of May 4, 2013, with 43,420 women and 43,757 men. The average density is 39inhabitants/km². Several sociocultural or ethnic groups coexist in the commune where the Shabè are the majority. There are also the Fons, the Idaasha, the Fulani, the Adjas, etc. Several religions are practiced there such as Catholicism, Islam, Protestantism, animism etc[6].

Experimental method: Selection of the sampling site: The selection criteria for these villages were based primarily on the fact that they do not use water distributed by SONEB and, secondly, on the population's high traffic volume at the water points of the boreholes in question.

Sampling technique: Before sampling, all materials used for collecting water samples (bottles and flasks) were thoroughly rinsed with tap water in the laboratory and sterilized. In the field, care was taken to sterilize the tap to be used for sampling using alcohol and cotton wool. The materials were then rinsed at least two to three times with the water to be sampled. Afterward, the sampling itself was carried out, ensuring that no air bubbles formed. The same procedure was repeated for all samples except for the bacteriological analysis, where the bottles were not filled to the brim. We had to conduct two sampling campaigns for the bacteriological analysis with 12 (twelve) samples per campaign and for the physicochemical analysis we had to conduct one campaign consisting of 06 (six) samples[7]. All parameters are measured at the SONEB laboratory.

The physicochemical analysis consists of analyzing the physical parameters on the one hand and the chemical parameters on the other hand. The physical parameters analyzed include pH; turbidity; temperature and conductivity. As for the chemical parameters, we have the volumetric assays which are the Total Alkalimetric Title (TAC); the Alkalimetric Title (TA); the Total Hardness (TH); the determination of chloride ions (Cl^-); free CO_2; oxidizability; aggressive CO_2 and the colorimetric assays which are the determination of total iron (Fe^{2+}); total manganese (Mn^{2+}); ammonium (NH_4^+); Nitrates; nitrites (NO_3^-); sulfates (SO_4^{2-}). The bacteriological analyses performed are: the enumeration of germs on solid media and the presumption of coliform germs on liquid media.

Statistical analysis: The collected data and analysis results were entered and processed using Excel spread sheets.

Results and Discussion

Results of physicochemical analyses are given in Table-1.

Table-1: Table of physicochemical results.

Parameters	Alafia (06/11/2024)	Igbodja (13/11/2024)	Oke-Owo (13/11/2024)
pH	6.9	6.78	7.45
Conductivity (Cond in µs/cm)	705 µs/cm	635 µs/cm	1091 µs/cm
Temperature (°C)	27°C	30.8°C	31.1°C
Turbidity (NTU)	0.45 NTU	0.42 NTU	0.44 NTU
Free CO_2 (mg/L)	72.16 mg/L	42.24 mg/L	3.52 mg/L
TAC (°f)	34 °f ; 414.8 mg/L	19.8°f ; 241.56 mg/L	15.2°f ; 185.44 mg/L
Chloride (mg/L)	1.6 °f ; 11.36 mg/L	95.14 mg/L	73.84 mg/L
Total hardness (TH in °f and mg/L)	31.328 °f ; 313.28 mg/L	38.27°f ; 382.7 mg/L	20.8°f ; 208.26 mg/L
Calcium hardness (mg/L)	66.348 mg/L	66.34 mg/L	43.51 mg/L
Magnesium Hardness (mg/L)	35.468 mg/L	50.60 mg/L	25.95 mg/L
Oxidity (mg/L of $KMnO_4$)	0.74 mg/L de $KMnO_4$	0.814 mg/L de $KMnO_4$	0.296 mg/L de $KMnO_4$
Fe^{2+} /Fe^{3+} (mg/L)	0.1 mg/L	<0.1 mg/L	<0.1 mg/L
Nitrite (mg/L)	0 mg/L	0 mg/L	0.01mg/L
Nitrate (mg/L)	4mg/L	120 mg/L	40 mg/L
Sulfate (mg/L)	<25 mg/L	110 mg/L	26 mg/L
Manganese (mg/L)	0.15 mg/L	0 mg/L	0 mg/L
Ammonium (mg/L)	0 mg/L	0 mg/L	0 mg/L
Aggressive CO_2 (°f or mg/L)	1.2 °f ; 5.28 mg/L	2.2°f ; 9.68 mg/L	-0.2°f (dirty water)

Temperature: Temperatures range from 27°C in the village of Alafia, to 30.8°C in the village of Igbodja, and to 31.1°C in the village of Oke-Owo.

The temperature and its variation depend on the aquifer type as well as the groundwater regime, aquifer depth, and surface water-groundwater interaction[8].

Hydrogen Potential (pH): The pH values found for water are 6.9 in the village of Alafia; 6.78 and 7.45 in the villages of Igbodja and Oke-Owo, respectively. These values fall within the neutrality range, which is the norm in Benin and is $6.5 < pH < 8.5$. Hydrogen Potential (pH) does not directly affect the health of consumers; but it is one of the most important operational parameters for determining whether water is potable or not[9].

pH balance: The pH values in equilibrium are respectively 6.82; 6.86 and 7.34 in the villages of Alafia; Igbodja and Oké-owo. The difference between this pH in equilibrium and the pH of the water allowed us to define the carbonic carbonic balance ($CaCO_2$) of the waters of these villages. After this difference, the water of the villages of Alafia and Igbodja was described as aggressive water and that of the village of Oké-owo as scaling. These so-called aggressive waters contribute to the corrosion of the metal parts (pipes, taps etc.) of a network, which is therefore likely to contain toxic or undesirable metals such as lead, copper, cadmium etc. These waters can also dissolve limestone and scale (calcium or magnesium carbonate). Scaling waters are waters that have a high concentration of limestone, which leads to scaling, which consists of the deposit of lime scale inside the pipes, to a drop in flow in the pipes and they help prevent corrosion of metals. These waters do not represent a danger to our health but rather they provide the body with additional limestone.

Electrical Conductivity: The values obtained after measuring conductivity in these environments are 705µs/cm; 635µs/cm; and 1091µs/cm, respectively, in the villages of Alafia, Igbodja, and Oke-Owo; this is significantly higher than the Beninese standard, which is between 200 and 250µs/cm.

Achieving high electrical conductivity depends on the decomposition and mineralization of endogenous and exogenous organic matter present in the environment, thus generating salts[10]. Conductivity also varies depending on the geological substrate crossed. High conductivity is not harmful to health but can have a negative effect on water quality because the higher it is, the greater the quantity of impurities (dissolved substances, chemicals, and minerals) in the water.

Turbidity: After analyzing the village water sample, we observed turbidity values of 0.45 NTU, 0.42 NTU, and 0.44 NTU for the villages of Alafia, Igbodja, and Oke-Owo, respectively. These values are well below the WHO standard for Benin, which is <5 NTU, and are therefore acceptable. Water with visible turbidity reduces the acceptability of the water as potable. Although most particles that contribute to turbidity have no impact on human health[9], low turbidity helps reduce the amount of reagent required during treatment. Furthermore, the absence of suspended matter helps reduce the presence of microorganisms, as they generally attach to suspended solids.

Alkalinity or Total Alkalimetric Title (TAC): The total alkalinity results obtained were 34°F or 414.8mg/L ; 19.8°F or 241.56mg/L ; and 15.2°F or 185.44mg/L, respectively, in the villages of Alafia, Igbodja, and Oke-Owo. These results are well above the Beninese standard of <8°F, making them unfit for consumption. Alkalinity is related to bicarbonates, so the high alkalinity of this water is due to the high concentration of bicarbonate ions (HCO_3^-), which contributes to better digestion by preventing stomach congestion. However, high alkalinity gives the water an unpleasant taste and can be harmful to human health. It can also cause limescale deposits or mineral buildup in pipes.

Total Hardness (TH): Total hardness, or TH hydrotimetric strength, corresponds to the sum of calcium and magnesium concentrations as a function of calcium carbonate concentration. This is related to the geological formation of groundwater and its chemical components.

The results obtained after analyzing the samples are 31.328°F or 313.28 mg/L in the village of Alafia; 38.27°F or 382.7mg/L in the village of Igbodja; and 20.8°F or 208.26mg/L in the village of Oké-owo. The results obtained are higher than the standard of 200 mg/L, meaning these waters are considered hard water.

Water from limestone and especially gypsum soils can have very high hardnesses, possibly reaching 1 g/L of $CaCO_3$. On the other hand, water from crystalline, metamorphic or schistose terrains will have very low hardness[11]. Hard water has properties that are beneficial to our health by providing mineral salts such as calcium and magnesium which are beneficial for bones and the cardiovascular system but represents a problem for our comfort by causing rough and dull laundry for example or by making the cooking of certain foods very long.

Chloride: The chloride concentration (mg/L) in the village of Alafia is 11.36 mg/L; 95.14 mg/L in the village of Igbodja; and 73.84mg/L in the village of OKE-OWO. These values are below the guideline value, which is 900 mg/L for the WHO standard and 250mg/L for the Beninese standard, and therefore acceptable for consumption.

Chlorides can have multiple origins: either through contamination by wastewater or through the dissolution of salts by leaching from saline soils[12]. These salts dissolve very easily, hence their presence in high concentrations in water that has passed through clay and marl formations. Chlorides impart an unpleasant taste and pose a problem of corrosion in pipes and reservoirs at concentrations above 50 mg/L[9]. Chloride in normal amounts in the body contributes to normal digestion by stimulating the production of hydrochloric acid in the stomach. It also helps maintain the acid-base balance of the blood.

Sulfates: Sulfate concentrations (mg/L) in the analyzed waters were <25 mg/L in the village of Alafia; 110 mg/L in the village of Igbodja; and 26 mg/L in the village of Oke-Owo. The borehole waters are considered to be of good quality, as sulfate levels are below the standards tolerated by Beninese regulations (500 mg/L) and the WHO standard (250 mg/L).

The origin of most sulfate compounds is the oxidation of sulfite ores, the presence of shale, or industrial waste. Some soils and rocks contain sulfate minerals, so when groundwater passes through, the sulfates present dissolve in them[13]. The abundance of sulfates could be the result of the presence of evaporites. Sulfates have very low acute toxicity, however a laxative effect is observed for levels above 1000 mg/L[13].

Nitrates: The nitrate content is 4 mg/L in the village of Alafia; 120 mg/L in the village of Igbodja; and 40 mg/L in the village of Oke-Owo. It should be noted that the acceptable standard in Benin is 45 mg/L and that of the WHO is 50 mg/L.

In the Igbodja area, which is an agricultural zone, an increase is observed, which can be explained by the probable intensive use of chemical and organic fertilizers in agriculture or by reaching groundwater through runoff from these lands and the decomposition of organic matter[11]. Rainwater may contain nitrates from nitrogen oxides and ammonia present in the atmosphere[11]. The soil in this area does not have the physicochemical properties to retain nitrate, which leads to its easy leaching by rainwater. In addition, the geology of the basin-shaped area associated with an aquifer layer made up of permeable formations (gravel and sand), has favored the immigration of nitrogenous elements towards the saturated zone and the contamination of the latter, thus playing a primordial role in the distribution of nitrates. The excess of nitrate in these waters represents a danger for the health of these consumers, particularly infants and fetuses. Indeed, the presence of these nitrates in the blood can cause methemoglobinemia which corresponds to the oxidation of blood hemoglobin (red blood cell) into methemoglobin incapable of ensuring the transport of blood oxygen to the tissues which can cause death by asphyxiation in infants and fetuses.

Nitrites: Analysis showed a complete absence of nitrites in the borehole waters of the villages of Alafia and Igbodja, and a concentration of 0.01 mg/L in the village of Oke-Owo. All concentrations were below the national and international limit value of 0.1 mg/L.

It is important to note that water in contact with certain soils may contain nitrites. They are also found in oxygen-deficient waters and are toxic to living beings. They transform hemoglobin in the blood into a similar substance, methemoglobin, which no longer plays its role in the oxygenation of cells and tissues[14].

Ammonium: Analysis showed a complete absence of ammonium in all borehole waters. The presence of ammonium is usually considered a sign of pollution, as this form of nitrogen only exists in water rich in decomposing organic matter, especially when the O_2 content is insufficient to transform it into (NO_3^-) ions[15]. The presence of ammonium in water is linked to the reduction of nitrogen forms (nitrates and nitrites) under reduced conditions.

Iron: Iron is one of the most abundant elements in soil. According to analyses, a concentration of 0.1 mg/L was observed in the water of the village of Alafia and a concentration <0.1 mg/L in the water of other villages. Iron is an unsightly element, generally present in groundwater, generating undesirable colored precipitates. Its origin is either natural (rock weathering) or industrial (mining or metallurgy activities)[16]. The low iron content observed allows us to deduce that it is not the result of pollution but rather natural.

Bacteriological Analysis Results: For the bacteriological analyses, two samples were taken at each sampling point in each village. The readings were taken after 24 and 48 hours.

The analysis of the first samples in the village of Alafia revealed that despite the lack of chlorine in this water, its consumption was safe, as these results were in compliance with Beninese standards. However, the results obtained from the analysis of the second samples revealed non-compliance with the standard, with presumptively positive tests at all sampling points except the first, which remained compliant. The analysis of the first samples in the village of Igbodja reveals non-compliant results with uncountable colonies of germs, with positive presumptive tests at points 1 and 2, 16 colonies of germs with a positive presumptive test at point 3 and 10 in the presence of champion with a positive presumptive test at point 4. The analysis of the second samples shows that the four (04) points are positive in the presumptive test with a number of germ colonies of 6 for point 1, 18 for point 2, uncountable for point 3 and finally 15 in the presence of champion for point 4. This water does not comply with the standards. The absence of a disinfectant in this water has favored the development of these micro-organisms.

The analysis of the first samples in the village of Oké-Owo shows that all the other points except point 4 are positive in the presumptive test with point 1 which groups together 12 colonies of germs in the presence of champion, point 2 which presents 20 colonies of germs in the presence of champion, point 3 which presents innumerable colonies of germs in the presence of champions and finally point 4 presents 6 colonies. The analysis of the second samples shows points 1, 2 and 4 which are positive in the presumptive test. All the points present innumerable colonies of germs. So this water does not comply with the standards in addition we observe a total absence of chlorine.

The specific microorganisms present have not yet been identified, making it impossible to determine whether the water contains total coliforms, fecal coliforms, or fecal streptococci.

Total coliforms (TC): Elevated TC levels reflect a decline in water quality[17]. Such contamination may stem from pollutant discharges, manure, soakaway pits, or chemical fertilizers near boreholes, as well as from inadequate sanitation in the surrounding area. In general, the health risk linked to total coliform bacteria is low, except for certain *Escherichia coli* strains and some opportunistic bacteria capable of causing severe infections in vulnerable individuals[18]. Nonetheless, several studies have demonstrated a link between the presence of total coliforms and the occurrence of waterborne outbreaks[19].

Fecal coliforms: Fecal coliforms, such as *Escherichia coli*, typically originate from animals, including humans. Potential sources include manure, grazing lands, latrines, and wildlife. Their presence can signal contamination by pathogenic microorganisms[20] such as *Salmonella*[21] and Norwalk virus[22]. Fecal coliforms also indicate a potential health risk from waterborne diseases, most commonly presenting as short-lived gastrointestinal symptoms (nausea, vomiting, and diarrhea).

Conclusion

This study allowed us to assess the importance of treating raw groundwater in the villages of Alafia, Igbodja, and Oké-owo in the commune of Savè through a physicochemical and bacteriological characterization of the borehole water.

Physicochemically, the water is hard due to high calcium and magnesium levels, especially in the village of Alafia. However, the water in the village of Igbodja is contaminated by nitrates, and that in the village of Oké-owo has very high conductivity. Not to mention the significant amounts of toxic elements such as nitrites, ammonium, and iron. The analysis results therefore allowed us to conclude that this water does not fully meet the criteria for drinking water. Furthermore, from a bacteriological point of view, these waters do not meet the criteria for drinking water, given that almost all the presumptive tests carried out have proven positive, which can be explained by the lack of hygiene and sanitation of the environment of these water points and storage reservoirs. In any case, whatever the origin of the contamination, an adequate treatment system would have made it possible to ensure compliance with the standards for the potability of water in these villages of the commune of Savè, which was not the case according to the results of the study, confirming the importance of implementing a groundwater treatment system before consumption. In view of all the above, it is necessary that measures be taken by the population and the government so that the objective 6 of the SDGs (SDG 6) in Benin is not limited only to access for all to water in general but rather to access for all to truly potable water, hygiene and sanitation by 2030.

Acknowledgement

To all the staff of the SONEB water production department in Gobé, in particular Mr. KOUWANOU Raymond, who despite his many responsibilities, made himself available to provide supervision throughout our study.

References

1. Garcia E., (2024). The essential role of water: a critical resource for life and sustainability. *J Aquat Pollut Toxicol*, 8, 27, 10.21767/2581-804X-8.3.27

2. Hossain, M. Z., & Floryan, J. M. (2014). Natural convection in a fluid layer periodically heated from above. *Physical Review E*, 90(2), 023015.

3. Touahria K. (2013). Evaluation of the quality of borehole water by comparing its physicochemical characteristics (Tébessa region). Master's thesis. University of Souk Ahras., pp. 12, 13, 28.

4. Anaepmr, (2024). Universal access to drinking water in Benin, semi-annual report (January-June).

5. World Health Organization. (1991). Water supply, sanitation and health in rural areas: report of the second consultation of the WHO Working Group on Water, Sanitation and Health, Geneva, 9-11 April 1991 (No. WHO/CWS/91.5). World Health Organization.

6. Amadou M., (2008). The problem of communication in local governance in Benin: the case of the commune of Save.

7. EPA, U. (2005). Quick guide to drinking water sample collection. *USR Laboratory and Editors*.

8. Schürch M., Monica Bulgheroni, Michael Sinreich, (2009). Groundwater Temperature, Federal Office for the Environment (FOEV). Hydrology Division, p. 44.

9. World Health Organization. (2004). Guidelines for drinking-water quality (Vol.1). World Health Organization.

10. Belghiti, M. L., Chahlaoui, A., Bengoumi, D., & El Moustaine, R. (2013). Etude de la qualité physico -chimique et bactériologique des eaux souterraines de la nappe plio-quaternaire dans la région de Meknès (Maroc). *Larhyss Journal*, (14).

11. Rodier J., (2009). Water Analysis. 9th Edition Fully Updated. *Dunod Paris*, pp. 86, 78, 50.

12. Dib, I. (2009). The impact of agricultural and urban activity on the groundwater quality of the Gadaine plain-Ain Yaghout (East Algerian). *Magister memory in hydraulics, hydro-technical construction and environment, Faculty of Engineering Sciences, hydraulic department, University of Hadj Lakhdar Batna*, *127*.

13. Zouaoui S, (2014). Determination of nitrites, nitrates, sulfates, and orthophosphates in the waters of some boreholes in the city of Djelfa. 26.

14. El Ouedghiri, K., El Oualti, A., El Ouchy, M., Zerrouq, F., Chahdi, F., & Lalami, A. (2014). Risques sanitaires liés aux composés chimiques contenus dans l'eau de boisson dans la ville de Fès: Cas des ions nitrates et nitrites (Health risks of the chemicals in drinking water in the city of Fez: nitrate and nitrite ions). *J. Mater. Environ. Sci*, 5(S1), 2284-2292.

15. Dovonou, F. (2014). Groundwater pollution by heavy metals and their impact on the environment : the case of the superficial aquifer of the Godomey intensive catchment area in southern Benin. Doctoral thesis, UAC. 64.

16. Drouiche A., (2012). Contribution to the Study of Specific Vulnerability to Pollution by Trace Metals and Hydrocarbons in the Groundwater of East Mitidja. De Magister Dissertation, p. 95.

17. Guessoum, H., Benbrahim, F., Halilat, M. T., Laouar, F., Bensalama, M., & Darem, S. (2015). Pollution biologique des eaux phréatiques de la région de Ghardaia (Cas de Sebseb). *Journal of Advanced Research in Science and Technology*, 2(2), 246-257.

18. El Haissoufi H., Barradah S., Marzuqi M., Aabouch M., Bennani L., Benlemlih M.… [et al.]. (2011). Pollution of Well Water in Certain Neighborhoods of the City of Fez, Morocco. *J. Ind. Sanit. Environ. Microbiol*, 5(1), p. 56.

19. Barwick, R. S., Levy, D. A., Craun, G. F., Beach, M. J., & Calderon, R. L. (2000). Surveillance for waterborne-disease outbreaks—United States, 1997–1998. *MMWR CDC Surveill Summ*, 49(4), 1-21.

20. Zmirou, D., Ferley, J. P., Collin, J. F., Charrel, M., & Berlin, J. (1987). A follow-up study of gastro-intestinal diseases related to bacteriologically substandard drinking water. *American journal of public health*, 77(5), 582-584.

21. Goodman, R. A., Buehler, J. W., Greenberg, H. B., Mckinley, T. W., & Smith, J. D. (1982). Norwalk gastroenteritis associated with a water system in a rural Georgia community. *Archives of Environmental Health: An International Journal*, 37(6), 358-360.

22. Craun, G. F., Nwachuku, N., Calderon, R. L., & Craun, M. F. (2002). Outbreaks in drinking-water systems, 1991-1998. *Journal of Environmental Health*, 65(1), 16.