Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2019, 6(11):22-29

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Contribution to the Physico-Chemical Study of Groundwater in Senegal's Groundnut Basin

***Hamath SENE[1], Baba NGOM[1], Diadioly GASSAMA[2], Séni TAMBA[1]**

[1] Laboratory of Science and Technology of Water and Environment (LaSTEE), Polytechnic School of Thies BP 10 Thiès, Senegal, (senevieux@yahoo.fr);
[2]University of Thies, UFR Science and Technology, Cité Malick Sy, BP 967, Thiès, Senegal

Abstract The challenge for the study of the water problem in the Groundnut Basin today is essentially based on an understanding of the hydrodynamic and hydrogeochemical functioning of the aquifer systems [1]. The problem of eliminating the excess fluoride and chloride ions present in water intended for human consumption in this area is a multi-faceted scientific theme that requires an approach multidisciplinary. This article is a state of the art of the domain; it presents a study of the complete characterization of the different chemical parameters of the water taken from 56 boreholes in order to determine their geochemical facies and to verify the correlation of the various elements studied. The results obtained from the simulation using the Diagram and xlstat software showed their relevance to the water abstracted from the groundnut basin in Senegal and enabled us to state our opinion on the quality of its water.

Keywords Drinking water, Groundnut Basin, hydrodynamic, hydrogeochemical, aquifer systems, fluoride and chloride, facies

1. Introduction

The drinking water supply in rural areas of Senegal and particularly in the Groundnut Basin (Kaolack, Kaffrine, Diourbel, Thiès) is mainly provided from groundwater [1]. It is recognized that the issue of water in Senegal does not arise in terms of overall quantity but in terms of availability and/or quality of resources due to the exploitation of groundwater [2]. Water pumped through boreholes and distributed to the population often contains high levels of fluorine and salt that are much higher than the WHO guidelines (1.5 mg/l) [3] and is not subject (in most cases) to any prior treatment [4]**.** Fluoride ion is incorporated into teeth and bones, preventing tooth decay at low doses (0.5 mg/l) and salt can cause high blood pressure. However, at concentrations greater than 1.5 mg/l (Fluor), it promotes dental fluorosis often appearing as a modification of dental email. Water containing a fluoride concentration between 3 and 6 mg/l can cause fluorosis of the skeleton, which is manifested by deformations and joint and bone pain [4]. Thus, the use of groundwaters in the groundnut basin is a major health problem for the populations of that locality, and may jeopardize the achievement of Senegal's sustainable development goals in terms of drinking water supply. Fluorine (F_2) is one of the most abundant elements of the earth's crust. It is found in the form of fluorine (CaF_2), biotite ($(Mg,Fe)_2Al_2(K,H)(SiO_4)_2$), fluoro-apatite…[5]. As these minerals are poorly soluble in water, the concentration of fluoride ions in surface waters is generally low [6]. However, the physico-chemical characteristics of certain salts and water bodies (high temperatures for example) in contact with these rocks favour the dissolution of minerals containing fluorine [7, 8]. The presence of excess fluoride ions in drinking water is then a source of serious intoxication. Like any trace element, fluorine is necessary and beneficial to the human body at low concentrations, but toxic at higher doses [4,6].

In this study we will first characterize the different samples taken from the peanut basin in order to check the chemical content of the water, determine the water surfaces and classify risk areas using the Wilcox method. The study was carried out by means of the digital software Diagram for the geochemical facies of the waters and the software XLSTAT for the statistical analysis.

2. Materials and methods

2.1. Zone study

The study area concerns the groundnut basin that lies towards the centre of Senegal. It consists of Five (05) regions: Diourbel, Fatick, Kaolack, Kaffrine and Thiès [9]. The groundnut basin is characterized by precarious water resources [10].

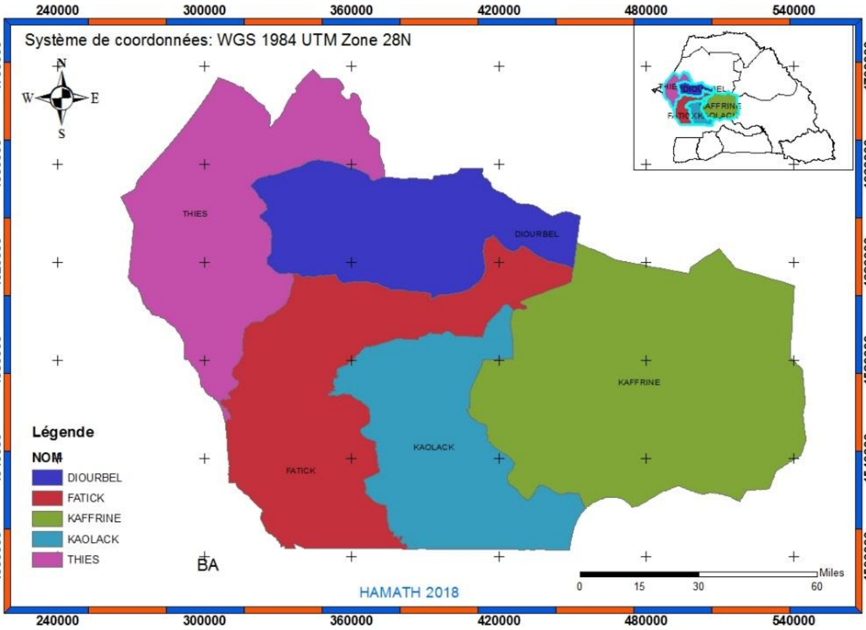

Figure 1: zone study (Groundnut Basin)

2.2. Taking

Of the five regions, we randomly selected a total of 56 sampling sites, or 12 samples of area. Water samples were placed in well-labelled 500 ml vials indicating the origin and date of collection. After collection, the samples were stored in a cooler, and immediately sent to the laboratory of the Polytechnic School of Thies for analysis.

2.3. Analytic methods

Some physicochemical parameters, such as temperature, conductivity and pH, were determined on site using a portable pH meter (HANNA).However, the other parameters were determined in the laboratory by spectrophotometer (Spectrophotometer Al800). These analyses were carried out with water physicochemical analysis kits.

2.5. Analyze statistics

After the characterization we determined the water facies using the software DIAGRAMME version 6.51 and the software XLSTAT to check the correlation of the elements studied. The latter is a multi-language hydrochemistry software to understand the water facies. It was created by Roland SIMLER of the Avignon Hydrogeology Laboratory. It is a free distribution hydrochemistry software facilitating the operation of water analysis. These functions are varied and complete [11].

The working methodology is based on several axes defined below:

With respect to the method of determining water surfaces, water characterization was then necessary to be able to process the data on the diagram software and the XLSTATS software for the analysis of the main components. The processing of these data will allow us to determine first the surface of the water to decide on the physico-chemical quality, to make the classification of the areas at risk. The latter will identify potential catchment areas without the need for advanced drinking water treatment.

3. Results and Discussion

3.1. Groundwater facies in the Groundnut Basin

The results obtained show that both for the aquifers of the Continental Terminal (CT) and Maastrichtian, the water collected exceeds the permissible standards for chloride and sodium ions as well as for fluorides. However, when we look at the hydrochemical data we have, we see that the water in the Eocene, Paleocene and Maastrichtian aquifers is too mineralized to provide completely safe water. However, it turns out that water can be found locally by capturing surface aquifers such as the Continental terminal, which contains almost fluoride-free fresh water. As a result, we expanded this present study to determine the water surfaces of each collection area with an average of twelve (12) samples for area. The results are shown in Figures 2 and 3:

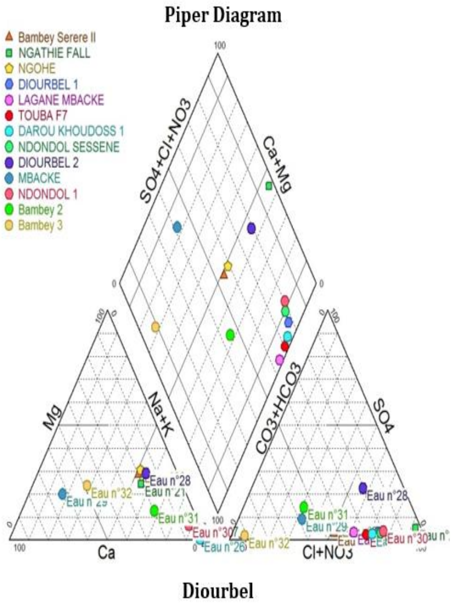

Figure 2: Piper diagram for the abstracted water of the Diourbel

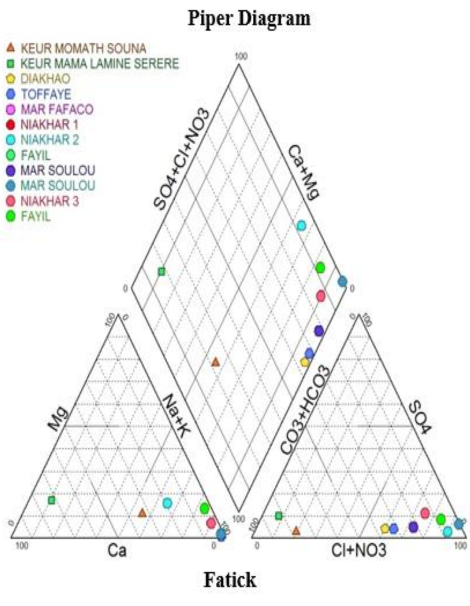

Figure 3: Piper diagram for the abstracted water of the Fatick

After sampling and analysis, the groundwater is presented in a Piper diagram, which allows to represent in percentage the relationships between anions and cations without notion of mineralization, it allows to characterize a water in function of geochemical facies, but also to represent the evolution between waters of different geochemistry. The geochemical facies of the Diourbel and Fatick regions (Figures 2 and 3), shows that the majority of the geochemical facies are hyper sodium chloride. The Piper diagram shows for the waters capturing on the one hand maestrichtian, Éocene and on the other hand the problem of fluorines present in the waters, the sodium chloride content. There are however only 04 boreholes that stand out from the others with different facies. In these waters, the main variations are due to the levels of Na^+, K^+ and Cl^-. The Paleocene water table collected in these areas is present at depths between 60 and 200 meters. This tablecloth is important only in the Fatick region and especially in the districts of Fimela, Tattaguine, and Niakhar. Most of the drilling in the Paleocene groundwater has poor hydrodynamic characteristics. Indeed the sodium chloride content indicates that in this zone the salinity is clearly present and thus pushing the abandonment of some drilling. We have also noted for these two regions that the salinity that is present in depth at the level of the maestrichtian is higher at the surface, surface water bodies are the most accessible and are overexploited by wells and boreholes.

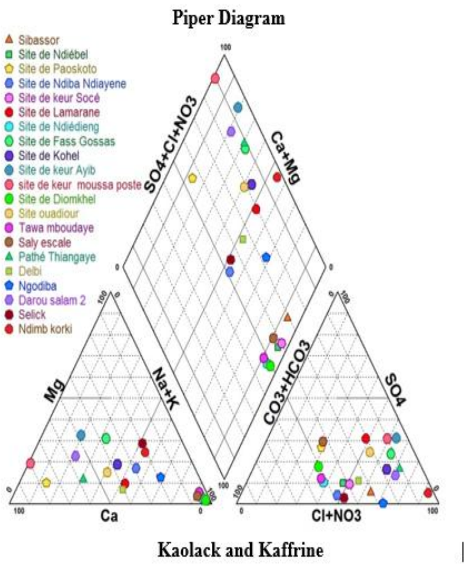

Figure 4: Piper diagram for the abstracted water of Kaolack and Kaffrine

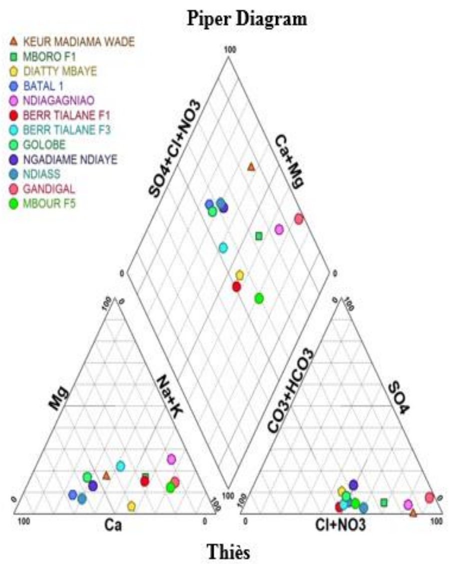

Figure 5: Piper diagram for the abstracted water of the Thiès

A) For samples from the Kaolack, Kaffrine regions (Figure: 4), we have a facies that do not show a particular trend. Here we also note for these two regions that the salinity that is present in depth at the level of the maestrichtian is higher on the surface, surface water is the most accessible and overexploited by wells and boreholes. This implies a number of them which exceed the standard of potability in ion present. However, water quality and mineralization remain favorable in some of these boreholes. The salinity is therefore much more noticeable with the Continental Terminal water table, where a dry residue content of more than 3000mg/l exceeds the World Health Organzation (WHO) guidelines of 1500mg/l [3]. The Paleocene aquifer captured in these two regions whose thickness varies from 200 m to 350 m, is a marl and sandstone formation that contains large quantities of water, but not usable because loaded with fine suspended matter. Also, this tablecloth is fed by the waters of the maestrichtian, which are easily loaded with fluorides (up to 3 to 4 mg/l) [12]. Thus, this geological formation is not as interesting for water exploitation. They represent the family of the most vulnerable groundwater table present in Senegal.

B) The results obtained for the Thiès region (Figure 5) do not show any specific particularities. We have instead a distribution of facies either chloride and sulphate calcium and magnesium or sodium chloride and potassium or sulphate and magnesium or sodium chloride and potassium or sodium sulphated. The waters that tend towards sodium sulphate facies are found in the Mbour zone by going towards Fatick or the levels of salinity and fluorides constitute a real danger to the health of the populations.

We also note that the water collected in the Diourbel and Fatick regions, although having substantially the same characteristics, does not come from the same horizons. In the case of this study, the mechanism involved is a little more complex than for the layers of maestrichtian and Paleocene. It appears that the acquisition of mineralization is done by process:

- A first acquisition of mineralization by water-rock interaction in the sodium chloride system
- The waters that tend towards sodium sulphate facies are found in the Mbour zone by going towards Fatick or the levels of salinity and fluorides constitute a real danger to the health of the populations.

3.2. Classification of waters

From a qualitative perspective for drinking water, we classified water based on conductivity using the Wilcox method.

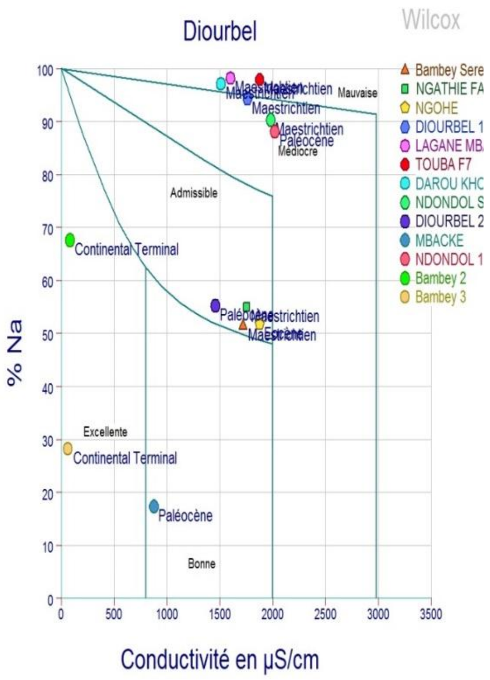

Figure 6: Wilcox diagram for water taken from the Diourbel area

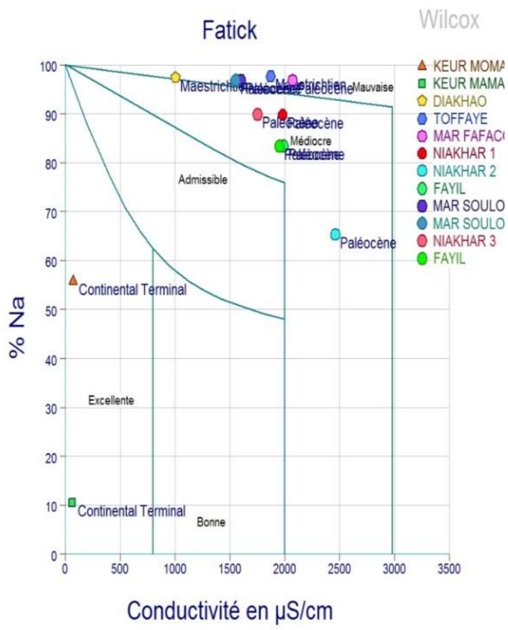

Figure 7: Wilcox diagram for water taken from the Fatick area

Our results obtained from the classification of Wilcox, Diourbel and Fatick present on average three (03) drilling of excellent quality capturing the Continental Terminal and the Paleocene (Fig 6-7). The water quality of these sites is, however, worse in the approximately section of the Fatick line to Kaolack where the dry residue is above 2000 µs/cm. Everywhere else, water quality is average (1000 to 2000 µs/cm).Fluoride levels in water are generally high and well above the allowable standard.

A) Between Kaolack and Kaffrine the water quality is excellent in the part of Kaffrine where there are favorable points for water transfer to areas where water quality is poor [10] .On a sample set studied in these localities, we note that in this area almost all the drilling, capturing the groundwater, has good water quality.

B) As for the region of Thiès, only two (02) boreholes located at Ndiaganiao and Gandigal which have poor water quality with conductivities exceeding 2000 µs/cm (Figure 9).

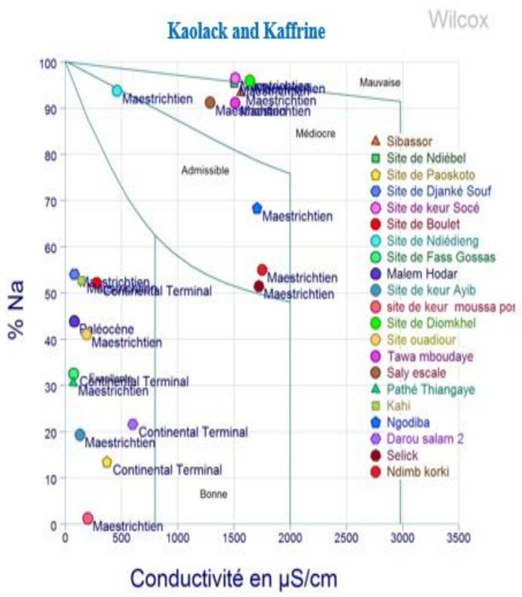

Figure 8: Wilcox diagram for water taken from the Fatick and Kaffrine area

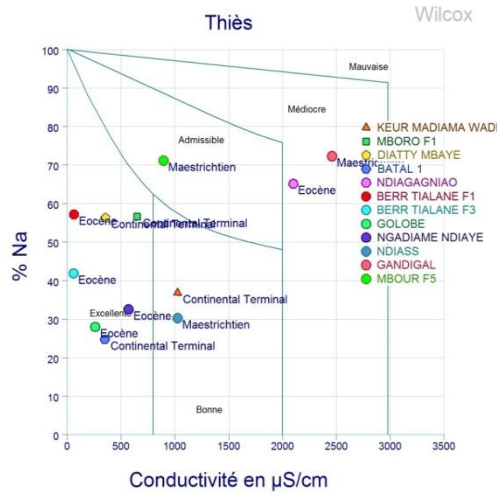

Figure 9: Wilcox diagram for water taken from the Thiès region

3.3. Impact of the nature of the water table on water composition

We know that the quality of groundwater is determined by the characteristics of the reservoir:temperature, soluble salts, and ion exchange clays. For this study, however, attention was paid to the physical characteristics of the peanut basin. In this area, most of the works capture either the Paleocene or the maestrichtian. The latter, being part of the oldest geological formations, can play on the characteristic of the water from which we speak of the Water-Roche interaction. With a high temperature in the subsoil we observe the phenomenon of dissolution sometimes leading to pollution as is the case in this present work with the fluorine that comes from the dissolution of the Maestrichtian. However, these high levels are natural and result from the interaction between water and rock, the latter being composed of fluorinated minerals associated with phosphate sedimentation (fluorapatite).

3.4. Correlated study of the different physicochemical parameters of water

In order to better understand the interdependence between the physicochemical parameters, a correlation map of these parameters was designed using the XLSTAT software (Figure 10).

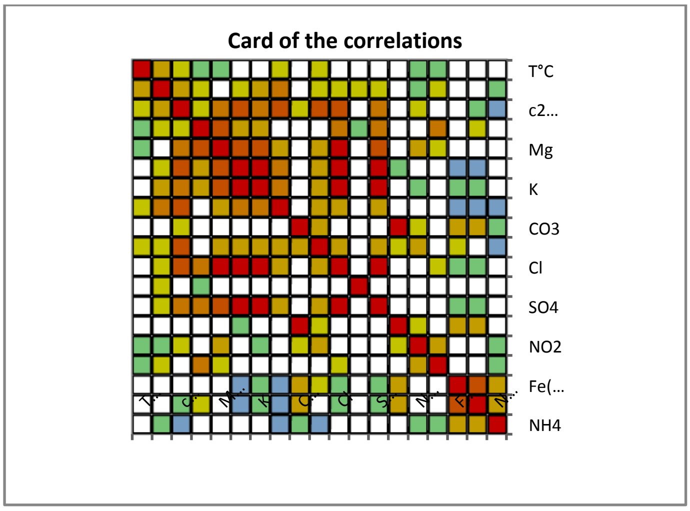

Figure 10: Card of the correlations

This map uses a color scale from blue to red (cold-hot scale) to display correlations. The blue colour corresponds to a negative correlation close to -1 and the red colour corresponds to a positive correlation close to 1.In the case of our study, we proposed to verify the correlation between the elements. And looking at the correlation map, we notice for example that Mg^{2+} magnesium ions are positively correlated close to 1 with chloride ions (Cl^-)and other elements cations (K^+ and Na^+) which tend to correlate perfectly with Mg^{2+} ions. Chloride ions are correlated with Na^+, Mg^{2+}, and K^+, and vice versa. The map in Figure 10 shows the correlation of the elements. This map shows both the x-axis and the y-axis, that the elements that are very well correlated, are visible whatever the reading axis. We can therefore say that this correlation makes it possible to know the intensity of this relationship (low or strong), the form of relationship (linear or non-linear) and the meaning of the relationship (positive or negative monotone).

4. Conclusion

The objective of our present work is to carry out an experimental study to determine the surface of the waters of the Groundnut Basin. This determination is based on the data set acquired during the field campaign and the results obtained. The experimental study allowed us to do this by classifying water according to conductivity to determine its quality.

Our results showed that all the mineralized waters of Maestrichtien and Paleocene have a well-representative behaviour of high fluoride and chloride content for the Continental Terminal, the influence of lithology on the chemical composition of aquifers is important. In fact for the same lithology, depending on the time of stay that conditions the time of water-rock interaction, the volume of water in contact with rocks and possibly, a dilution-concentration effect can also give highly variable concentrations at different points in the aquifer.

Acknowledgments

This work was supported by the Director of the Laboratory of Water and Environmental Science and Technology (LaSTEE) and the staff of the hydraulic laboratory of the Polytechnic school of Thiès (SENEGAL).

References

[1]. B. LOPEZ, Les processus de transfert d’eau et de dioxyde de carbone dans l'épikarst, THèse de Doctarat 3ème cycle: Université Bordeaux 1, 2009.

[2]. C. h. kane., health Effets of groundwater contaminated by Fluorine-case study in Senegal, 2010.

[3]. Rodier., l'analyse de l'eau, 9ème Edition éd., Dunod Paris, 2009.

[4]. B. DIENG, Etude comparative des solutions pour l’amélioration de la qualité de l’eau PEPAM-AQUA, 2013.

[5]. Dakoure Danis., modélisation, Etude hydrogéologique et géochimique de la bordure sud-Est du bassin sédimentaire de taoudeni (Burkina Fasso-Mali): Essai de modélisation, Thèse de Doctorat 3ème cycle: Université Pierre et Marie Curie, 2003.

[6]. B. Nasr, Performances des procédés physico-chimiques et membranaires pour l'élimination des ions fluorure dans les eaux de forage: application aux eaux tunisiennes, thèse de Doctorat 3ème cycle, 2013.

[7]. Diawara et al., Mise au point d’un procédé d’élimination du fluor en excès dans l'eau de boison: la nanofiltration, Journal des sciences et technologie, vol. 7, n° %12, pp. 25-31, 2008.

[8]. Pontié M et al., le problème de la fluorose au Sénégal: bilan des connaissaances et présenation d'une nouvelle méthode de défluoruration des eaux de boisson, Fluor et envirennement n°301-302, pp. 2-8, octobre-novembre 2006.

[9]. NDIAYE Mbaye., «ansd,» 01 Avril 2013. [En ligne]. Available: www.ansd.sn. [Accès le 12 Mars 2016].

[10]. S. CONSULT, «Revue documentaire et analyse des études réalisées sur le recencement des points d'eau et la qualité des eaux de consommation des régions de Diourbel, Fatick et Kaolack, Dakar, 2006.

[11]. R. SIMLER, Laboratoire hydrochimie université d'Avignon, Avignon, 2014.

[12]. C. A. KANE, Etude d’avant projet détaillé et élaboration de dossiers d'appel d'offres pour la mise en place de sources alternatives d'eau potable, PEPAM-AQUA: DAKAR, 2011.