International Journal of Engineering Sciences &Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

STUDY OF THE VULNERABILITY OF WATER CAPTURED IN DRILLING EQUIPMENT INSTALLED IN WET AND POLLUTED AREAS

Narcisse MALANDA[1*], Laurent MATINI[2], Ima Darlyce MAHOUNGOU NTONDO[1], Paul LOUZOLO-KIMBEMBE[1, 2] & Fulbert Mbouaka

[1]National Polytechnic High School
[2] Normal High School
Marien Ngouabi University,
BP 69, Brazzaville, Congo

DOI: 10.5281/zenodo.1539757

ABSTRACT

This study deals with the vulnerability and risks of groundwater pollution from drilling equipment installed in four districts of Brazzaville, namely; Poto-Poto, Moungali, Ouenzé and Talangaï. This equipment is subject to a humid and relatively polluted soil environment. A statistical study was conducted in the selected study area. This shows that several households (72%) claim not to have carried out hydrogeological studies before the installation of their boreholes, and also that they express their distrust of the potability of these waters (74%).

Physicochemical analyzes of the samples taken from 27 selected sites (drilling) were carried out in order to characterize these waters. These analyzes covered thirteen (13) parameters including: hydrogen potential (pH), redox potential (PR), temperature T, total dissolved solids (TDS), electrical conductivity (EC), total iron (Fe_{tot}), dissolved oxygen (O_2dis.), Nitrates (NO_3^-), chlorides (Cl^-), phosphates (PO_4^{3-}), complete total alkalinity (TAC), total hardness (THt), bicarbonate ions (HCO_3^-).

The application of the ascending hierarchical classification (AHC) has made it possible to identify the relevant parameters describing the quality of this groundwater, to show the spatial variability, to group the boreholes homogeneously within the framework of a possible study of the follow-up temporal and spatial quality of groundwater. The results obtained confirm the doubt of certain populations because they have shown that of the 27 selected sites, only two drilling show an acceptable mineralization. Thus, the reliability of all the drilling installed in these areas is questioned.

Key words: Drilling, groundwater, pollution, physicochemical parameter, mineralization

1. INTRODUCTION

The supply of drinking water is one of the essential needs for every household user. Indeed, water contributes to the proper functioning of the body, the balance of human physiology, and the survival of man. It is necessary in the life of man by its use for various domestic needs, (Akodogo, 2005).

However, in many cities in developing countries, the continued supply of water from the public distribution system is not always properly ensured (Blindu, 2004; Vaishnav and al., 2012). Unintentional water breaks in the network are often noted. This shortage is steadily increasing in the face of ever-increasing demographic pressures and socio-economic needs **(**Chkir and al., 2008). In some of these cities, obtaining safe water for human consumption has become a serious problem due to a lack of real policy on water management and environmental protection.

This is particularly important in sub-Saharan countries and specifically in Congo (Brazzaville), where the non-permanent supply of drinking water through the national distribution network has led people to resort to groundwater (Matini and al., 2009) and capture is done from wells or boreholes. However, in the presence of an environment made of moist and relatively polluted soil, the waters of the aqueduct are likely to be altered by contamination. This problem is recurrent in spontaneous and densely populated areas.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

The question is therefore whether the increase in human activities due to the speeding up urbanization of cities can cause serious problems on the physicochemical quality of groundwater in certain areas, especially those deemed humid and polluted. However, this quality of water can be altered when toxic external substances come into contact with the underlying groundwater by infiltration. This situation does not exclude the various households that are settled in these areas, because seemingly clear water can hide micro-organisms or dissolved pollutants.

Moreover, other studies (Moukolo, 1993; Malanda, 2014) have revealed a contamination of groundwater due to human activities in four (04) districts of Brazzaville (Poto-Poto, Moungali, Ouenzé and Talangaï).Thus, the populations living in these areas use this groundwater captured without real awareness of their vulnerability while the quality of these waters is supposed to be degraded (Das, 2013). Currently, 3.1% of deaths worldwide are due to poor water, sanitation and hygiene (WHO, 2012).

In addition, the consumption of polluted water can be the cause of several diseases including cholera, typhoid, diarrhea, dysentery, hepatitis ..., underlines the WHO which calls for immediate action as a global community to ensure water and sanitation for all (AESN, 2006).

2. MATERIAL AND METHODS

2.1 Location of the city of Brazzaville

Presentation of the study area

Brazzaville extends for a third on a marshy plain where the water table outcrops frequently in Poto-Poto, Moungali, Ouenzé, Mpila, downtown, Talangaï and for two thirds it extends on a plateau located about 20 m higher and cut by ravines. Capital city of Congo, it is located on the right bank of the Congo River downstream of Stanley Pool. It stretches for about 30 km and is bordered to the north by the foothills of the landscape Batéké and the Djiri river, to the east and south by the Congo River, to the west by the Mfilou and Djoué rivers.
The city of Brazzaville culminates at an average altitude of 335m and its area is of the order of 263.9 km². Brazzaville is cut administratively in (10) districts: Makelekele, Bacongo, Poto-Poto, Moungali, Ouenzé, Talangai, Mfilou, Madibou, Djiri and Kintélé. Bordered by the Congo River whose average flow is 43,000 m^3 / s, the river system of Brazzaville is formed by many tributaries from the landscape Batéké and which all flow to the South and East in the Congo River (Moukolo and al, 2001). Brazzaville water table represents an area of 270 km². Its upper limit is constituted by a piezometric surface. Soils in Brazzaville are generally sandy, acidic and highly denatured with a fragile structure that is sensitive to water erosion and mechanical compaction (Moukolo, 1992).

2.2 Climate

The long series of climate data divide the Congo into two climatic types: the equatorial climate in the North and the humid tropical climate in the South (Samba and Nganga, 2011). Brazzaville belongs to the humid tropical climate. This climate is under the dominating influence of low inter-tropical pressures from October to May and high southern subtropical pressures from June to September. The cloud cover is all the more important and almost permanent as the activity of the Intertropical Convergence Zone (ITCZ) is reversed. It directly influences sunstroke and solar radiation. It is also characterized by an alternation of two seasons: a rainy and dry season that extends from November to April with a very strong rainfall and a dry and rainy season from June to September during which the water balance is in deficit. The months of October and May provide a transition period for the entry and exit of the dry season (Samba and Nganga, 2011; IPCC, 2007).

2.3- Location of the study area

Our study area extends from 4,109° East to 4,268° North latitude and 15,254° North to 15,907 ° East longitude. It includes the Poto-Poto, Moungali, Ouenzé and Talangaï districts (Figure 1). The average altitude in this area is 276.44 m.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

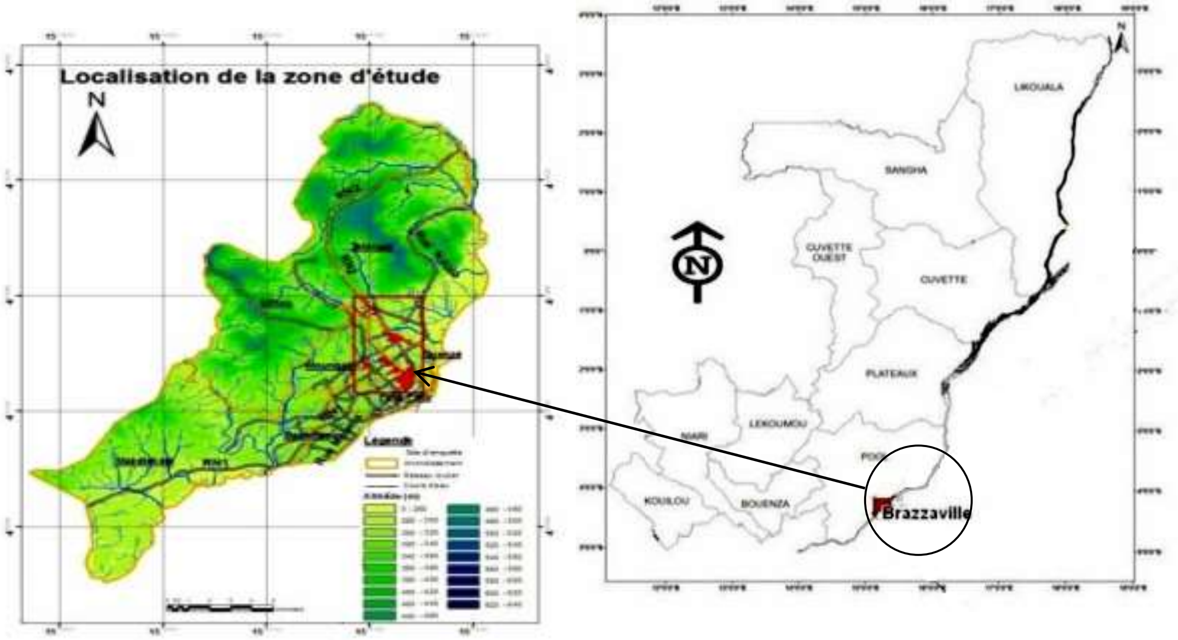

Figure 1: Location of the city of Brazzaville and the study area

2.4- Survey carried out in the study area among borehole users

By means of a questionnaire, this work was carried out in the various targeted districts where we counted 50 dwellings with installed boreholes. The questionnaire consisted of four (4) main modules, the two most important of which are drilling knowledge and knowledge of portability by the users interviewed of the drilling.

The other two modules, namely the identification and the conditions of the interview, which are appreciated by the investigator, are of relative interest. Based on the global "representativeness" with a figure of 50 which facilitates the calculation of proportion and other statistical parameters, we can say that our sample of 50 households in drilling use remains statistically representative, since the standard minimum requirement is set at 30 statistical units (Table 1).

Table 1: Distribution of users of identified boreholes by borough

Number of Drilling / District	Number of holes users	Percentage (%)
Poto-Poto	18	36
Moungali	14	28
Ouenzé	12	24
Talangaï	6	12
Total: 4 districts	**50**	**100**

2**.5 - Physicochemical analysis of samples**

This study conducted during July-October 2015 focused on 27 boreholes located in areas known as vulnerable areas of Brazzaville (Table 2).

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 2: Geographical coordinates of 27 drillings

CODE	ADDRESS	Altitude Z (m)	Latitude	Longitude
FE01	37 Yakomas Street	305	4°15'46.6''S	15°16'47.0''E
FE02	26 Ter Makoua Street	301	4°15'49.5''S	15°16'45.9''E
FE03	73 Kouyous Street	294	4°15'34.1''S	15°16'55.8''E
FE04	89 Yakomas Street	300	4°15'33.5''S	15°17'01.7''E
FE05	64 Yaoundé Street	295	4°15'56.8''S	15°17'12.8''E
FE06	103 Haoussa Street	292	4°15'41.0''S	15°16'43.2''E
FE07	50 Paul-Kamba Street	271	4°15'56.4''S	15°17'19.6''E
FE08	13 Makoua Street	293	4°15'52.2''S	15°16'43.2''E
FE09	100 Bacongo Street	288	4°15'49.5''S	15°16'45.9''E
FE10	94 Bacongo Street	294	4°15'35.9''S	15°17'08.6''E
FE11	107 Makotopoko Street	289	4°15'28.01''S	15°16'25.07''E
FE12	109 Franceville Street	291	4°16'07.6''S	15°17'13''E
FE13	105 Zananga Street	303	4°15'33.6''S	15°16'28.1''E
FE14	105 Osslé Street	310	4°15'02.8''S	15°16'35.4''E
FE15	10 bis Osslé Street	299	4°15'39.2''S	15°16'19.4''E
FE16	35 Lénine Street	287	4°15'7.0''S	15°16'21.6''E
FE17	35 Mboté Street	305	4°14'53.6''S	15°16'28.7''E
FE18	33 Malanda Street	308	4°14'32.4''S	15°16'30.5''E
FE19	150 Tsaba Street	309	4°16'07.6''S	15°17'13''E
FE20	166 Kouyous Street	303	4°16'411.8''S	15°17'04.3''E
FE21	148 Mbamou Street	297	4°14'41.8''S	15°16'44.4''E
FE22	85 Cité de 16 Street	313	4°12'44.8''S	15°16'37.3''E
FE23	72 Boya Street	348	4°12'42.2''S	15°16'34.4''E
FE24	46 Boya Street	324	4°12'44.8''S	15°16'37.3''E
FE25	152 Assiené Street	318	4°12'38.4''S	15°16'54.0''E
FE26	143 Ngoko Street	303	4°12'37.6''S	15°16'56.3''E
FE27	Kouango Street	316	4°13'05.9''S	15°16'27.8''E

Vulnerable areas are places predisposed to any contamination of chemical and bacteriological origin because of their geographical situation and the presence of landfills in these places.

Physicochemical parameters

The assessment of groundwater quality was based on the measurement of the following physicochemical parameters: hydrogen potential, redox potential, temperature, dissolved total solids, conductivity, resistivity, total iron, dissolved oxygen, nitrates, chlorides, phosphates, complete total alkalinity, total hardness, bicarbonates and general mineralization.

The material that allowed us to carry out the study is:

- Survey sheets to collect various information from borehole users;
- A GPS type E-trex for geo-location;
- 0.5L plastic bottles for taking water samples from the various boreholes;
- A multiparameter device of the type CONSORT C6030
- A lightwave spectrophotometer
- Reagents according to the ions considered.

Sampling

During this study, water samples were collected in the dry season (July-August 2015), a period that does not correspond to the recharge of the water table. The water was collected in polyethylene bottles of 0.5L capacity previously washed with nitric acid, distilled water and then with the water to be analyzed. After sampling, the bottles were labeled in a simple way: rounding, number of passage, address, date and time of sampling, code. Once the water was put in the bottles, they were hermetically closed to avoid any exchange with the surrounding environment. The samples of water collected have been stored at 4 °C and then transported to the laboratory for analysis within 24 hours or 48 hours after collection.

Photo 1 : Samples

Photo 2 : CONSORT C6030 multi-parameter camera equipped with electrodes

Photo 3 : Measurement of physico-chemical parameters

Physicochemical analyzes of samples

The physicochemical analyzes were carried out in the Laboratory of Materials Engineering and Environmental Engineering. These analyzes were carried out in three methods namely: the electrometric method, the spectrophotometric method and the titrimetric method (APHA, 1989).

Electrometrical method

Seven (07) parameters were determined in situ using the CONSORT C6030 multi-parameter (photos 1, 2 and 3), namely: the hydrogen potential (pH), the redox potential (PR), the total dissolved solids (TDS), electrical conductivity (CE), resistivity (Re), dissolved oxygen (O_2 dis.) and temperature (T).

Spectrophotometric method

The apparatus used was the Lightwave spectrophotometer (Photos 4, 5, 6, 7 and 8).

Photo 4 : Spectrophotometer

Photo 5 : Phosphate spectrum

Photo 6 : Staining samples containing nitrate

Six (6) key characteristical parameters were measured, namely: nitrate, chloride, phosphate, total iron, bicarbonates and general mineralization. The procedure is in accordance with the spectrophotometer protocol for these parameters.

Photo 7 : Staining samples containing chlorides

Photo 8 : Staining samples containing phosphate

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Titrimetric method
It is an acid-base assay for the determination of the complete total alkalinity (TAC); total hardness (THt) is determined by complexometric determination with EDTA.

3. RESULTS AND DISCUSSION

Data relating to drilling knowledge
Drilling carried out by companies accounts for 92% of the total, that makes 46 out of 50 (Table 3).
However, engineers who carried out the works represent 22%, technicians 26%, that is to say 48% of the drilling done by professionals. Workers and craftsmen who are not professionally qualified represent only 8%. However, 45% of the non-respondents to this question are quite numerous and 76% of the borehole owners are unaware of the depth level of the groundwater table. This confirms their ignorance about the technical specifications of their drilling.

The knowledge of the drilling accounts for on the reliability of the collected data in proportional comparability of the answers to variables of study of the same objective complicity.

Table 3: Presentation of statistical data according to the variables of the drilling knowledge module by borough

Variables and response results / Rounding absolute number and %		Poto-Poto		Moungali		Ouenzé		Talangaï		Total	
		Sample number	%	absolute number	%	absolute number	%	absolute number	%	Absolute value	%
Company Name	Registered	2	11	2	14	0	0	0	0	4	8
	Not registered	16	89	12	86	12	100	6	100	46	92
	Total	**18**	**100**	**14**	**100**	**12**	**100**	**6**	**100**	**50**	**100**
Having attended the Assisted drilling work	Registered	14	78	5	36	3	25	4	67	26	55
	Not registered	4	22	9	64	9	75	2	33	24	45
	Total	**18**	**100**	**14**	**100**	**12**	**100**	**6**	**100**	**50**	**100**
Qualification of the technician who carried out the work	Engineer	6	33	1	7	1	8	3	50	11	22
	Technician	3	17	3	21	6	50	1	17	13	26
	Worker	0	0	1	7	1	8	0	0	2	4
	Artisan	0	0	1	7	1	8	0	0	2	4
	Not determined	9	50	8	57	3	26	2	33	22	4
	Total	**18**	**100**	**14**	**100**	**12**	**100**	**6**	**100**	**50**	**100**
Depth level of the groundwater table	5 to 15 m	0	0	3	22	0	0	0	0	3	6
	15 to 30 m	1	6	1	7	0	0	0	0	2	4
	30 m and more	3	17	1	7	2	17	1	17	7	14
	Not determined	114	77	9	64	10	83	5	83	38	7
	Total	**18**	**100**	**14**	**100**	**12**	**100**	**6**	**100**	**50**	**100**
Hydrogeological study carried out	Yes	4	22	1	7	5	42	4	67	14	28
	No	0	0	4	29	3	25	0	0	7	14
	Not determined	14	78	9	64	4	33	2	33	29	5
	Total	**18**	**100**	**14**	**100**	**12**	**100**	**6**	**100**	**50**	**100**

Data relating to the knowledge of the potability of drilling water
Among the types of drilling water use, the most preferred is domestic use, namely, the household and the kitchen, which account for 32% and 41% respectively of the 50 boreholes (Table 5). The consumption of this drilling water as drinking water concerned only 17% of the owners. In order to identify the elements

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

characterizing the potability of the water collected, clear (clear) water and odorless water respectively have 42% and 34% of the 50 owners.
In addition, the number of non-responders to this variable identifying the physical elements determining the potability of water is 13 out of 50 or 26%. The three physical qualifiers of knowledge of the potability of water (clear water, undisturbed water, and odorless water) are recognized by 74% of the owners of boreholes and who also express their distrust of the quality of drinkability of these waters. Thus these owners are aware to resort to method allowing the important of the potability of their drilling water. The disinfection of drilling water by chlorine is approved by only 6% of owners who prefer other chemicals and microbiology means to enhance water quality.

Of all the owners of boreholes, disinfection is 56% overall. Based on other knowledge benchmarks, 96% of borehole owners do not know the flow of their drilling pump relative to the capacity of the water table. Only two of the 50 (4%) borehole owners were able to provide pump information or pump flow knowledge. The ignorance that the aggressive environment can influence the quality of the groundwater was expressed by 46% of the owners. This ignorance is reinforced by 16% of non-answered the question is a total of 62%. On the question related to the impact of runoff and urban waste on groundwater quality, 52% of landowners do not know that runoff and urban waste have a negative impact on boreholes. Of the three options proposed for remedying stormwater pollution and urban waste, cleaning up the urban area is preferred by 25% of homeowners, followed by 15% who think they treat urban waste and other say what is the best way 8%

As a result, the 52% of those who did not answer the question of the choice of means of remedying the pollution overlap with those who did not answer the question about the impact of runoff water.

Physico-chemical analysis data
These values are compared with those given by WHO (2006) as guideline values (Table 4). The physico-chemical parameters measured are presented in Table 6.

Table 4: Guidance Values for the Quality of Drinking Water [WHO, 2006]

PARAMETER	UNIT	WHO Standards
Hydrogen potential (pH)	-	6.5 – 8.5
Redox potential (PR)	mV	-
Temperature (T)	°C	déc-30
Total Dissolved Solids (TDS)	mg/L	250
Electrical conductivity (C.E)	$\mu s/cm$	300
Total iron (Fe_{tot})	mg/l	0.3
Dissolved Oxygen (O_2 dis)	mg/L	>10
Nitrates (NO_3^-)	mg/L	50
Chlorides (Cl^-)	mg/L	200
Phosphates (PO_4^{3-})	mg/L	5
Full Alkalimetric Title (TAC)	mg/L$CaCO_3$	100
Total Hydrotimetric Title (THt)	mg/L$CaCO_3$	150
Bicarbonates (HCO_3^-)	mg/L	200

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 5: Statistical data of the variables of the potability knowledge module.

Rounding and absolute number and % / variables and response results		Poto-Poto		Moungali		Ouenzé		Talangaï		Total	
		Absolute number	%	Absolute number	%	Absolute number	%	Absolute number	%	Absolute value	%
Use of collected water	Kitchen	17	43	10	29	8	26	4	27	39	32
	Household	18	45	14	41	11	35	6	40	49	41
	Consumption	4	10	4	12	7	23	5	33	20	17
	Other	1	2	6	18	5	16	0	0	12	100
	Total	**40**	**100**	**34**	**100**	**31**	**100**	**15**	**100**	**120**	**100**
Elements that tell you about potability	Clear water	16	57	5	28	8	42	4	27	33	42
	Water not disturbed	0	0	1	6	0	0	6	40	7	9
	Odorless water	10	36	4	22	8	42	5	33	27	34
	Not determined	2	7	8	44	3	16	0	0	13	100
	Total	**28**	**100**	**18**	**100**	**19**	**100**	**15**	**100**	**80**	**100**
Reassured of the potability of drilling water	Yes	5	28	2	14	3	25	3	50	13	26
	No	13	72	12	86	9	75	3	50	37	74
	Total	**18**	**100**	**14**	**100**	**12**	**100**	**6**	**100**	**50**	**100**
Make it drinkable	Chlorine disinfection	2	10	1	7	0	0	0	0	3	6
	Other treatments	14	70	6	40	7	58	3	50	30	57
	Not determined	4	20	8	53	5	42	3	50	20	37
	Total	**20**	**100**	**15**	**100**	**12**	**100**	**6**	**100**	**53**	**100**
Flow rate relative to the capacity of the water table	4 m^3/h	0	0	1	7	0	0	0	0	1	2
	6 to 7 m^3/h	0	0	1	7	0	0	0	0	1	2
	Other	0	0	0	0	0	0	0	0	0	0
	Not determined	**18**	100	12	86	12	100	6	100	48	96
	Total	**18**	**100**	**14**	**100**	**12**	**100**	**6**	**100**	**50**	**100**
Influence of the environment on groundwater quality	Yes	11	61	3	21	3	25	2	33	19	38
	No	7	39	7	50	7	58	2	33	23	46
	Not determined	0	0	4	29	2	17	2	34	8	16
	Total	**18**	**100**	**14**	**100**	**12**	**100**	**6**	**100**	**50**	**100**
Impact runoff	Yes	10	56	4	29	3	25	2	33	19	38
	No	8	44	7	50	7	58	2	33	24	48
	Not determined	0	0	3	21	2	17	2	34	7	14
	Total	**18**	**100**	**14**	**100**	**12**	**100**	**6**	**100**	**50**	**100**
Ways to remedy water pollution	Treaturbanwaste	5	22	1	6	2	14	1	14	9	15
	Sanitation of the urban area concerned	10	43	2	12	2	14	1	14	15	25
	Other possibilities	0	0	3	19	1	8	1	14	5	8
	Not determined	8	35	10	63	9	64	4	58	31	52
	Total	**23**	**100**	**16**	**100**	**14**	**100**	**7**	**100**	**60**	**100**

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 6: Values of arithmetical means of physico-chemical parameters

Code	pH	PR	T	TDS	C.E	Fe_{tot}	$O_{2\ dis}$
FE01	6.5	63.5	20	312.8	587.8	9.5	0.00
FE02	5.4	162.9	20	247	464	7.2	0.00
FE03	6.3	74.1	20	347.3	653.8	9.5	5.10^{-3}
FE04	6.3	75.1	20	511.3	960.5	9.5	$7.5x10^{-3}$
FE05	5.2	138.4	20	503	944.3	9.5	$2.5x10^{-3}$
FE06	6.4	67.4	20	419.5	788.5	9.5	0.00
FE07	4.7	169.3	20	571	1071.5	9.5	0.00
FE08	5.7	107.6	20	298.5	559.8	9.5	0.00
FE09	5.8	103.9	20	418.8	787	9.5	0.00
FE10	6.3	68.3	20	423.2	795	9.5	0.00
FE11	5.2	134.0	20	61.4	115.3	9.6	0.00
FE12	6.5	60.6	20	276.8	526	9.5	0.00
FE13	6.3	71	20	300.8	565.5	9.5	0.00
FE14	5.11	142.8	20	71.9	135.5	9.6	0.00
FE15	5.9	91.4	20	303.3	571	9.5	0.00
FE16	4.6	174.3	20	232	436.8	9.5	0.00
FE17	4.3	192.6	20	154.8	291	9.5	0.00
FE18	4.22	195.5	20	191.3	359.5	9.5	0.00
FE19	6.27	74.1	20	306.3	575.5	9.5	0.00
FE20	4.85	158.4	20	287.3	540.3	9.5	0.00
FE21	5.2	134	20	229.6	432	9.5	0.00
FE22	4.31	191.3	20	153	287.3	95	0.00
FE23	4.5	180.9	20	102.3	191.4	9.4	0.00
FE24	4.9	153.1	20	26.7	50.7	9.5	0.00
FE25	4.7	164.5	20	15.7	31.3	9.4	0.00
FE26	4.79	159.9	20	250.3	470.5	9.6	0.00
FE27	4.5	180.4	20	376.8	709.3	9.6	0.00

Table 6 (continued): Values of arithmetical means of physico-chemical parameters.

Code	NO_3^-	Cl^-	PO_4^{3-}	TAC	THt	HCO_3^-
FE01	55.8	61.9	22.6	29	306.3	35.4
FE02	49.8	48.8	45.9	7.5	231.3	9.2
FE03	53.8	68.8	40.2	7.5	131.3	9.2
FE04	80.5	101.1	35.3	51	171.9	62.2
FE05	47.5	99.4	44.2	5.5	318.8	6.7
FE06	48	83	32.1	55	309.4	67.1
FE07	39.8	112.8	49.1	1.3	537.5	1.5
FE08	59.3	58.9	31.9	1.3	362.5	1.5
FE09	60	82.8	44.8	23	193.8	112.3
FE10	39	83.7	35.6	26	271.9	31.7
FE11	63.5	12.1	3	8	68.8	9.8
FE12	36	55.4	22.3	46.5	278.1	56.8
FE13	55	59.5	25.4	15.5	193.9	18.9
FE14	61.8	14.3	2.8	3	87.5	3.7
FE15	45.5	60.1	32.2	13	321.9	15.9
FE16	56	46	21.6	1.3	162.5	1.5
FE17	55.5	30.6	6.1	1.25	100	1.5
FE18	50.5	37.8	7.6	0.9	206.3	1.1
FE19	44.8	60.6	31.2	13	381.4	15.9
FE20	57.6	56.9	49.4	10.5	153.1	12.8
FE21	47.5	45.5	37.7	4	284.3	4.9
FE22	62	30.2	6.1	3	181.3	3.7
FE23	71.8	20.1	4	4.1	93.8	5
FE24	13.4	5.3	1.1	19	159.4	23.2
FE25	7.9	3.3	0.7	13	15.6	15.9
FE26	53.5	49.5	9.9	4	243.8	4.9
FE27	60.5	74.7	38.7	10	343.8	12.2

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Hydrogen potential (pH)

This histogram (Figure 2) shows that the water from these holes is aggressive. Because the pH values vary between 4.2 and 6.5.The FE01 and FE12 drillings are the only ones to respond to the standard given by the WHO which is 6.5-8.5.FE18 drilling is more aggressive than other drilling. This aggressiveness is justified by the low values of TAC and bicarbonate. The aggressiveness of this drilling water is due to the presence of carbonic acid (H_2CO_3) formed by the mixing of CO_2 and water. This is justified by very low concentrations of dissolved oxygen (Tables 6 and 4).

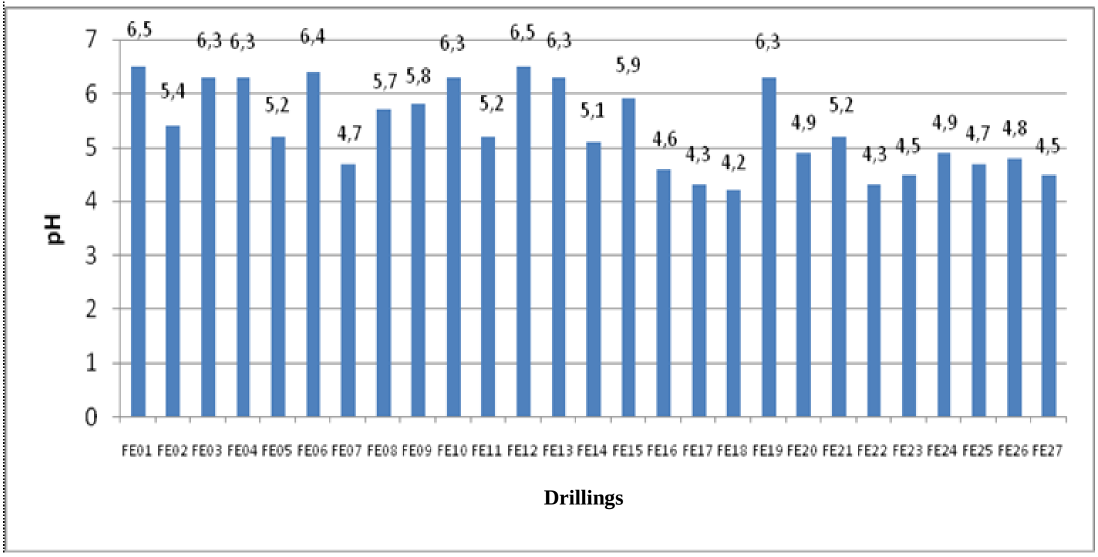

Figure 2: Spatial variation of pH

Electrical conductivity

This figure 3 shows that the conductivity varies from 31.3 to 1071.5 µS/cm. This means that the water from these holes is divided into four classes of mineralization:

- Drilling waters with conductivities less than 100 µS/cm are very weakly mineralized; this is the case of drilling FE24 and FE25. The conductivities of these boreholes are in line with WHO standards of 300 µS/cm.
- The drilling waters with conductivities between 100 and 200 µS/cm are weakly mineralized; this is the case of drilling FE11, FE14 and FE23 which verify the WHO standard.
- For conductivities between 200 and 300 µS/cm we have a normal mineralization water. Case of drilling FE17 and FE22.
- For values greater than 300 µS/cm, the water from these holes is mineralized, this is the case of drilling FE01, FE02, FE03, FE04, FE05, FE06, FE07, FE08, FE09, FE10, FE12, FE13, FE15, FE16 , FE18, FE19, FE20, FE21, FE26 and FE27.

The knowledge of the classification of conductivity is very important to characterize water physico-chemically because there are harmful mineral salts like the nitrates and the phosphates which increase the mineralization (ground water) to make the water out of the standard of potability of the water WHO.

The drilling water whose conductivities are out of standard of potability according to WHO require physico-chemical treatments of demineralization to bring back these waters to normal conductivities.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

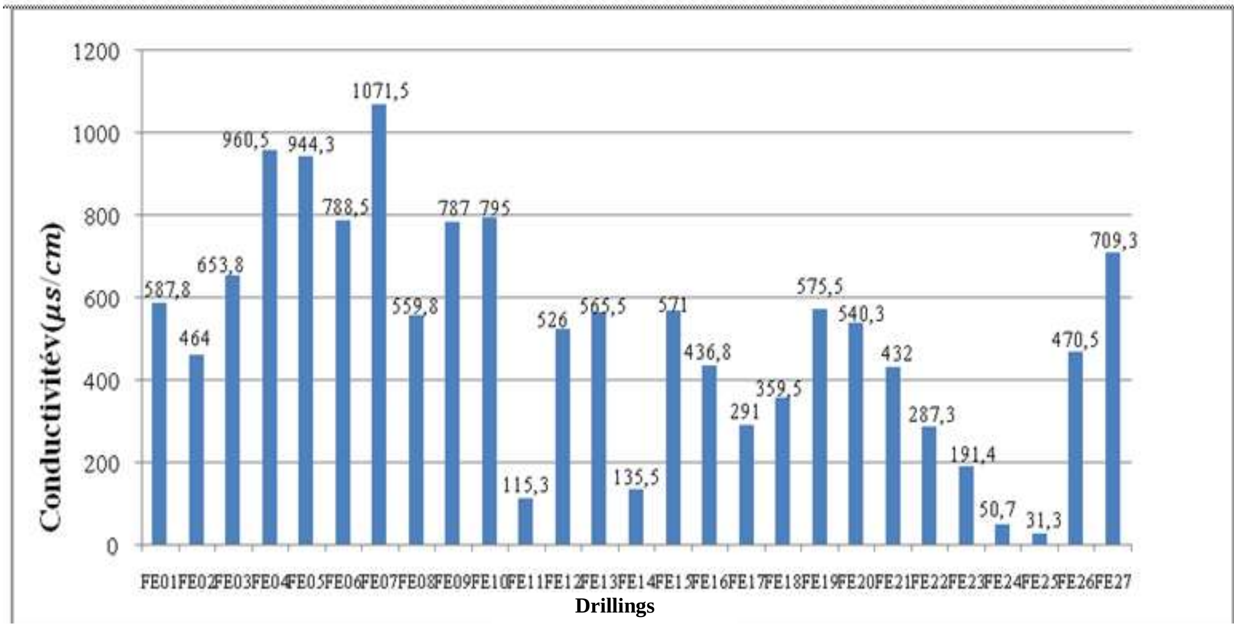

Figure 3: Spatial variation of electrical conductivity

Nitrates (NO_3^-)

The values ranged from 7.9 to 80.5 mg /L (Figure 4). This means that the water from the FE25, FE24, FE12, FE10, FE07, FE19, FE15, FE05, FE21, FE06, FE02 drillings has acceptable amounts of nitro compound (nitrates) because its values are below the WHO standard (50mg /L). On the other hand, the other boreholes are out of standard for the presence of nitrates high level in these waters shows that there are organic compounds which can be indicator of pollution of these waters because nitrates are reduced in nitrites which highlight the pollution of drinking water, in the presence of nitrobacteria; this is the case of drilling waters FE01, FE03, FE04, FE09, FE11, FE13, FE14, FE16, FE17, FE18, FE20, FE22, FE23, FE26, FE27.

Differences in nitrate concentrations in these boreholes can be influenced by:

- The geological composition of the soil (presence or absence of the seeds or organic matter)
- Wastewater infiltration
- The depth of the drilling

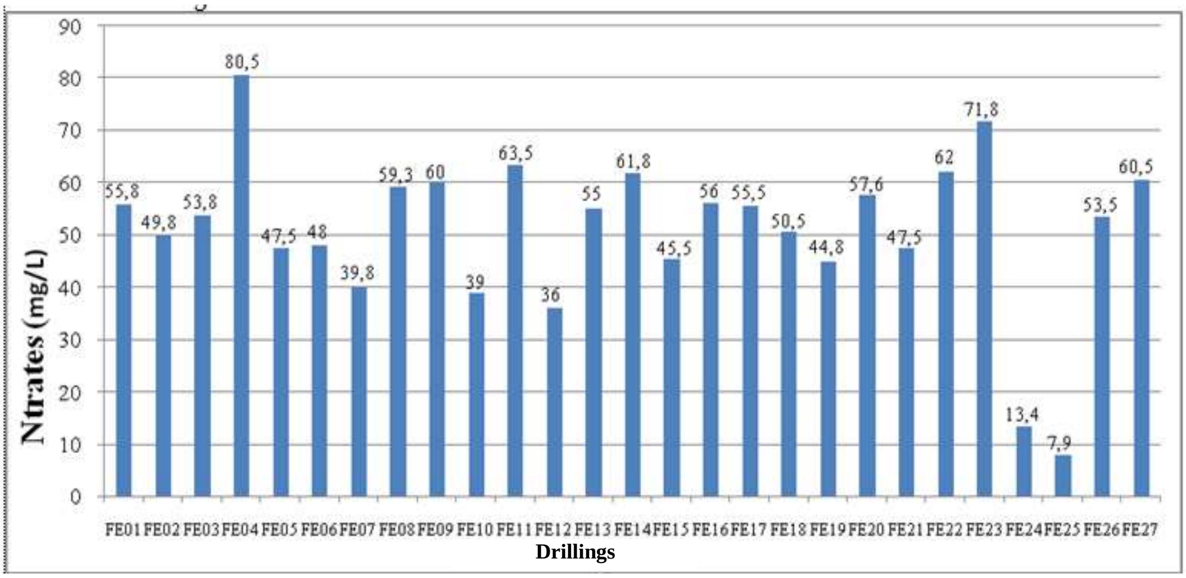

Figure 4: Spatial variation of nitrate concentrations as a function of boreholes

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Chlorides

The values of the chloride concentrations (Figure 5) of the boreholes are all in accordance with WHO standards of 200mg / L. These values which vary between 3.3 and 112.8 mg/L mean that these drillings are divided into two classes of strong acid salt (SAF) which are: chlorides, sulphates and nitrates. For chlorides less than 50 mg /L it is in the class where the water of the boreholes has low SAF. For chlorides greater than 50 mg /L, the concentrations of SAF are high, as is the case for drilling waters.

The differences in chloride concentrations on these drillings may be influenced by the following:

- The geological composition of the soil
- Infiltration of brackish wastewater (water rich in sodium chloride or potassium)
- The depth of the drilling

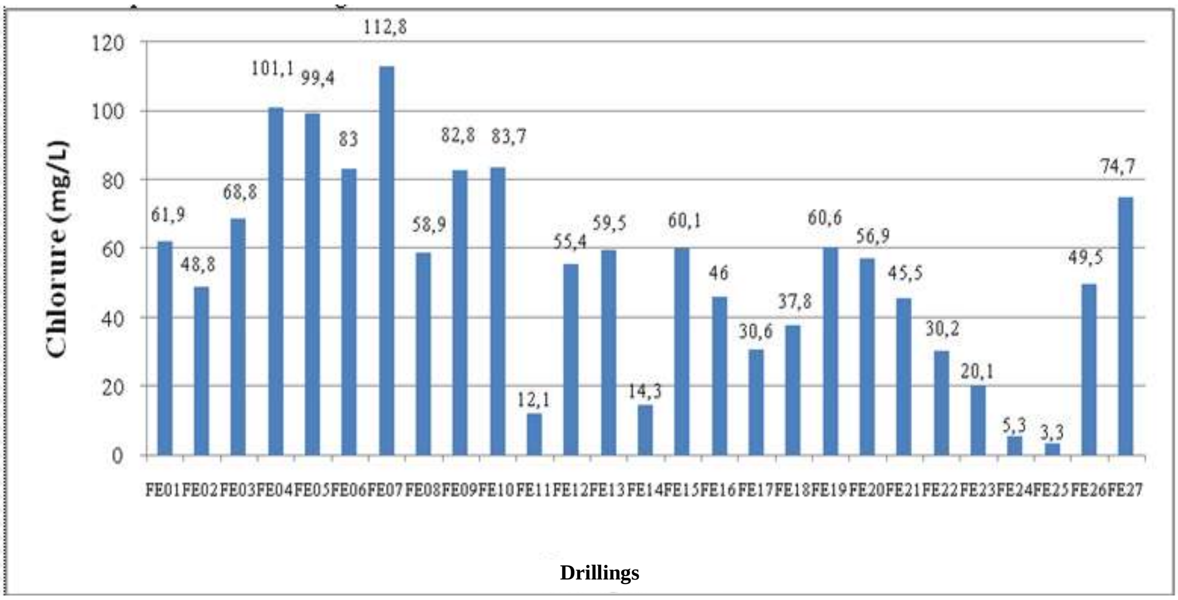

Figure 5: Spatial variation of chloride concentrations as a function of boreholes

Phosphates (PO_4^{3-})

Phosphate concentrations of the boreholes range from 0.7 to 49.4 mg / L (Figure 6). The figure shows that the drilling waters FE25, FE24, FE23, FE14 and FE11 have low microbiological pollution levels because their phosphate concentrations are in accordance with the WHO standard of 5 mg/L. In the water of these boreholes the decomposition of organic matter is non-existent. While the drilling waters FE22, FE18, FE17, FE26 are slightly polluted because the values of the phosphate concentrations out of standard are low. On the other hand, the waters of the holes FE01, FE02, FE03, FE04, FE05, FE06, FE07, FE08, FE09, FE10, FE15, FE16, FE19, FE20, FE21, FE26 and FE27 have phosphate concentrations out of WHO limit. These results show that the degree of microbiological pollution of these waters is considerable (decomposition of the organic matter which is at the origin of phosphate).

Differences in phosphate concentrations on these holes can be influenced by:

- The geological composition of the soil (presence or absence of organic matter)
- Wastewater infiltration containing the detergent
- The depth of the drilling

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

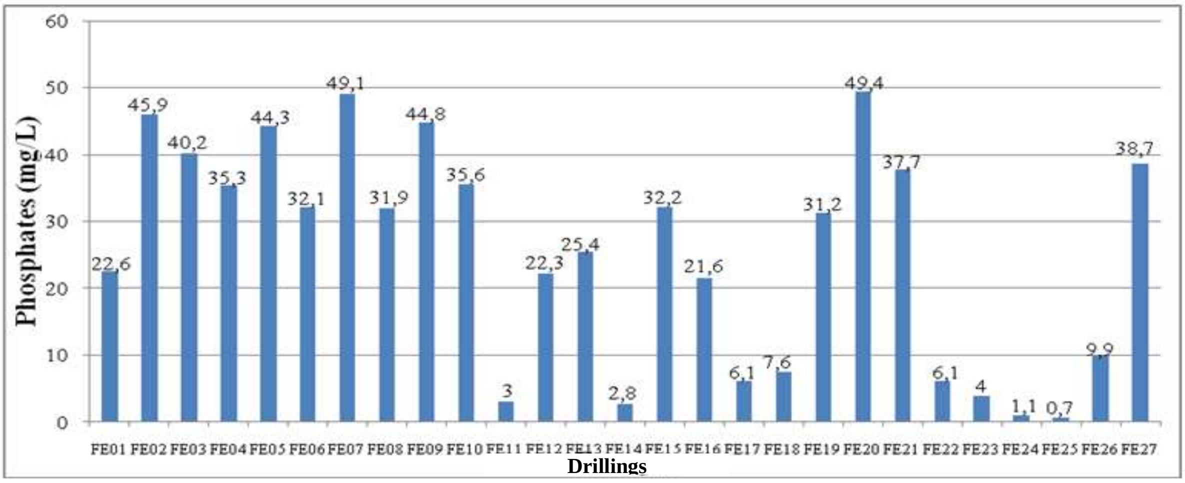

Figure 6: Spatial variation of phosphate levels

Total hardness (THt)

THt values varies from 15.6 to 537.5 mg / L $CaCO_3$ (figure 7). The water from these boreholes can be divided into five categories:

- Very mild waters with THT below 50 mg/L $CaCO_3$. In the case of our study, the FE25 is the only well to have very soft water which implies that the calcium and magnesium concentrations are very low
- Drilling with freshwater is characterized by THT values between 50 and 150mg/L $CaCO_3$. What accounts in our study holes FE03, FE11, FE14, FE17, FE23 involving low concentrations of calcium and magnesium
- THt of boreholes between 150 and 200 mg/L $CaCO_3$ is moderately hard, this is the case of drilling FE04, FE09, FE13, FE16, FE20, FE22 and FE24
- Drilling waters with THt between 200 and 300 mg/L $CaCO_3$ are hard, as in the case of drilling FE02, FE10, FE12, FE18, FE21 and FE26
- Finally, when the THt of the drilling water is above 300 mg/L, the drilling water is very hard. Drilling case FE01, FE05, FE06, FE07, FE08, FE15, FE19 and FE27

Drilling waters of the first two cases are in accordance with the WHO standard of 150mg/L $CaCO_3$.
On the other hand, other boreholes with high calcium and magnesium concentrations have total hardness above the standard.

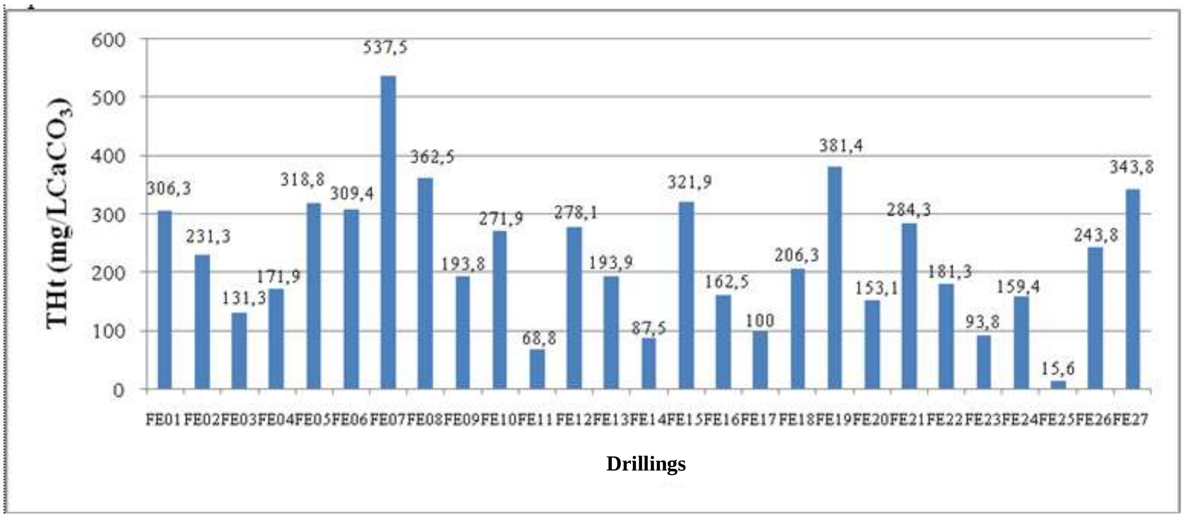

Figure 7: Spatial variation of THt levels

Bicarbonates (HCO_3^-)

The bicarbonate values (Figure 8) in this figure vary between 1.1 and 112.3 mg / L. This shows that the majority of these boreholes have a water rich in CO_2 which reflects the aggressiveness of water related to the dominance of carbonic acid (H_2CO_3) in these waters.

The water from the FE09 borehole has an average concentration of the WHO standard of 200mg / L, which shows that it is the only well with a low concentration of carbon dioxide (CO_2). So the water from these holes does not contain the acid.

On the other hand the water of the FE18 well is very rich in carbonic acid which dominates on the bicarbonate which is translated by its low value which is of 1.1mg/L.

Drilling water with bicarbonate concentrations below 100 mg/L (the average of the standard) requires equilibrium that is to say, brought the pH of these waters to a value close to the equilibrium pH. The bicarbonate values (Figure 8) in this figure vary between 1.1 and 112.3 mg/L. This shows that the majority of these boreholes have a water rich in CO_2 which reflects the aggressiveness of water related to the dominance of carbonic acid (H_2CO_3) in these waters.

The water from the FE09 borehole has an average concentration of the WHO standard of 200 mg/L, which shows that it is the only well with a low concentration of carbon dioxide (CO_2). So the water from these holes does not contain the acid.

On the other hand the water of the FE18 well is very rich in carbonic acid which dominates on the bicarbonate which is translated by its low value which is of 1.1mg/L.

Drilling water with bicarbonate concentrations below 100 mg/L (the average of the standard) requires equilibrium that is to say, brought the pH of these waters to a value close to the equilibrium pH.

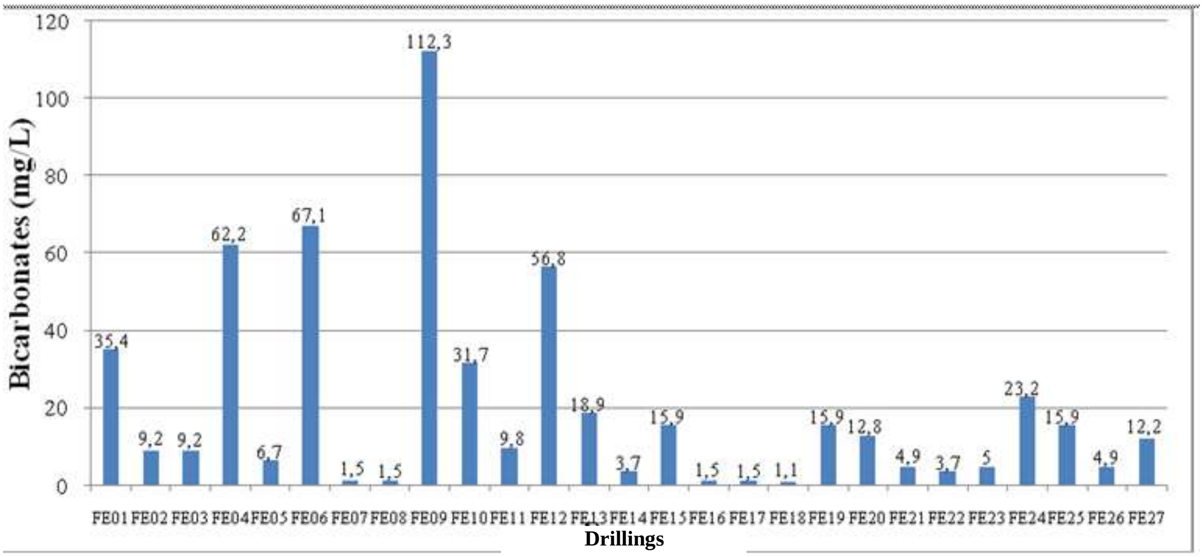

Figure 8: Spatial variation of Bicarbonates contents

Ascending hierarchical classification

The ascending hierarchical classification makes it possible to reduce the number of sampling sites in the case of a temporal monitoring program. Thus, figure 9 presents the results of the classification of sampling points in homogeneous zones.

This classification has two groups: I and II and subgroups in group II. In these groups we can observe associations between boreholes, as is the case of drilling FE17-FE22-FE25-FE23 and FE11-FE14 in group I;

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

FE01-FE20, FE02-FE21, FE18-FE24 in subgroup IIB; FE03-FE09 and FE04-FE07 in subgroup IIA (Figure III9)

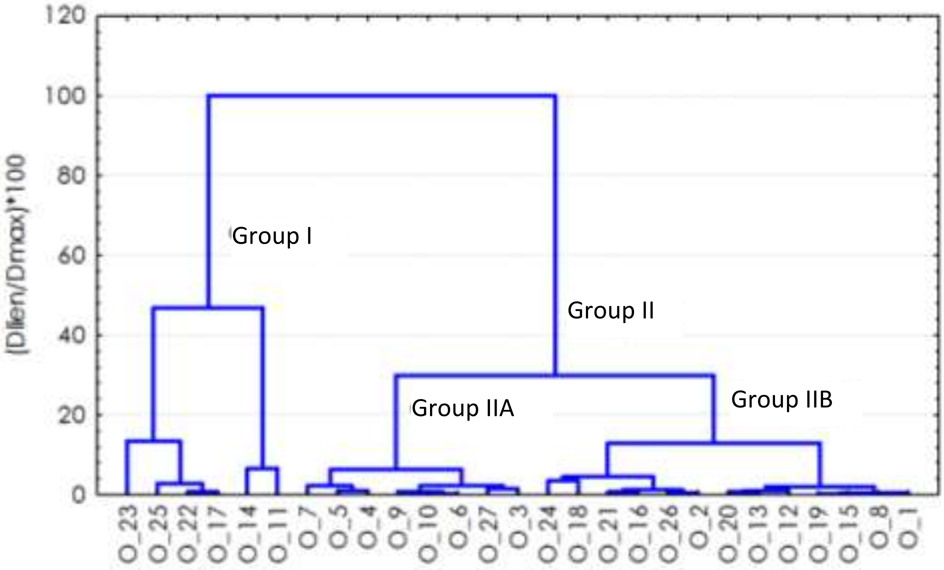

Figure 9: Drilling Dendrogram

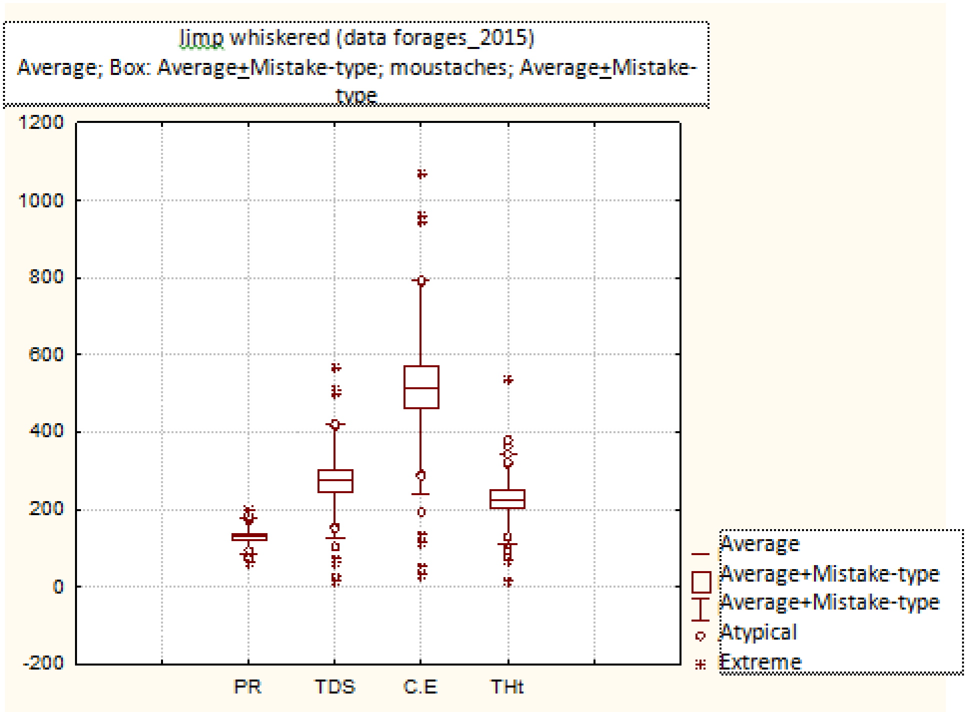

*Figure 10: **Redox potential variability (PR), total dissolved solids (TDS), electrical conductivity (EC), total hardness (THt).***

However, in Figure III there is a small variability of the Redox Potential (PR) compared to the mean (129.2). The TDS, THt parameters have remarkable variability with respect to their respective means (274; 226.3). The electrical conductivity (EC) meanwhile has a significant variability compared to the average (514.9µS / cm), with an extreme value of 1071 µS/cm for FE07.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

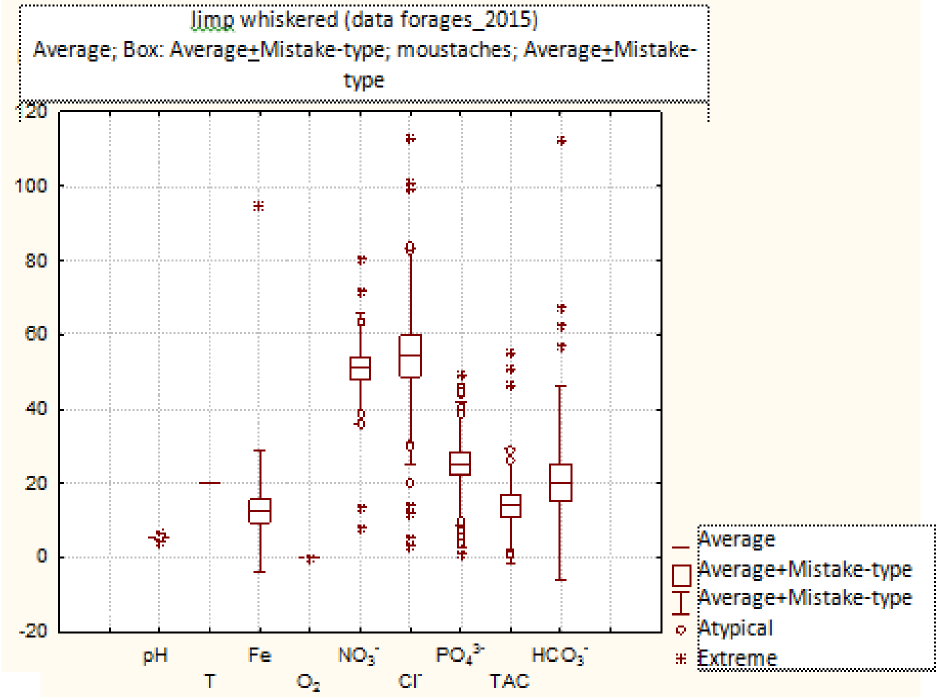

Figure 11: Variability of hydrogen potential (pH), temperature (T), total iron (Fe), dissolved oxygen (O_2), nitrates (NO_3^-), chlorides (Cl^-), phosphate (PO_4^{3-}), complete total alkalinity (TAC) and bicarbonate (HCO_3^-).

By contrast, in Figure 11, there are three trends:

- Constant temperature variation, dissolved oxygen
- Low variability of hydrogen potential (pH)
- Average variability in nitrate, full alkalinity, and bicarbonate ion concentrations
- Very large variability in chloride and phosphate ion concentration.

4. DISCUSSION

The analytical methods used in this work for the physicochemical characterization of these waters have already been the subject of several publications among which (Matini and al., 2009), (Nkounkou et al., 2016), (Chkir and al., 2008), (Malanda, 2016), (Moukandi Nkaya, 2012) and (Abdelkader and al., 2012). According to Moukolo and Gaye (2001), the study area that formed the framework of our work does not have a viable drinking water supply and wastewater treatment system, or even waste treatment plants. Thus, this area is exposed to potential risks of contamination of groundwater by contamination. Similarly, a study conducted on the physicochemical quality of water stored in underground concrete tanks installed in the same area showed that 27 water reservoirs show a very significant variation in the overall parameters of water quality (Malanda and al., 2014). In addition, this study reveals that 80.7% of the water samples taken and analyzed have significant concentrations of pollutants. In addition, the study by Chkir and al., (2008) highlights the impact of climatic conditions and anthropogenic pressures on aquifer water quality.

The analyzed water samples show nitrite concentrations that exceed the normative value of 0.1 mg/L (Wendy and al, 2013) and a high microbiological activity that is characterized by an absence of dissolved oxygen in 81.84 % some samples. This once again highlights the vulnerability of groundwater in this area (Malanda and al, 2014).
The present study thus reveals that the groundwater collected in these different quarters and districts of Brazzaville present a significant anthropogenic pollution.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

5. CONCLUSION

In this work, the analysis of the physico-chemical parameters of the boreholes shows that they are highly mineralized. This mineralization is due to the infiltration of runoff and domestic wastewater into the underground water. On the whole, these waters are weakly acidic in nature and are considered as oxidizing and acidic environments. The variability of the parameters in the set of samples highlights three trends: a low dispersion of the redox potential (PR), hydrogen potential (pH), temperature (T), total iron (Fe_{tot}) and oxygen values dissolves (O_2 dis); an average dispersion of total dissolved solids (TDS), total hardness (THt), nitrate (NO_3^-), complete total alkalinity (TAC) and bicarbonate (HCO_3^-), the third of which values is large consists of electrical conductivity (EC), chlorides (Cl^-) and phosphates (PO_4^{3-}).

Anthropogenic activities are sources of contamination in the studied area. The reliability of these drillings finally questioned and requires appropriate treatment before use.

REFERENCES

[1] AESN ,2006**.** Agence Seine de Normandie. Les enjeux de la gestion de l'eau. Rapport d'étude. Disponible en ligne sur : http//www.eau-seine-normandie.fr/fileadmin/…/AESN-COL= cours-4.1.pdf du 04/11/2014.

[2] Akodogbo Hervé. Contribution à l'amélioration de la qualité de l'eau à usage domestique dans le 5ème arrondissement de la commune de Porto-Novo-bénin. Maitrise professionnel en environnement et santé 2005.

[3] Blindu I. Outils d'aide au diagnostic du réseau d'eau pour la ville de Chisinau par analyse spatiale et temporelle des dysfonctionnements hydrauliques. Thèses de Doctorat, École Nationale Supérieure des Mines de Saints Etienne, Université Jean Moumet : spécialité ; sciences de génie de l'environnement, 2004.

[4] Matini L.et al. Évaluation hydro-chimique des eaux souterraines en milieu urbain au Sud-Ouest de Brazzaville, Congo. Afrique Science 05(1) (2009) 82-98.

[5] Malanda N. (2016) . Problème de stockage de l'eau domestique dans les réservoirs en béton armé enterrés Modélisation de la diffusion non linéaire en milieu poreux .Presse Académiques Francophones (PAF), ISBN 978-8416-3031-5 , 239 pages.

[6] Moukolo N. (1992).État des connaissances actuelles sur l'hydrogéologie du Congo. Brazzaville, hydrogéologie, n°1-2, pp 47-58.

[7] Moukolo N., Gaye C., B. (2001). Problème de contamination des nappes phréatiques par les rejets domestiques dans les métropoles d'Afrique Noire : cas de la nappe de Brazzaville. Brazzaville 2001, sécheresse 12(3), pp 175-185.

[8] OMS 2012. Statistiques mondiales en temps réel. Disponible en ligne sur http://www.planetoscope.com /mortalité/49-nombre-de-deces-dus-a-la-pollution-de-l-eau-dans-le-monde.html du 08/11/2015.

[9] OMS 2006. Directives de la qualité pour l'eau de boisson. Critères d'hygiène et documentation à l'appui. 2èmeédition, vol II

[10] Vaishnav M.M. and Dewagnan S. Anatycal and statistical evaluation of surface and sub-surface water of Balco industrial area, Korba, C. G. India. International journal of environmental sciences, 02 (3), 2012, 1369-1379.

[11] Chkir N., Trabelsi R., Bahir M., Hadj Ammar F., Zouari R., Chamchati H., et Monteiro J.P. (2008). Vulnérabilité des ressources en eaux des aquifères côtiers en zones semi-arides. Étude comparative entre les bassins d'Essaouira (Marco) et de la Jeffara (Tunisie). Communicaço es geologicas, 2008, t. 95, PP. 107-121. En ligne sur http://www.ineg.pt/download/4603/comumgeol v95-N1-article%20(7).pdf du 15/12/2013.

[12] Wendy M.R., John M., Sharp Jr. (2013). Variability of groundwater nitrate concentration over time in arid basin aquifers: sources, mechanisms of transport, and implication of conceptual models. Environ earthSci (013) 69 : 2415-24 26. DOI 10.1007/S12665-012-2069-1.

[13] Moukandi Nkaya G. D. (2012). Étude hydrogéologique, hydro chimique in situ et modélisation hydrodynamique du système aquifère du bassin sédimentaire côtier de la région de Pointe-Noire. Thèse de doctorat de l'université Marien Ngouabi (2012) – Brazzaville Congo.

[14] Abdelkader R, Fethi B., Nacer K., Larbi D. (2004). Vulnérabilité et risque de pollution des eaux souterraines de la nappe des sables miocènes de la plaine d'Ei Ma El Abiod (Algérie). Science et changement planétaires/sécheresse. Volume 15, numéro 4 ; 347-52, octobre – Novembre – Décembre 2004.

[15] Malanda N., Matini L., Louzolo-Kimbembe P. (2014). Evaluation of physicochemical quality of water stored in underground reinforced concrete tanks: case study f wet lands in Brazzaville (CONGO). International Journal of advanced research in engineering and technology (IJARET). ISSN 0976-6480 (print). ISSN 0976-6499 (Online).

[16] Apha (1989). Standard methods for the examination of water and wastewater, 18th edit, WPCF Washington DC, 1989.
[17] Das N.C., Physicochemical characteristics of selected ground water samples of Ballarpur City of Chandrapur District, Maharashtra, India, Int. Res. J. Environment Sci., vol 2, 10-11, pp 96-100, 2013.
[18] NkounkouTomodiatounga D., Mabiala B., Moukandi Nkaya G.D. (2016). Hydrochemical characteristics of the groundwater AQ1 of the region from Pointe-Noire to Congo Brazzaville. Journal of Geoscience and environment protection, 2016, 4, 95-109. Scientific Research Publishing. ISSN online: 2327-4344. ISSN print: 2327-4336
[19] Samba G. and Nganga D. (2011): Rainfall variability in Congo-Brazzaville 1932-2007. Int. J. Climatol. Published online in Wiley
[20] IPCC, (2007): IPCC Fourth Assessment Report: climate change 2007 (AR4). IPCC, Geneva, Switzerland.