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RESEARCH ARTICLE

PHYSICOCHEMICAL AND BACTERIOLOGICAL ANALYSES OF WELL WATER IN ANGONDJENTOM AREA (LIBREVILLE SUBURB)

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Abstract

The aim of this work was to assess the quality of well water used as the main source of water by people living in AngondjeNtom area (Libreville suburb). In this regard, twelve wells were submitted from physicochemical and bacteriological analyses. The values obtained for each parameter were compared to the standard value set by the World Health Organization (WHO) and were found within the safe limits set by the WHO. In this regard this water does not present a particular danger for the populations drinking it. A bacteriological analysis has shown the presence of pathogenic germs exposing populations to diseases. This exposure is all the more worry because, in AngondjeNtom area, wells are very frequently located near showers and/or latrines and are often poorly maintained. In addition, the same physicochemical analyses carried out in rainy season reveal an increase in conductivity and turbidity values.

Introduction:-

In many African countries, people lack access to drinking water. This is the case in Mozambique where 13.3 million people (49% of the population) live without safe drinking water (Burgess T., 2016). This leads to 7.000 annual child deaths due to diarrhea. In Ethiopia, 42.2 million people (33% of the population) are in need of potable water, with 15.000 annual child deaths (Burgess T., 2016). Yet, with 17 major rivers and 160 large lakes irrigating it, the African continent has abundant renewable water resources, estimated at more than 5.400 billion m3 per year (Snanoudj G., 2014). While drinking water consumption is high in United States and Europe (700 and 175 liters per day per person respectively, daily supply is 50 liters in Africa (Réveillard M.-F., 2020). On the African continent, the urban population with access to drinking water increased from 82 million in 2000 to 124 million in 2015 (Van Der Berg C. and Danilenko A., 2017). Despite this increase, many efforts remain to be made to achieve the WHO target. According to J. Seguin and A. Gutirrez (2016), the African continent needs to focus on optimizing groundwater resources which are more reliable than surface water because groundwater resources are less sensitive to climate variability and pollution (Seguin J. J. and Gutierrez A., 2016). Groundwater is one of the main sources of drinking water for humans. For example, the majority of rural regions in Senegal are not served by the drinking water supply networks and communities living in these areas often use well water and borehole (Hane M. et al., 2020). In Libreville and its suburb, to make up for the lack of drinking water, people are increasingly resorting to boreholes and wells, especially in areas which are not yet supplied by the national company (SEEG) responsible for the supply sanitation of the clean water distributed in Gabon. Wells, which are less expensive than boreholes, are dug not far from the place of residence, often near latrines, making water prone to fecal contaminations (Tahirou

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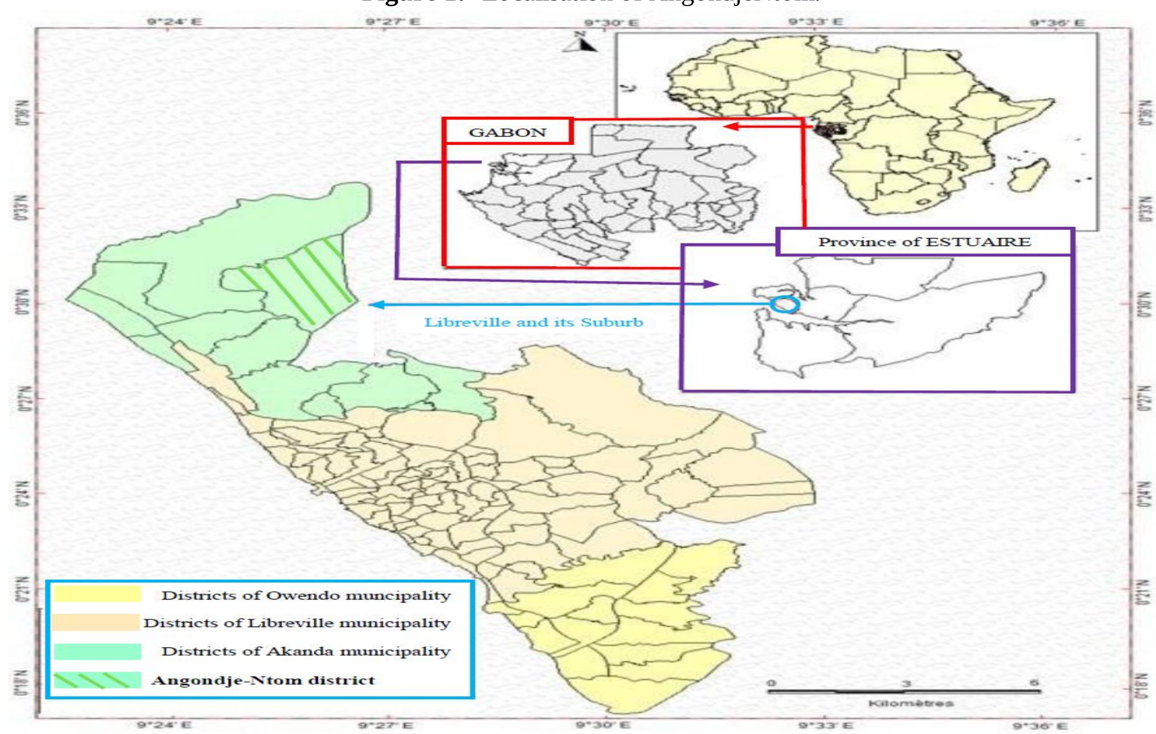
Z.et al., 2021). In addition, one well is frequently used by several families, which often practice laundry and dishes at the well, thus exacerbating the degradation of water quality. The use of such water to drink or to cook food, without prior quality control, as well as a lack of maintenance may lead to waterborne diseases which are a principal cause of death in Africa (Snanoudj G., 2014). The present work was conducted in order to assess the physicochemical and bacteriological quality of these water wells and to assess health risks to the populations could be exposed to.

Materials and Methods:-

Location of Wells:-

AngondjeNtom is a district located in the municipality of Akanda, near Libreville (figure 1)(Makita-Ikouaya E., 2020). Created in 2013, Akanda is located in the province of Estuaire. With an area of 540 km2, Akanda includes several districts such as Avorbam, La Sablière, Cap Estrias(Journal Officiel de la RépubliqueGabonaise, 2013). AngondjeNtom is one of the rare districts of Akanda which is not yet supplied with water by the national company (SEEG). Thus, in AngondjeNtom area, the population mainly uses wells and less frequently boreholes to have water. Each of the twelve wells selected for this study is used at the same time by several (3 to 5) families for their daily water needs. Akanda municipality is surrounded by a huge forest that stretches, with mangroves, over a vast, almost uninhabited space. The Atlantic coast which stretches from north to south of the city, is dotted with sandy beaches. The climate is tropical, hot and humid with alternating dry and rainy seasons: the great rainy season (February to April), the great dry season (May to September), the short rainy season (October to November) and the short dry season (December to January).

Figure 1:- Localisation of AngondjeNtom.



Presentation of Wells:-

Twelve wells W1 to W12, all located in AngondjeNtom, have been analyzed in this study. The wells were selected with the objective that their geographical distribution permits to represent the whole district. The wells are dug in the family yard of twelve different homes and each of the wells selected is used by 3 to 5 other neighboring families. The wells are dug to a sufficient depth of about 10 meters to have water during the dry season. They are often located near latrines and / or outdoor showers. The water from the wells is mainly used for domestic activities but also for gardening and brickyard activities. Some wells are covered simply by a plank or a piece of metal sheet, while others are left permanently opened.

Sample collection:-

The water samples were collected mainly during the great dry season (August 2020). Water samples were taken from each well using a small bucket. Water samples were collected in 1.5 liters polyethylene bottles, which were washed with deionized water before use. These sample bottles were sealed and placed in an ice box at a constant temperature of 4 °C to avoid any contamination. Each of the triplicate samples was analyzed in the LAPLUS (LaboratoirePluridisciplinaire des Sciences) to determine the overall drinking water quality.

Analytical Methods:-

On-site Analysis:-

Temperature, pH, electrical conductivity and turbidity were recorded on-site using a multimeter (HI 991300 HANNA model) for the first three parameters and a turbidimeter (HI 98713 HANNA model) for turbidity. Temperature was measured by introducing the probe in the water samples. After achieving the reading stability, the value was recorded. Before taking the measurements of pH, a calibration was done with the three standard solutions (pH 4.0 – pH 7.0 – pH 10.0). The value of each sample was taken after submerging the pH probe in the water sample and holding for a few minutes to achieve a stabilized reading. After the measurement of each sample, the probe was rinsed with deionized water. The probe was first calibrated with a standard solution of knows conductivity before measuring the conductivity of the samples. The probe was then submerged in the water sample and the reading was recorded. After each measurement, the probe was rinsed with deionized water. After a calibration, turbidity was measured by introducing into the turbidimeter, the cell containing the water sample.

Laboratory Analysis:-

Total hardness, calcium (Ca2+), magnesium (Mg2+) were determined by volumetric metric method with EDTA [10]. Total hardness was determined in the presence of Eriochrome Black -T indicator and a pH 10 buffer solution and calcium titration was carried out in the presence of PR indicator, at a pH of 12 (Rodier J. et al., 2009). Concentration of chloride ions (Cl-) was determined by titration by the Mohr method (Rodier J. et al., 2009). Concentrations of Iron (Fe2+), phosphate (PO43-), nitrate (NO3-) and manganese (Mn2+) were determined by colorimetric method using a WEG 7100 spectrophotometer (Rodier J. et al., 2009). Bacteriological analysis was carried out by PPN method. This method consists in inoculating, using appropriated decimal dilutions of the sample to be analyzed, a lot of tubes containing the nutrient medium, for research of total flora. After an incubation of 24 h to 48 h, tubes presenting a trouble are considered positive (Rodier J. et al., 2009).

Results and Discussion:-

Physicochemical Parameters:-

Physicochemical parameters include temperature, pH, electrical conductivity and turbidity. The obtained results are presented in Table 1.

Table 1:- Average values of physicochemical parameters measured during dry season.

	Temperature (°C)	pH	Conductivity (µS/cm)	Turbidity (NFU)
W1	27.4 ± 0.1	5.90 ± 0.07	200 ± 2.5	17.2±1.6
W2	26.8 ± 0.1	5.4 ± 0.1	56.6 ± 3.7	5.6±0.6
W3	26.8 ± 0.1	6.70 ± 0.01	243.3 ± 5.7	19.9 ±1.6
W4	27.5 ± 0.3	5.9 ± 0.1	48.9 ± 2.6	3.6±0.2
W5	27.5 ± 0.3	6.3 ± 0.2	92.8 ± 1.4	11±1.2
W6	26.7 ± 0.1	6.8 ± 0.1	213.3 ± 5.7	18.5±1.5
W7	27.4 ± 0.1	7.1 ± 0.1	124.3 ±1.5	12.0 ±1.1
W8	27.5± 0.2	6.5 ± 0.3	100.5 ± 0.5	10.5 ± 0.4
W9	26.9± 0.1	6.8 ± 0.3	95.6 ± 0.4	4.2± 0.3
W10	27.0± 0.3	7.2 ± 0.1	220 ±2	18.6 ± 0.6
W11	27.5± 0.2	7.0 ± 0.1	98.9 ± 0.8	8.4 ±1.1
W12	26.8± 0.1	5.6 ± 0.2	118.6 ±1.1	10.2 ±1

Temperature:-

For the twelve wells, the temperature values are between 26.7 and 27.5 °C with an average value of 27.1 °C. These similar values clearly show that groundwater is less sensitive to temperature variations than surface water (Rodier J.

et al., 2005). These temperature values correspond to those recorded during the dry season in Libreville and its suburb (Essono Eni J. et al., 2007)

pH:-

pH is classed as one of the most important water quality parameters. The water samples have an acidic pH (5.4 to 5.9) for four wells, a slightly acidic pH (6.3 to 6.8) for five wells and a neutral (7.0 to 7.2) for three wells. With an average pH value of 6,4, only water samples from seven wells are found to be in the normal drinking water pH range mentioned by WHO (pH 6.5 to 8.5) (World Health Organization, 2007). pH values obtained are close to those found in literature (SouleyRabilou M. et al., 2018 ; Maoudombaye T. et al., 2015) : these waters are therefore generally aggressive with pH values with an acidic tendency. pH characteristics are linked to the geological nature of the aquifers and to the ground crossed (BoubakarHassane A. et al., 2010). The aggressive nature of water can also be explained by organic matter entrained by water infiltration: the microbial mineralization of organic matter contributes to increase dissolved CO2, which leads to decrease in pH (Soro G. et al., 2019).

Electrical Conductivity:-

The results show that the measured conductivity of all water samples ranges from 48.9 to 243.3 µS/cm (average value of 134.4 µS/cm) and therefore complies with the standard values of WHO for drinking water. These conductivity values are slightly lower than those found in literature (SouleyRabilou M.et al., 2018 ;Soro G. et al., 2019 ; NgoualaMabonzo M.et al., 2020). Among the twelve wells studied, water samples of two wells are weakly mineralized (48.9 and 56.6 µS/cm), six wells have a conductivity close to 100 (92.8 to 124.3 µS/cm) and three wells have a conductivity close to 200 (200 to 243.3 µS/cm). Electrical conductivity is the ability of any medium, water in this case, to carry an electric current. The presence of dissolved solids carries the electric current in water.

Turbidity:-

Turbidity is the measure of cloudiness of water, it is caused by large number of suspended organic and inorganic particles, such as sediments and microorganisms. Turbidity values obtained vary from 3.6 to 19.9 NTU, with an average value of 11.6 NTU. Only two wells have a turbidity value (3.6 and 4.2 NTU) below the limit set by WHO (5 NTU) () SouleyRabilou M. et al., 2018à. The majority (ten) of wells tested present high levels of turbidity. These high levels may be due to the presence of suspended solids carried by the wind in the wells and coming from unpaved and very dusty roads in AngondjeNtom area. Another cause could be the resuspension, during drawing, of particles deposited at the bottom of the well (Tahirou Z. et al., 2021). Indeed, in the dry season, the water level in the well is low, closer to the bottom of the well.

Chemical Parameters:-

Chemical parameters include calcium, total hardness, magnesium, chloride, iron, manganese, phosphate and nitrate. The obtained results are presented in Tables 2a and 2b.

Calcium, Total hardness and Magnesium:-

Water samples analyzed have a calcium and magnesium content ranging from 2.2 to 47 mg/L (average value of 17.1 mg/L) and from 0.4 to 3.7 mg/L respectively (average value of 2.3 mg/L). Calcium and magnesium are very widespread metals in nature especially in limestone rocks. Total hardness corresponds to the content of dissolved salts of calcium and magnesium in the form of bicarbonate, sulphate and chloride. It's directly linked to the nature of grounds crossed (BoubakarHassane A., 2010). Low values were obtained, ranged from 0.7 to 5.0 °F with an average value of 2.6 °F. These are therefore very soft waters. Water that is too soft and moreover acidic can cause corrosion of the constituent metals of the pipes and thus can release iron, copper, zinc, lead (NgoualaMabonzo M. et al., 2020). This may be the case with wells equipped with an automatic water pumping system. Total hardness can be correlated with conductivity: for the twelve wells, conductivity values recorded (< 300 µS/cm) also indicate that the well water is soft.

Table 2a:- Average values of chemical parameters (calcium, total hardness, magnesium) measured during dry season.

	Calcium Ca^{2+} (mg/l)	Total Hardness (°F)	Magnesium Mg^{2+} (mg/L)
W1	10 ± 0.9	2 ± 0.1	2.9± 0.2
W2	5 ± 0.5	0.8 ± 0.1	2.4± 0.2
W3	47 ± 1.1	5.0 ± 0.05	0.4±0.05
W4	2.2± 0.1	0.7± 0.05	0.5± 0.05

W5	9.8± 0.4	2.1± 0.1	1.7± 0.1
W6	29± 1.2	4.0± 0.5	3± 0.2
W7	12,5 ± 1.8	2.4± 0.3	3.1± 0.4
W8	26.7± 0.6	3.7 ± 0.2	2.9 ± 0.3
W9	8.9± 0.3	1.7 ± 0.3	1.4 ± 0.2
W10	15.6± 0.6	2.5 ± 0.1	3.2 ± 0.2
W11	21.1± 0.5	3.2 ± 0.4	3.1 ± 0.4
W12	17.8± 0.4	3.3 ± 0.2	3.7 ± 0.2

3.2.2. Chloride, Iron, Manganese, Phosphate and Nitrate

Table 2b:- Average values of chemical parameters (chloride, iron, phosphate and nitrate) measured during dry season.

	Chloride Cl^- (mg/L)	Iron Fe^{2+} (mg/L)	Manganese Mn^{2+} (mg/L)	Phosphate PO_4^{3-} (mg/L)	Nitrate NO_3^- (mg/L)
W1	1.8 ± 0.1	0.1 ± 0.01	0.2 ± 0.01	0.5 ± 0.01	5.8 ± 0.2
W2	4.4 ± 0.3	0.1 ± 0.01	0.2 ± 0.01	1.2 ± 0.02	13.2 ± 0.1
W3	4.6 ± 0.2	0.1 ± 0.01	0.3 ± 0.01	1.5 ± 0.01	2.5 ± 0.1
W4	3.2 ± 0.2	0.2 ± 0.01	0.2 ± 0.01	2.8 ± 0.03	5.4 ± 0.3
W5	1.6 ± 0.2	0.1 ± 0.01	0.2 ± 0.01	0.9 ± 0.1	3.2 ± 0.2
W6	6.5 ± 0.1	0.1 ± 0.01	0.3 ±0.01	3.3 ± 0.2	3.5 ± 0.1
W7	1.7 ± 0.1	0.1 ± 0.01	0.3 ±0.01	4.5 ± 0.3	4.8 ± 0.1
W8	5.3 ± 0.3	0.1 ± 0.01	0.3 ±0.01	3.6 ± 0.1	2.5 ± 0.1
W9	3.8 ± 0.1	0.2 ± 0.01	0.2 ±0.01	1.8 ± 0.2	5.5 ± 0.2
W10	6.2 ± 0.2	0.1 ± 0.01	0.2 ±0.01	2.6 ± 0.1	4.5 ± 0.2
W11	5.3 ± 0.2	0.2 ± 0.01	0.2 ±0.01	0.8± 0.1	10.4 ± 0.2
W12	3.7 ± 0.1	0.1 ± 0.01	0.1 ±0.01	4.8 ± 0.1	8.9 ± 0.3

Water samples analyzed have a chloride content much lower than limit set by WHO (250 mg/L), from 1.6 to 6.5 mg/L (average value of 4.0 mg/L). These values are lower than those found in literature (SouleyRabilou M.et al., 2018 ;Soro G. et al., 2019 ; Balloy Mwanza P. et al., 2019 ; Alemad A. K. et al., 2016). Very low iron and manganese contents were obtained: 0.1 mg/L and 0.2 mg/L respectively for almost all of the water samples. These values are below the limits set by WHO (0.3 and 0.4 mg/L respectively) (World Health Organization, 2007). When their levels are high, iron and manganese are often responsible for the reddish color of certain ground waters (Soro G. et al., 2019). Phosphate and nitrate are found at levels below the limits set by WHO (5 and 50 mg/L respectively). Thanks to these results it is safe to say that the use of fertilizer does not pollute the well water. Indeed, in AngondjeNtom, people often practice food crops and gardening using fertilizers.

Bacteriological Parameters:-

A bacteriological analysis of the well water was carried out. The results obtained are presented in Table 3.

Table 3:- Average values of bacteriological parameters measured during dry season.

	Total Coliforms (UFC/100 mL)	FaecalColiforms (UFC/100 mL)
W1	420 ± 6	100 ± 6
W2	30 ± 3.1	10 ± 2.1
W3	295 ± 5	55 ± 6
W4	1300 ± 8	126 ± 3.6
W5	250 ± 2	55 ± 1.5
W6	320 ± 2.5	125 ± 6
W7	130 ± 5.5	30 ± 4
W8	225 ± 2.5	85 ± 4.5
W9	380 ± 10.2	150 ± 5
W10	409 ± 25	90 ± 6.3
W11	58 ± 8.8	25 ± 2.5
W12	742 ± 15	102 ± 8

Bacteriological analysis reveals the presence of total and faecal Coliforms revealing a probable faecal contamination of water. It's therefore recommended to sanitize water before its consumption. In AngondjeNtom area, the proximity of many wells of latrines and/or outshowers exposes the population to water-bornes diseases. Numerous studies highlight the frequent presence of germs in well water, indicative of a bacteriological pollution (Balloy Mwanza P.et al., 2019 ;Alemad A. K.. et al., 2016).

Analysis in Rainy Season:-

All analyses presented until now have been carried out in dry season (August 2020). In order to know the effect of a change of season, measurements were also carried out in rainy season (February 2021) for the twelve wells. Water samples were therefore taken in rainy season, under the same conditions as those described in dry season.

Physicochemical parameters:-

Physicochemical parameters include temperature, pH, electrical conductivity and turbidity. The obtained results are presented in Table 4 and Figures 2a to 2d.

Table 4:- Average values of physicochemical parameters measured during rainy season.

	Temperature (°C)	pH	Conductivity (µS/cm)	Turbidity (NFU)
W1	28.3 ± 0.2	6.1 ± 0.2	307± 5	19.4 ± 1.2
W2	27.5 ± 0.1	5.5 ± 0.1	78.8± 3	7.3 ± 0.5
W3	27.1 ± 0.1	6.4 ± 0.1	279± 4	22.2 ± 1.8
W4	28 ± 0.1	5.7 ± 0.2	74.1± 3	5.5 ± 0.5
W5	29.2 ± 0.1	6.5 ± 0.1	160.4± 1.8	12.3 ± 2.2
W6	28.1 ± 0.2	6.6 ± 0.1	225± 3.2	18.8 ± 2.5
W7	27.7 ± 0.1	6.8 ± 0.2	128.2 ± 2.5	12.9 ± 2
W8	28.0 ± 0.1	6.4 ± 0.1	130.8 ± 2	13 ± 0.5
W9	27.8 ± 0.2	7.1 ± 0.2	97.6 ± 1.5	6.1 ± 1.6
W10	28.3 ± 0.1	7.1 ± 0.1	241.3 ± 4.2	20.3 ± 1.5
W11	28 ± 0.1	6.7 ± 0.2	99.1 ± 1	8.8 ± 0.2
W12	27.8 ± 0.2	5.4 ± 0.1	156.7 ± 3.5	11.9 ± 0.3

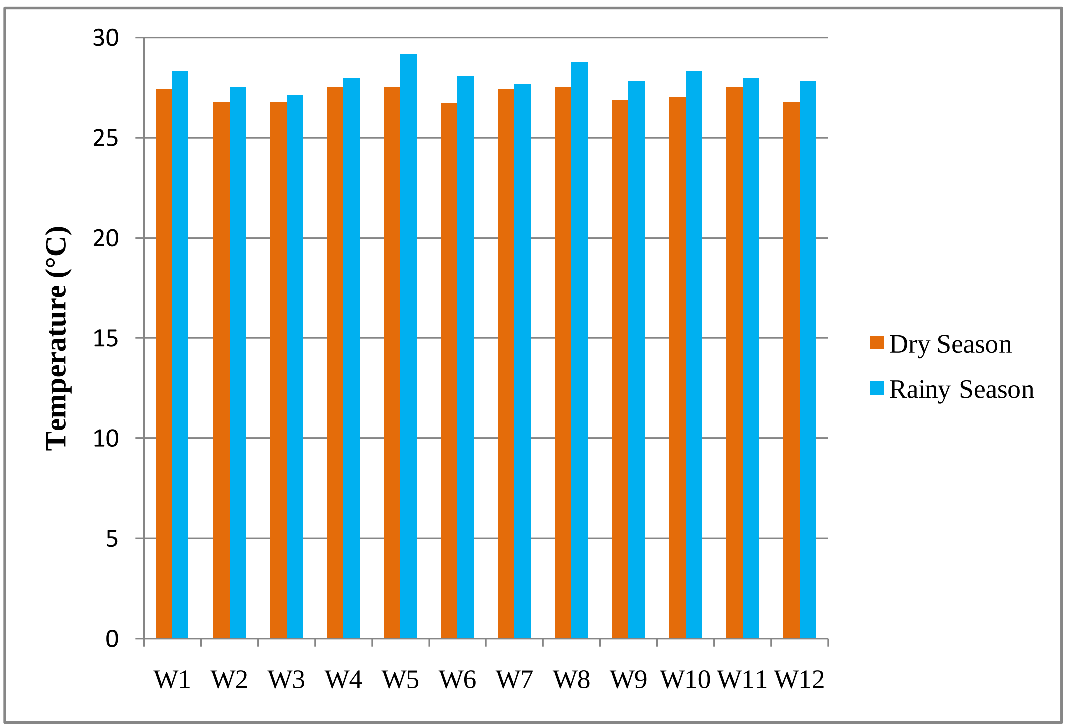


Figure 2a:- Average values of temperature in dry and rainy seasons.

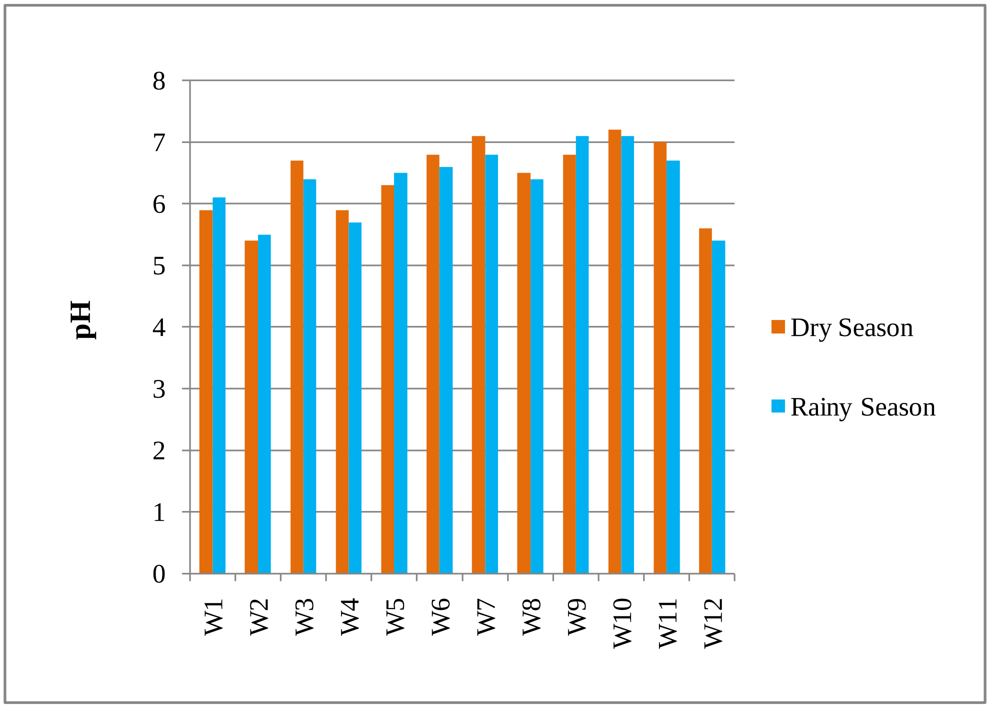


Figure 2b:- Average values of pH in dry and rainy seasons.

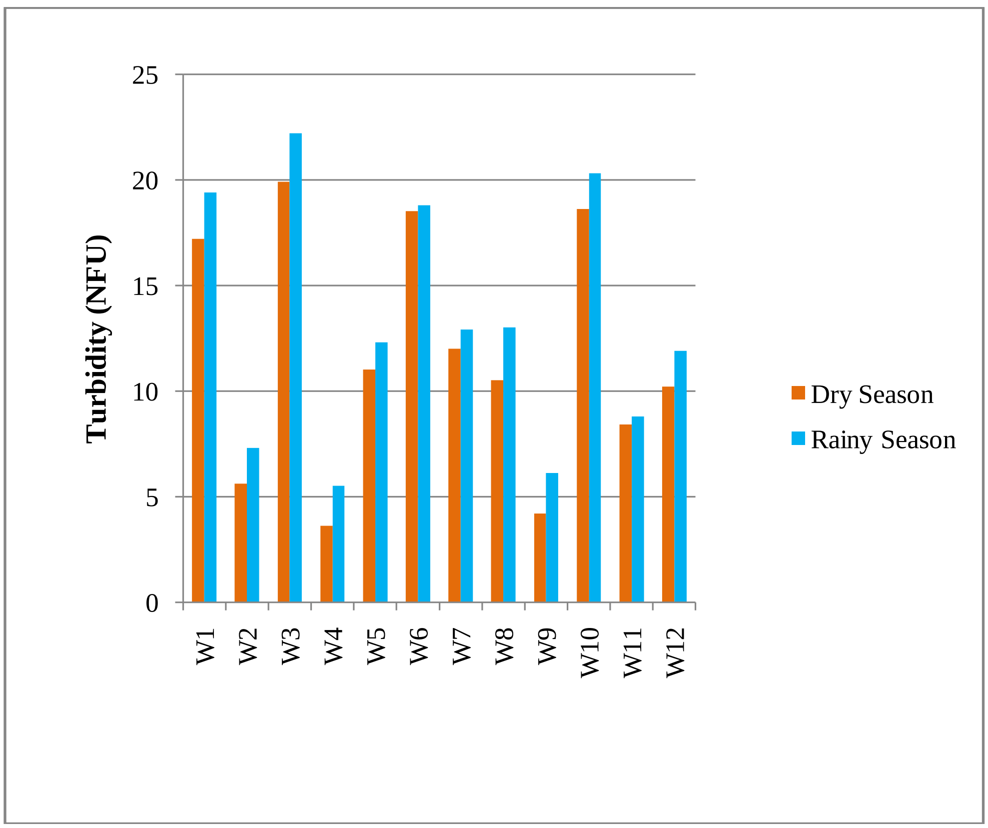


Figure 2c:- Average values of Electrical Conductivity in dry and rainy seasons.

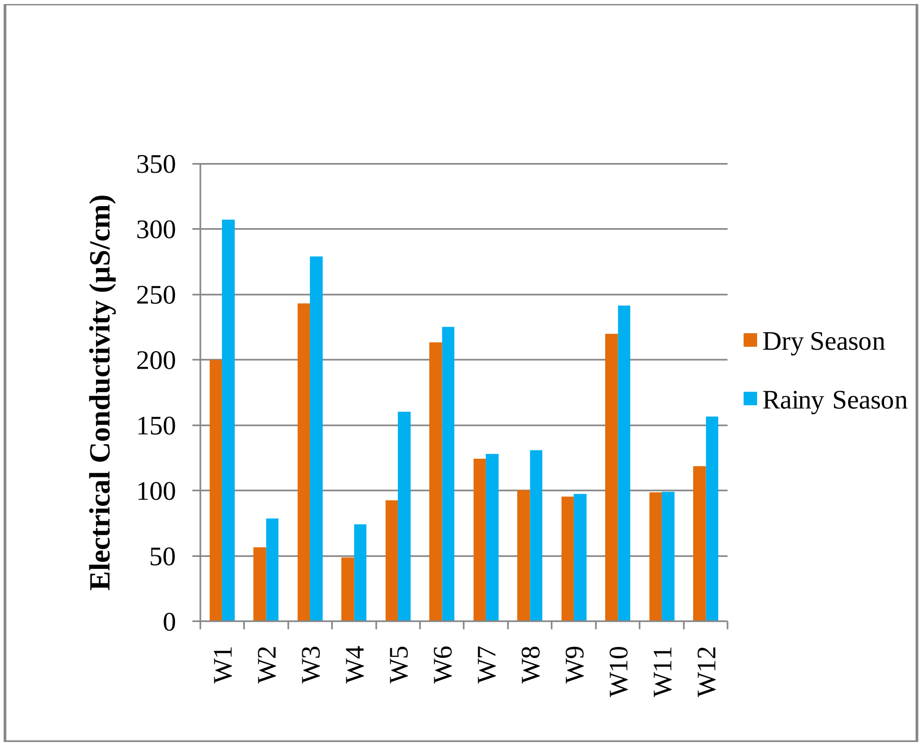


Figure 2d:- Average values of Turbidity in dry and rainy seasons.

Temperatures recorded in the rainy season are a little higher than those observed in dry season but remain within the average values observed in rainy season. Indeed, the rainy season is often marked by the alternation between hot, sunny days interspersed with rainy episodes, and days characterized by continuous rain. pH values in rainy season are generally similar to those obtained in dry season. A slight decrease in pH, noted for the majority of the wells (eight wells) can be explained by the dissolution of carbon dioxide, favored in rainy periods and coming from the widespread cooking over a wood fire. Well water therefore remains acidic in rainy season. Electrical conductivity values are all much higher in rainy season than those obtained in dry season. These results suggest that rain promotes an increase in dissolved salts in well water, in particular by the leaching of soil particles. The considerable differences observed between the two sampling campaigns indicate a strong heterogeneity of the mineralization of the water (Alemad A. K.. et al., 2016). But with conductivity values less than or equal to 300 µS/cm, well water remains soft. Turbidity values are also much higher in rainy season, it can be favored by rainfall.

Chemical parameters:-

Chemical parameters include calcium, total hardness, magnesium, chloride, iron, manganese, phosphate and nitrate. The obtained results are presented in Tables 5a and 5b, Figures 3a to 3h.

Table 5a:- Average values of chemical parameters (calcium, total hardness, magnesium) measured during rainy season.

	Calcium Ca^{2+} (mg/l)	Total Hardness (°F)	Magnesium Mg^{2+} (mg/L)
W1	9.6± 0.2	1.8±0.3	2.3± 0.4
W2	5.2± 0.3	0.7± 0.1	2.4± 0.2
W3	42.7± 0.5	4.5± 0.4	0.3±0.1
W4	2.3± 0.1	0.7± 0.1	0.4± 0.1
W5	10± 0.2	2± 0.3	1.9± 0.2
W6	27.8± 0.2	3.6± 0.3	2.5± 0.3
W7	12.2 ± 0.5	2.3 ± 0.2	2.8 ± 0.4
W8	25.1 ± 0.3	3.1 ± 0.3	2.7 ± 0.3
W9	8.8 ± 0.4	1.6 ± 0.2	1.2 ± 0.4
W10	15.7 ± 0.6	2.5 ± 0.3	3 ± 0.3

W11	20.5 ± 0.8	2.9 ± 0.4	2.7 ± 0.5
W12	16.9 ± 0.2	3.1 ± 0.2	2.9 ± 0.4

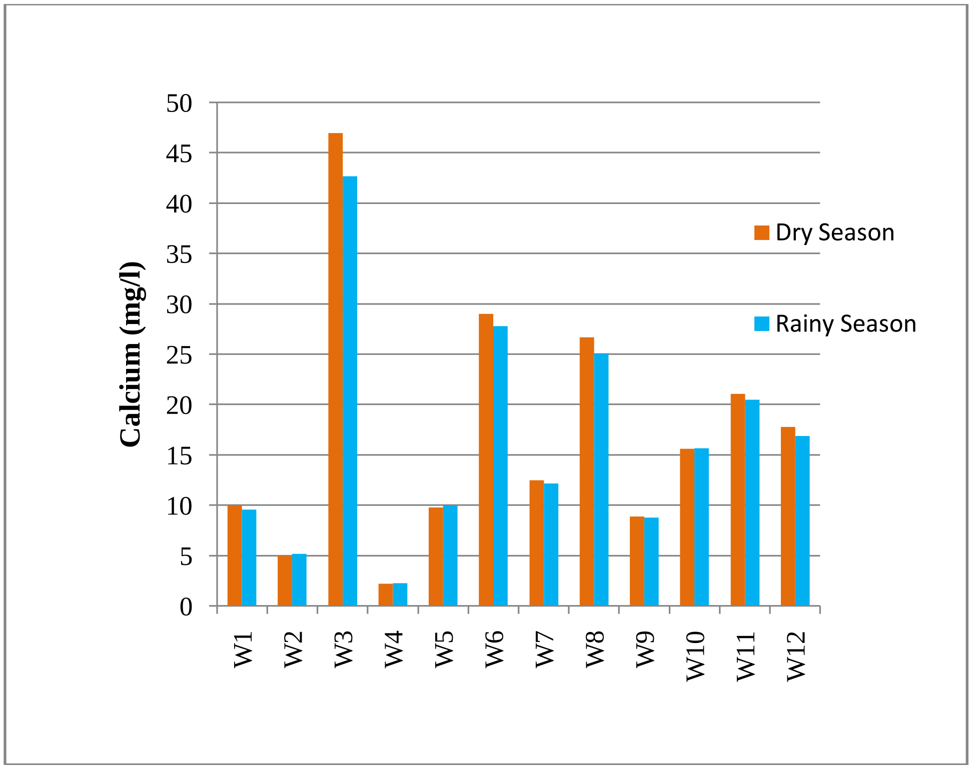


Figure 3a:- Average values of Calcium (Ca2+) in dry and rainy seasons.

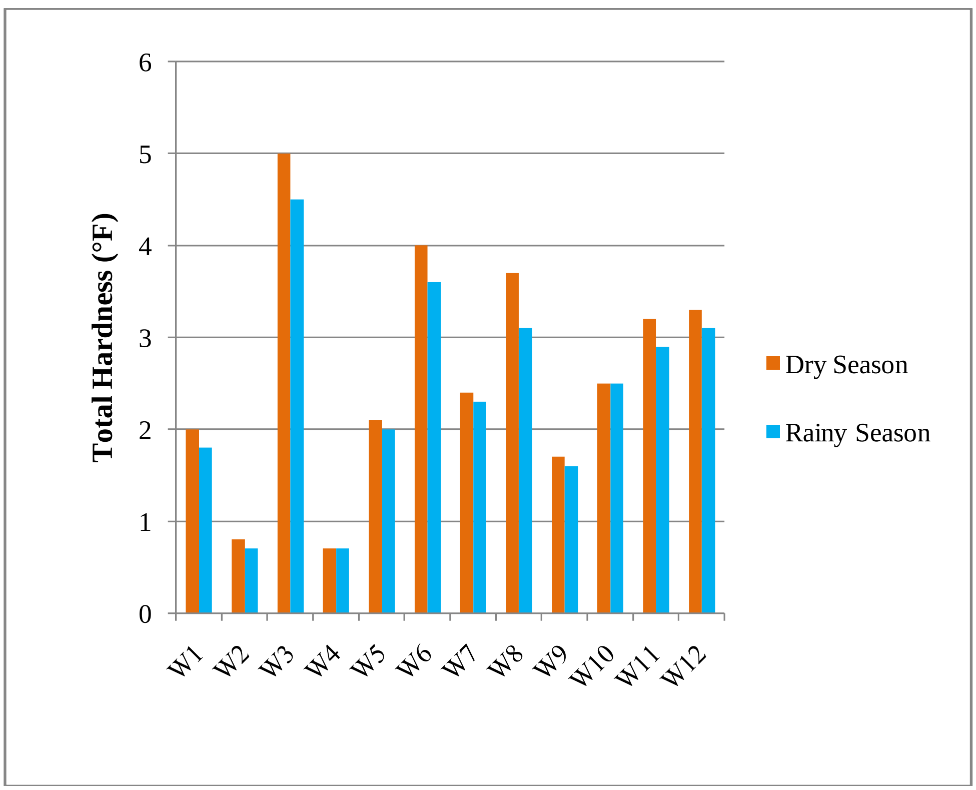


Figure 3b:- Average values of Total Hardness in dry and rainy seasons.

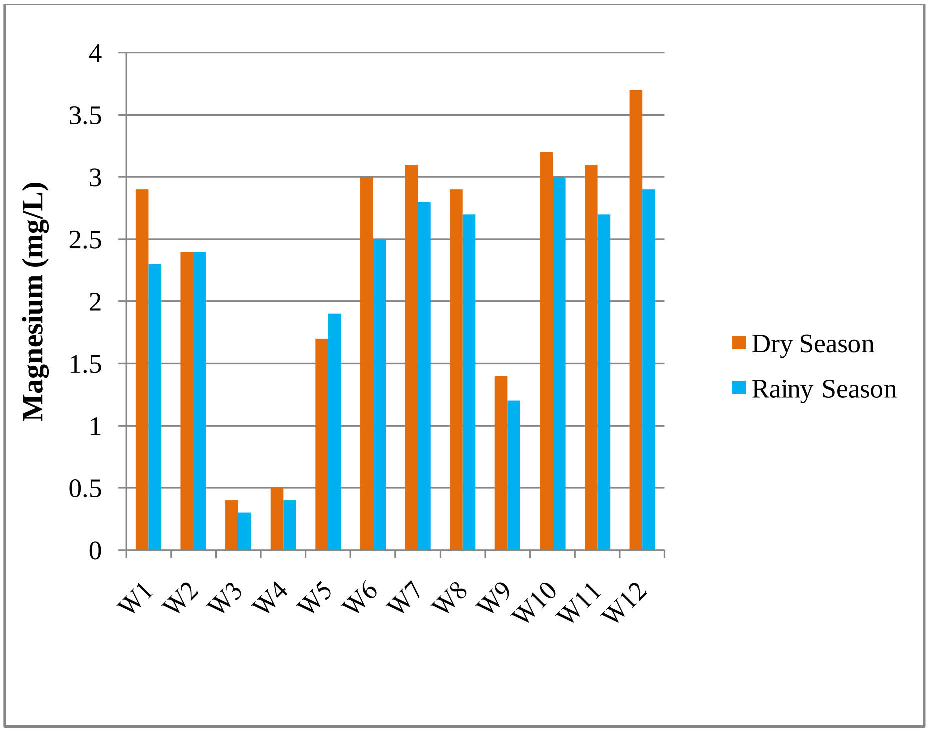


Figure 3c:- Average values of Total Hardness in dry and rainy seasons

Calcium contents in rainy season are slightly lower than those recorded in dry season. A similar evolution is observed with magnesium contents with slightly lower levels in rainy season than values obtained in dry season. These results lead to a total hardness slightly lower or even similar in rainy season than in dry season. Total hardness is directly linked to the nature of grounds crossed. The slight decrease of total hardness observed may be due to the increase flow of water during rainy season thus leading to a dilution effect.

Table 5b:- Average values of chemical parameters (chloride, iron, phosphate and nitrate) measured during rainy season.

	Chloride Cl^- (mg/L)	Iron Fe^{2+} (mg/L)	Manganese Mn^{2+} (mg/L)	Phosphate PO_4^{3-} (mg/L)	Nitrate NO_3^- (mg/L)
W1	1.7 ± 0.2	0.1 ± 0.01	0.1 ± 0.01	0.5 ± 0.1	4.9 ± 0.1
W2	4.4 ± 0.1	0.2 ± 0.01	0.2 ± 0.01	1.1 ± 0.1	11.7 ± 0.2
W3	4.2 ± 0.1	0.2 ± 0.01	0.2 ± 0.01	1.5 ± 0.2	2.0 ± 0.2
W4	3.0 ± 0.3	0.2 ± 0.01	0.1 ± 0.01	2.7 ± 0.01	5.6 ± 0.1
W5	1.7 ± 0.2	0.2 ± 0.01	0.1 ± 0.01	1.1 ± 0.1	3.1 ± 0.1
W6	6.6 ± 0.2	0.1 ± 0.01	0.3 ± 0.01	3.2 ± 0.1	2.9 ± 0.1
W7	1.5 ± 0.1	0.1 ± 0.01	0.3 ± 0.01	4.2 ± 0.01	4.1 ± 0.2
W8	5.0 ± 0.4	0.1 ± 0.01	0.2 ± 0.01	3.3 ± 0.2	2.8 ± 0.1
W9	3.5 ± 0.2	0.1 ± 0.01	0.2 ± 0.01	1.8 ± 0.1	5.1 ± 0.4
W10	6.4 ± 0.1	0.1 ± 0.01	0.2 ± 0.01	2.5 ± 0.1	3.8 ± 0.2
W11	5.5 ± 0.2	0.1 ± 0.01	0.1 ± 0.01	0.9 ± 0.3	9.8 ± 0.4
W12	3.9 ± 0.1	0.1 ± 0.01	0.1 ± 0.01	4.4 ± 0.1	7.7 ± 0.3

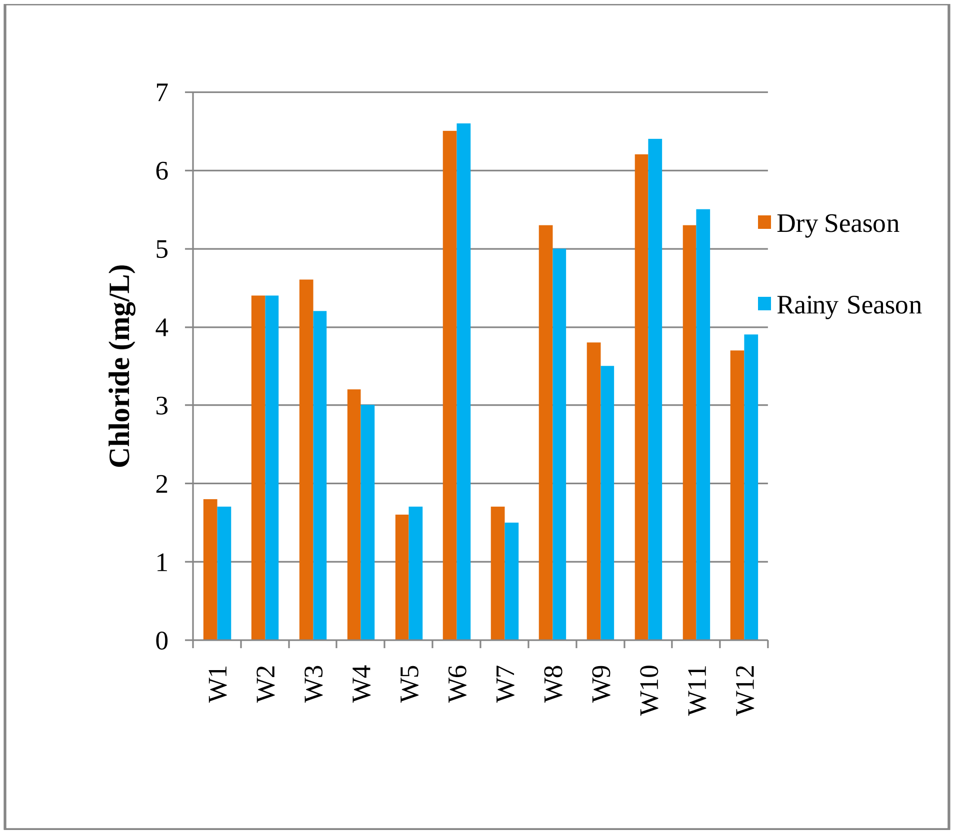


Figure 3d:- Average values of Chloride (Cl-) in dry and rainy seasons

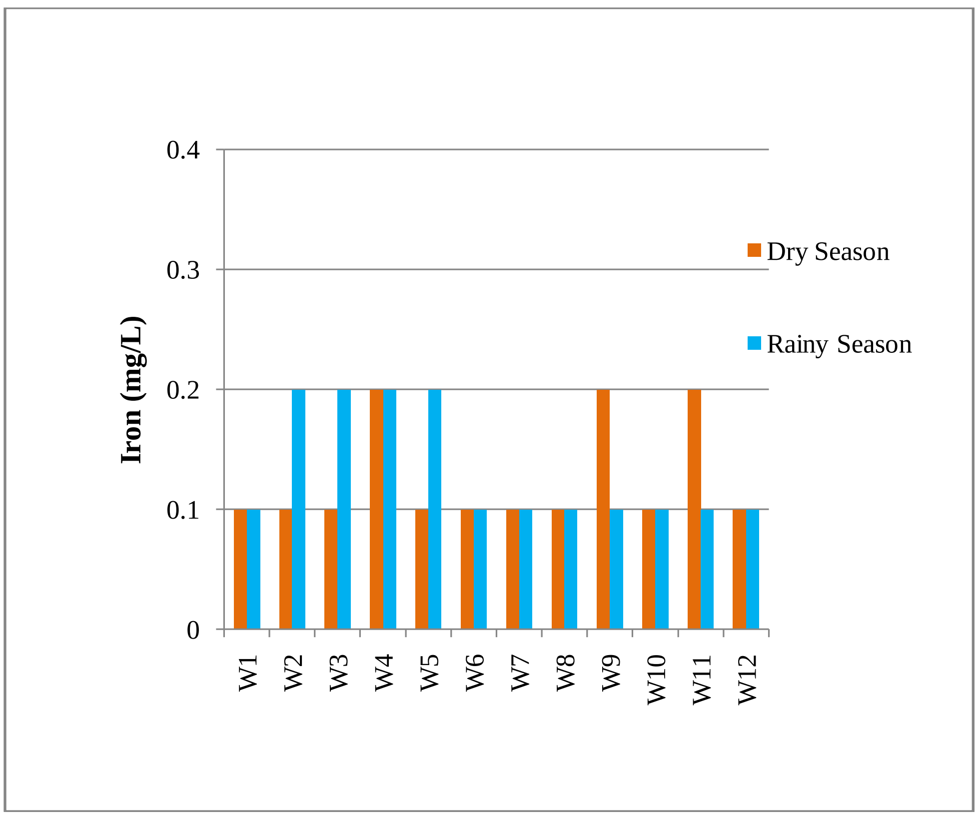


Figure 3e:- Average values of Iron (Fe2+) in dry and rainy seasons.

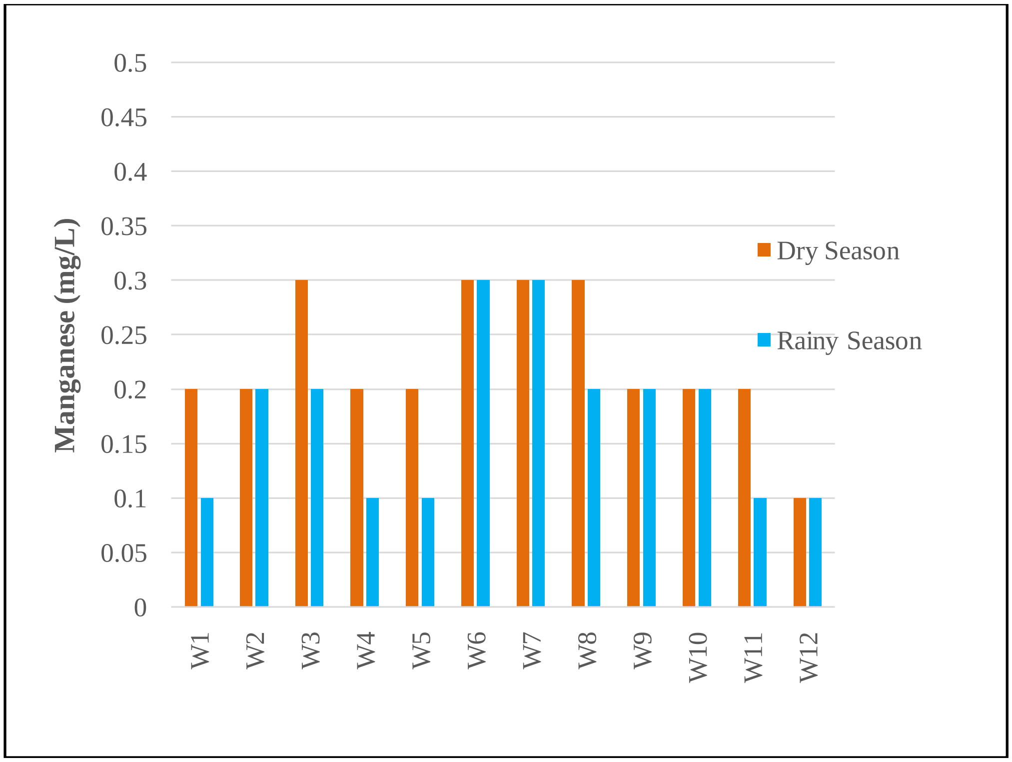


Figure 3f:- Average values of Manganese (Mn2+) in dry and rainy seasons.

Figure 3g:- Average values of Phosphate (PO43-) in dry and rainy seasons.

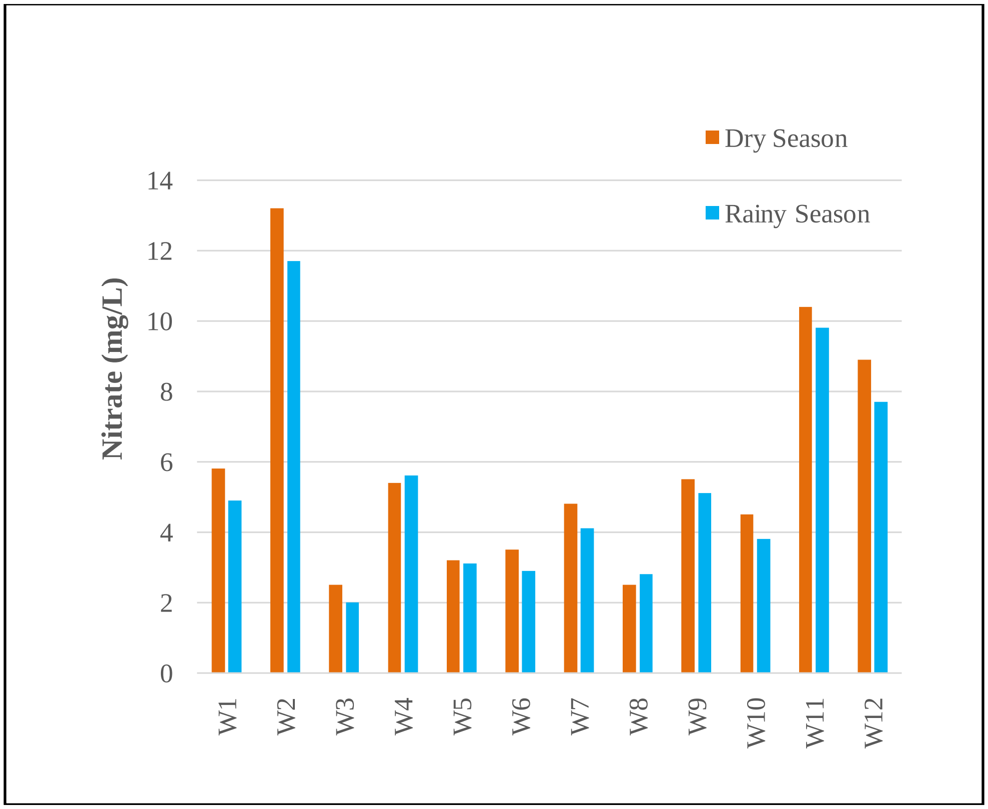


Figure 3h:- Average values of Nitrate (NO3-) in dry and rainy seasons.

Chloride, Iron, Manganese, Phosphate and Nitrate contents remain low. Indeed, these different parameters do not depend on season but are linked to the nature of grounds crossed, or an important agricultural activity.

Bacteriological parameters:-

A bacteriological analysis of the well water was carried out in rainy season. The results obtained are presented in Table 6 and Figures 4a, 4b.

Table 6:- Average values of bacteriological parameters measured during rainy season.

	Total Coliforms (UFC/100 mL)	FaecalColiforms (UFC/100 mL)
W1	550 ± 10	220 ± 2.5
W2	25 ± 2.5	12 ± 1.5
W3	450 ± 10.2	105 ± 3.3
W4	856 ± 6.4	455 ± 8.6
W5	283 ± 3.4	174 ± 2.5
W6	402 ± 4.5	275 ± 5.2
W7	128 ± 2.3	66 ± 4.4
W8	342 ± 5.5	189 ± 7.5
W9	556 ± 7.5	300 ± 10.2
W10	513 ± 10	210 ± 8.5
W11	75 ± 4.5	32 ± 1.5
W12	1050 ± 20	743 ± 20

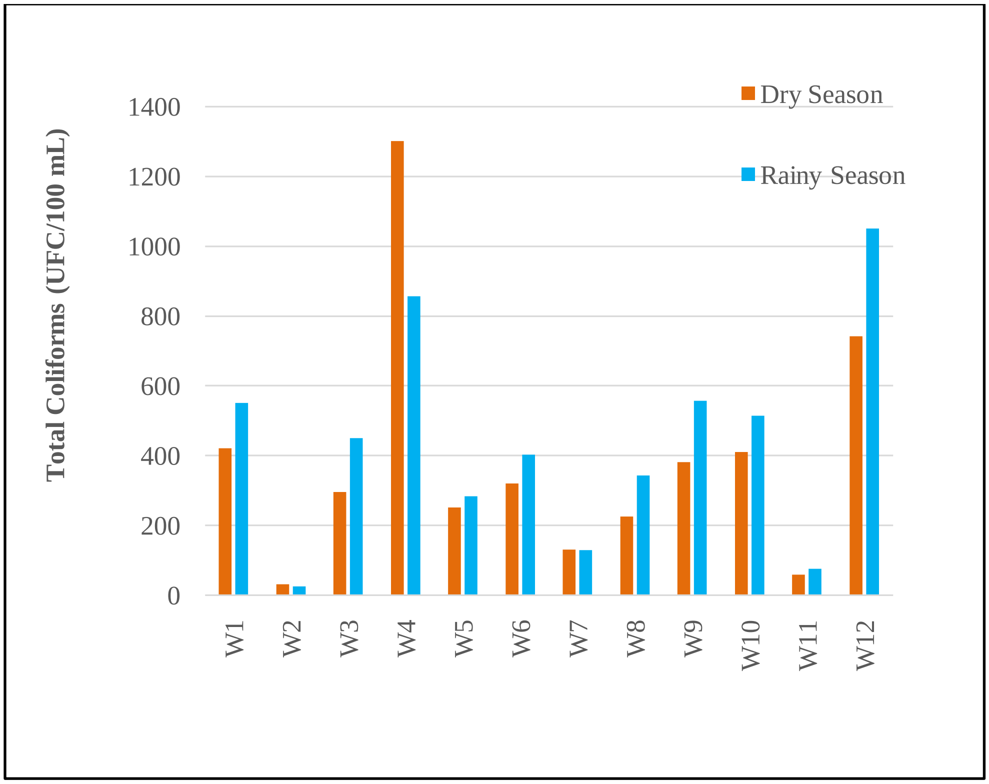


Figure 4a:- Average values of Total Coliforms in dry and rainy seasons.

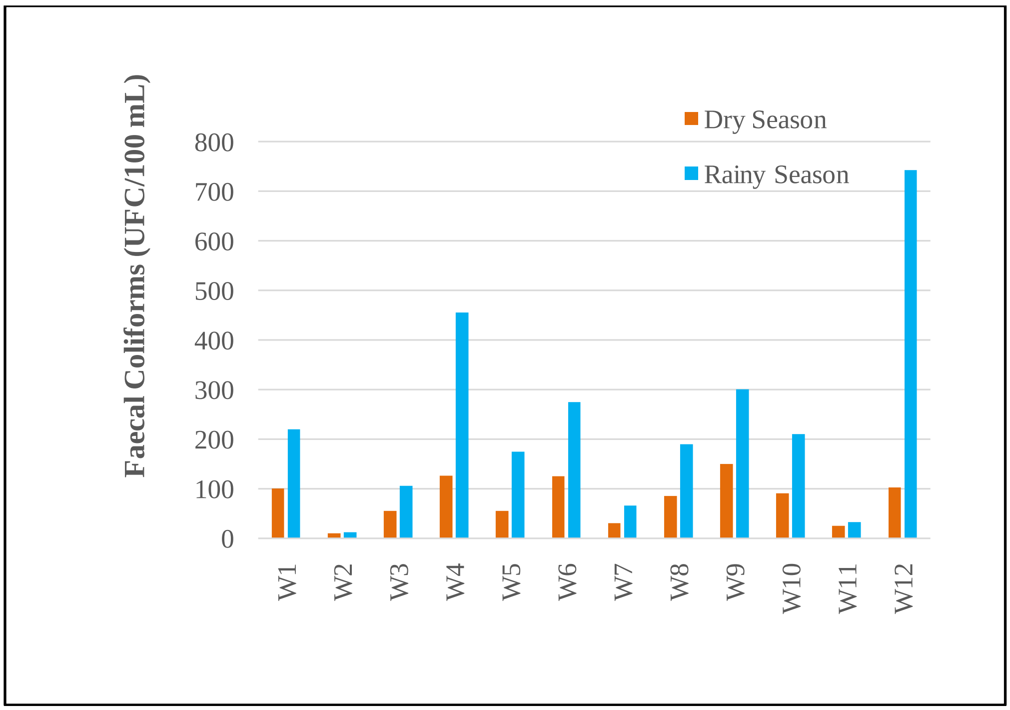


Figure 4b:- Average values of Faecal Coliforms in dry and rainy seasons.

Bacteriological analyses in rainy season confirm a faecal contamination of water for the twelve wells. The strong increase in Total and Faecal coliforms observed in rainy season shows that wells are poorly protected and are contaminated by seepage water. Regardless of the season, the water from these wells must be treated before any consumption.

Conclusion:-
This work has permitted to show that water well in AngondjeNtom area have in generally an acidic pH and a low total hardness. The high temperatures reflect the hot and humid climate characteristic of the studied area. In addition, the presence of faecal pollution indicators has been observed, showing that these waters can present a danger for human consumption. Efforts should be made by the populations on the cleanliness and good maintenance of wells. In order to better assess the quality of these waters, broader studies on other physico-chemical parameters are planned.

Conflicts of Interest:-
The authors declare no conflicts of interest regarding the publication of this paper.

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