International Research Journal of Biological Sciences ISSN 2278-3202
Vol. **3(12),** 16-23, December **(2014)** *Int. Res. J. Biological Sci.*

Distribution of Iron content in Urban Groundwater, Southeastern Brazzzaville, Congo

Massoumou Massolola A.C.[1], Matini L.[1], Morabandza C.J.[2] and Moutou J.M.[1]
[1]Department of Exact Sciences, E.N.S, University Marien Ngouabi, P.O. Box 69 Brazzaville, R CONGO
[2]Department of Natural Sciences, E.N.S, University Marien Ngouabi, P.O. Box 69 Brazzaville, CONGO

Available online at: www.isca.in, www.isca.me
Received 24th April 2014, revised 6th October 2014, accepted 22th November 2014

Abstract

Iron content associated with pH values and temperature of groundwater samples has been assessed in rainy (March 2013) and dry (July 2013) seasons in this study using standards methods. The mean variance skewness and kurtosis of pH and iron content were calculated and show that they exhibit an asymmetric distribution which characterizes a non-uniform distribution. This suggests that many chemical processes could control the groundwater quality. The mean of pH values (4.07±0.91 in rainy season and 5.08±0.86 in dry season) characterizes an acidic nature of the groundwater. The iron contents in some groundwater samples higher than 0.3 mg/L can be considered as contributors to deteriorating groundwater quality from both natural and anthropogenic sources. In view of these features, regular monitoring of groundwater quality in the study area is required to protect people against polluted groundwater.

Keywords: Groundwater, acidity, iron.

Introduction

Water is a precious resource for the survival of humans. Groundwater plays an important part in many domains and the health of many ecosystems depends of this water resource [1-3]. Throughout the world and precisely in developing countries like Congo-Brazzaville, groundwater becomes an important water supply[4-9] as well in urban area as in the rural communities. Unfortunately, there is a lack of information relating to the quality of groundwater used for drinking water and other domestic usages by the people. The increasing demand of water in the world has involved an intensive stress on the quality of groundwater due to some factors such as climate change, pollution arising from geology, geochemistry of the environment[10] and anthropogenic sources such as domestic waste, garbage, fertilizers and industrial waste[11]. Water of good quality is important in body metabolism and the work of cells. But this quality depends on many parameters such as the presence of metals whom the contents does not exceed the permissible limits. Iron is one the metals which occurs naturally in groundwater. Its most sources are weathering of iron bearings minerals and rocks. At the concentration approaching 0.3 mg/L Fe, the use of groundwater may become seriously impacted.

In this study, attempt is made to assess total iron concentration in shallow wells and bore wells located in a peri-urban area of Brazzaville in Congo.

Material and Methods

Study area: The study area is located in southeastern Brazzaville between 15°13’53” to 15°14’10” East and longitude and 4°15’7.2” to 4°15’28.8” South latitude (figure-1). The area is in the equatorial climate zone, with two seasons of rainy (October to May) and dry (June to September). Temperature varies from 25°C to 36°C in rainy season, while it is between 18°C and 24°C in dry season. The mean annual rainfall is 1470 mm. The vegetation is of savanna type (*Loutetia demeusi)* and presents a formation to sparse gramineous carpet, with a shrubby layer of *hymenocardia acida*. Aquifer is shallow and generally the deep wells do not exceed 2m depth. Therefore the lowering of the ground water table increases the risk of contamination[4].

The most well water present iron sheet as well casings in the study area. The main natural recharge to groundwater is from precipitation (rainfall). Farming activities are present around some well water sites and also agricultural activities near the River Mfilou. Belonging to the continental sedimentary basin of tertiary age, the southeastern Brazzaville is made of sedimentary deposits with recent alluvium formations covering the bed rock. These formations are also made with ochre sands or Batéké sands (silicate sandstones), which constitute the formation of Inkisi classically joined to the schisto-sandy group.

Sampling and Analysis: Twenty two samples of groundwater of which 19 wells water (P), 2 bore wells (F=BH, after running them for 10 minutes) and 1 water spring (S) were collected in three times in rainy season (October 2012) and in dry season (August 2013), in the study area (figure-1)

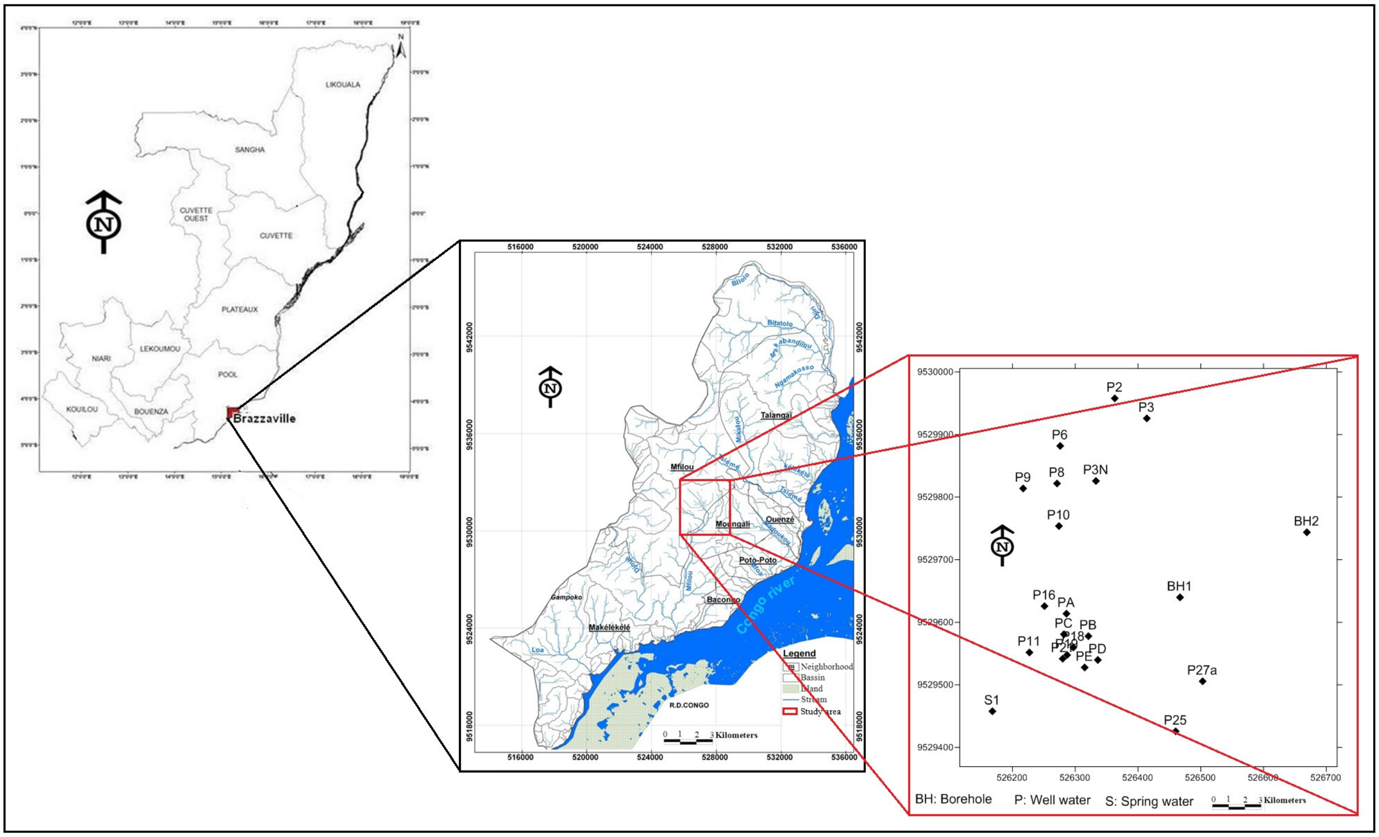

Figure-1
Location map of the study area

They were analyzed for temperature T (°C), pH and iron content (mg/L), following standards methods[12]. Before water sampling, all the polyethylene bottles were cleaned and rinsed thoroughly with water to be analyzed. All reagents used were of analytical grade. Samples were unfiltered and the concentration of iron could correspond to the total concentration if the groundwater was used by the consumers for drinking. Temperature and Hydrogen ion concentration (pH) were measured in the field by using Consort C933 multi-parameters portable. Iron content was determined by phenanthroline spectrophotometry method.

STATISTCA 7.1 software was used to perform descriptive statistics and hierarchical cluster analysis (HCA) which is a data reduction method used to classify entities or objects with similar properties into groups called clusters. Objects within the clusters are similar, while objects in different clusters are dissimilar[13-15]. To identify the number of clusters, hierarchical cluster analysis was performed on the dataset by Ward's method using Euclidean distance as similarity measure. A short Euclidean distance implies the high similarity between the measured objects. The distinct groups could reveal the interaction among the parameters (variables) or the interrelation between the samples (observations). Many studies have demonstrated the application of HCA through successfully in the analysis of hydrogeochemical data[16-20].

Results and Discussion

The results of physical and chemical analysis are presented in table-1 and table-2. Table 3 shows the descriptive statistics of the data. The distribution of pH values and total iron concentration in the groundwater samples are shown in both seasons in figures-2 and 3, respectively. The average temperature in the groundwater samples was 26°C ± 0.9 and 24°C ± 0.7 in rainy season and in dry season, respectively. The temperature varied very slightly with sampling location and time of collection in both seasons. Temperature values of groundwater samples in rainy season were higher than those observed in dry season. The pH values ranged between 2.8 (sample BH1) to 5.84 (sample P9) in rainy season and 4.0 (sample BH1) to 6.04 (sample P9) in dry season, which indicate that water is acidic to slightly acidic in rainy season and slightly acidic in dry season. In rainy season, pH values of groundwater samples were lower than those observed in dry season, except for groundwater sample P_C. In sedimentary formations, iron occurs as pyrite[21] and in oxidizing conditions pyrite is oxidized[22] as describe by the following equation:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \leftrightarrows Fe(OH)_3 + 4H^+ + 2\ SO_4^{2-} \quad (1)$$

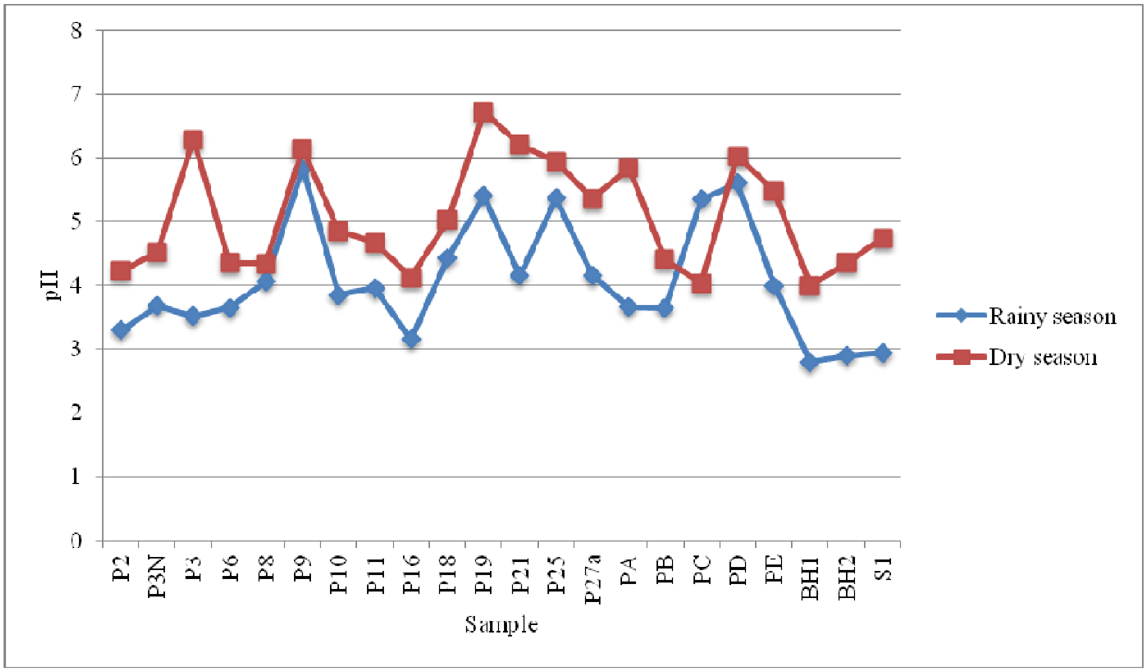

Figure-2
Distribution of pH in groundwater samples

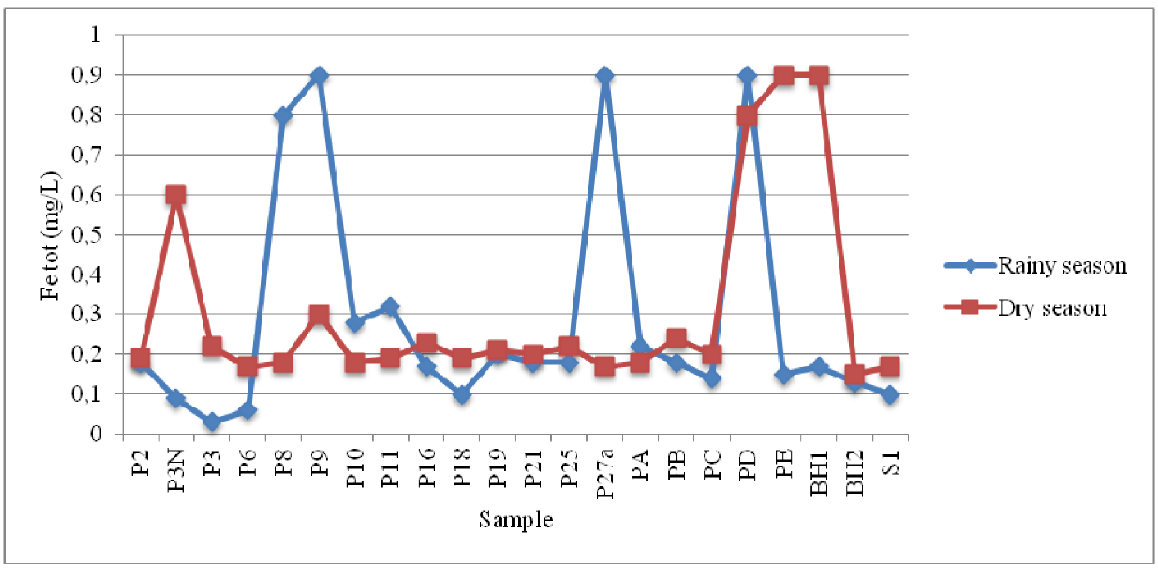

Figure-3
Distribution of total iron concentration in groundwater samples

Table-1
Physical and chemical groundwater data in rainy season

Code	**P_2**	**P_{3N}**	**P_3**	**P_6**	**P_8**	**P_9**	**P_{10}**	**P_{11}**	**P_{16}**	**P_{18}**	**P_{19}**
T	25.6	25.4	25.3	25	26.2	25	25.5	25.6	25.4	25	24.3
pH	3.3	3.69	3.52	3.66	4.07	5.84	3.86	3.97	3.16	4.44	5.41
Fe_{tot}	0.18	0.09	0.03	0.06	0.8	0.9	0.28	0.32	0.17	0.1	0.2
Code	**P_{21}**	**P_{25}**	**P_{27a}**	**P_A**	**P_B**	**P_C**	**P_D**	**P_E**	**F1**	**F2**	**S_1**
T	26.7	26.6	27.1	26	26.9	25.5	26	26	27.2	27.3	27.1
pH	4.16	5.38	4.17	3.67	3.65	5.36	5.61	4	2.8	2.9	2.95
Fe_{tot}	0.18	0.18	0.9	0.22	0.18	0.14	0.9	0.15	0.17	0.13	0.1

Table-2
Physical and chemical groundwater data in dry season

Sample Code	P_2	P_{3N}	P_3	P_6	P_8	P_9	P_{10}	P_{11}	P_{16}	P_{18}	P_{19}
T	23.5	23.4	23.3	24.1	23.5	22.9	24.1	23.9	24.6	23.8	22.9
pH	4.23	4.53	6.29	4.36	4.35	6.15	4.86	4.68	4.13	5.03	6.73
Fe_{tot}	0.19	0.6	0.22	0.17	0.18	0.3	0.18	0.19	0.23	0.19	0.21

(continued)

Sample Code	P_{21}	P_{25}	P_{27a}	P_A	P_B	P_C	P_D	P_E	BH1	BH2	S_1
T	24.1	24.3	24.8	23.7	25.3	24	24.1	23.4	25.1	24.2	24.8
pH	6.21	5.95	5.37	5.85	4.41	4.04	6.04	5.49	4	4.36	4.75
Fe_{tot}	0.2	0.22	0.17	0.18	0.24	0.2	0.8	0.9	0.9	0.15	0.17

Table-3
Descriptive statistics of T, pH and Iron contents in groundwater samples,
Rainy season

Parameter	Min	Max	Mean	S.D	Variance	Skewness	Kurtosis
T	24.3	27.3	26	0.9	0.72	0.13	-0.91
pH	2.80	5.84	4.07	0.91	0.83	0.64	-0.59
Fe_{tot}	0.03	0.90	0.29	0.29	0.08	1.59	0.97

Dry season

Parameter	Min	Max	Mean	SD	Variance	Skewness	Kurtosis
T	22.9	25.3	24	0.7	0.43	0.25	-0.40
pH	4,00	6.73	5.08	0.86	0.75	0.44	-1.28
Fe_{tot}	0.15	0.9	0.31	0.25	0.06	1.88	2.04

This reaction shows acid formation which expresses the acidic nature of groundwater. Thus, the decreasing of pH value in groundwater sample P_C in dry season in relation to rainy season could be explained by the oxidizing conditions. The pH values of groundwater samples were found to be below the WHO permissible limit of 6.5 to 8.5 for drinking water. Iron contents in the groundwater samples varied from 0.03 to 0.9 mg/L and from 0.15 to 0.9 mg/L with a mean of 0.29 and 0.31 mg/L for the rainy season and dry season, respectively. Iron contents have the higher values of skewness (1.59 and 1.88) than pH (0.69 and 0.44) in rainy and dry season, respectively. The skewness and kurtosis values for pH and Fe_{tot} in both seasons indicate that their distributions in the study area are not uniform (table-3). Therefore, the distribution is more asymmetric for iron in the two seasons as it is shown in figure-5.

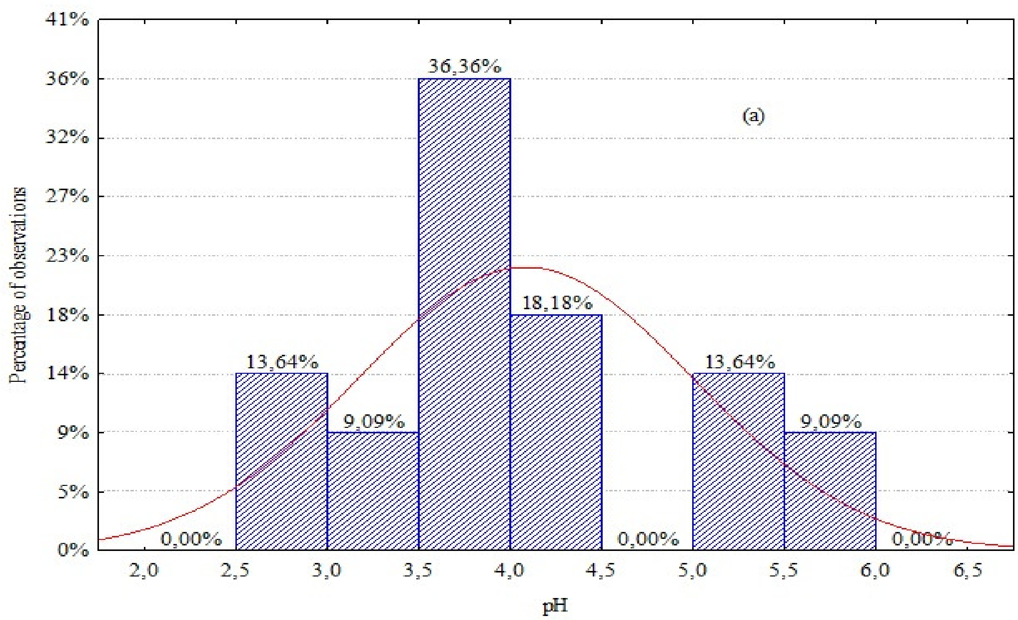

Figure-4
Histogram of frequency for pH: (a) rainy season, (b) dry season

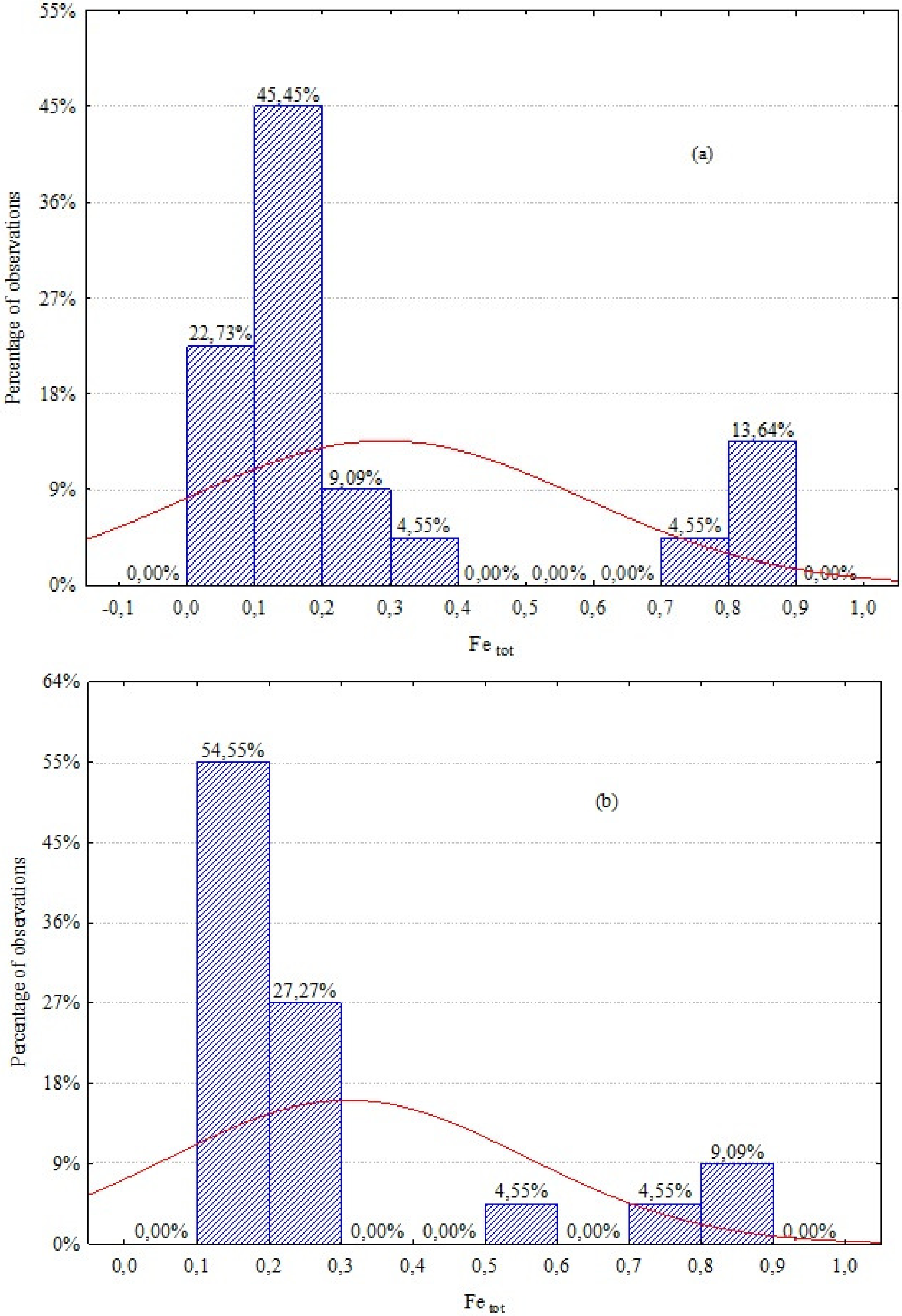

Figure-5
Histogram of frequency for iron content: (a) rainy season, (b) dry season

The diagram of frequency for groundwater samples in figures 4 and 5 illustrate the percentage of water samples versus pH values and iron contents, respectively. According the WHO permissible limit of iron content which is 0.3 mg/L for drinking water, in both seasons five groundwater samples have an iron content higher or equal to 0.3 mg/L such as P8, P9, P11, P27a, PD in rainy season and P3N, P9, PD, PE, BH1 in dry season. For iron contents higher or equal to 0.3 mg/L, one find again the wells water P9 and PD in both seasons. These water points are located in a wet part of the study area. In the case of iron, the distribution of frequencies was bi-modal in both seasons. In rainy season, the total concentration of iron in the samples P8, P9, P27a and PD was between 0.8 and 0.9 mg/L. In dry season, it was the samples PD, PE and BH1 which have a total iron concentration between 0.8 to 0.9 mg/L.

The correlation between the total iron concentration and pH at $p<0.05$ is low in rainy season ($r = 0.48$) and nil in dry season ($r = 0$). To the sight of the values of r (correlation coefficient), one can say that rainfall play a significant role in the process of water-rock interaction which supports the dissolution of certain minerals of iron present in the ground of the study area. It is clear that iron in the groundwater could come from the environment surrounding the location of the water points. The factors such as runoff, dissolution of iron minerals from the aquifer and iron sheet as well casings might be a source of iron in the groundwater[24], such is also the case in our study. At long term, the consumption of these waters could expose the people to the risk of liver disease.

The results of cluster analysis are presented in figures 6 and 7. The dataset were classified in three groups and two groups in rainy and dry seasons, respectively. In rainy season, group I contains six samples, seven samples for group II and nine samples in group III (figure-6). On the other hand, in dry season we observe two clusters or groups such as: group I with eight samples and group II with fourteen samples (figure-7). Clusters of samples are listed in table-4. In rainy season, groundwater samples in group III have the lowest mean of total iron concentration while group II contains the more acidic samples and groundwater samples slightly acidic were present in group I. In dry season, group I of contains the less acidic groundwater samples and less mean value of iron concentration relatively to group II.

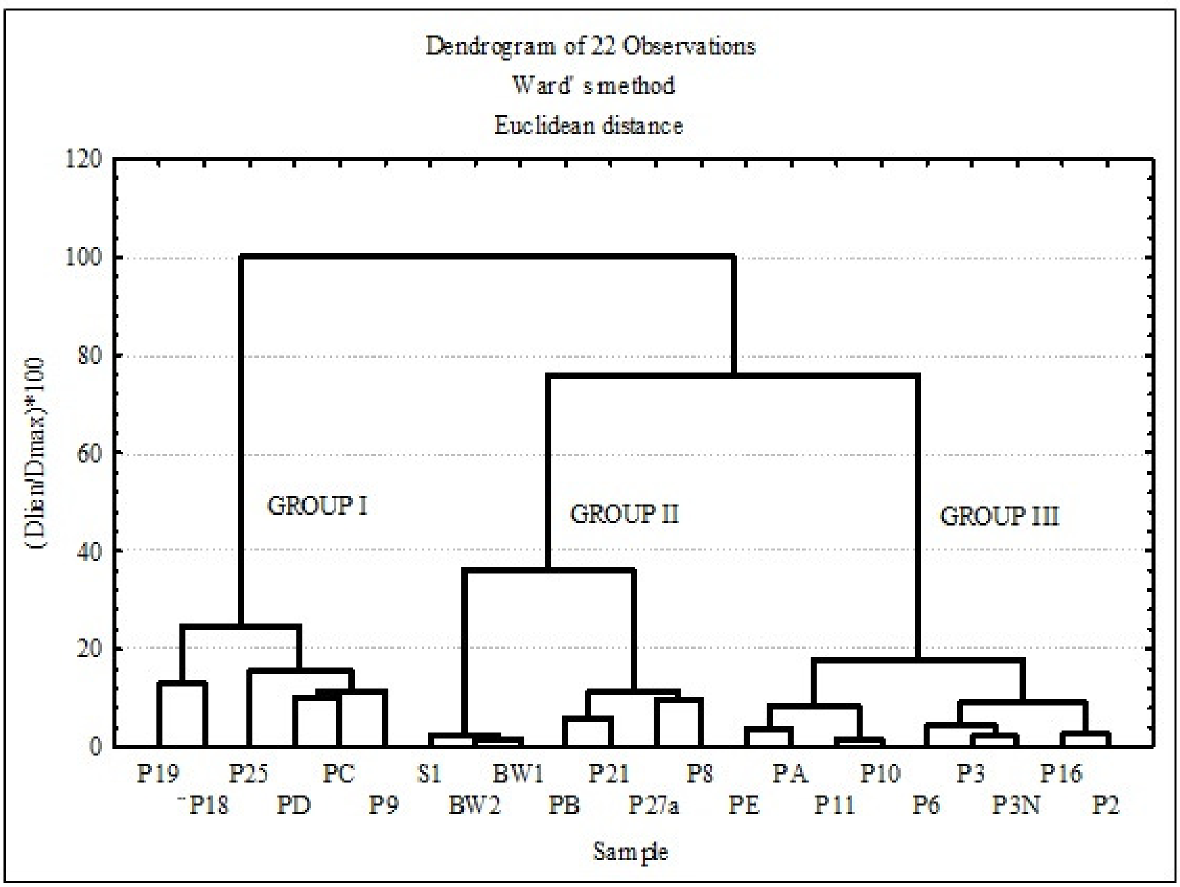

Figure-6
Dendrogram of groundwater samples in rainy season

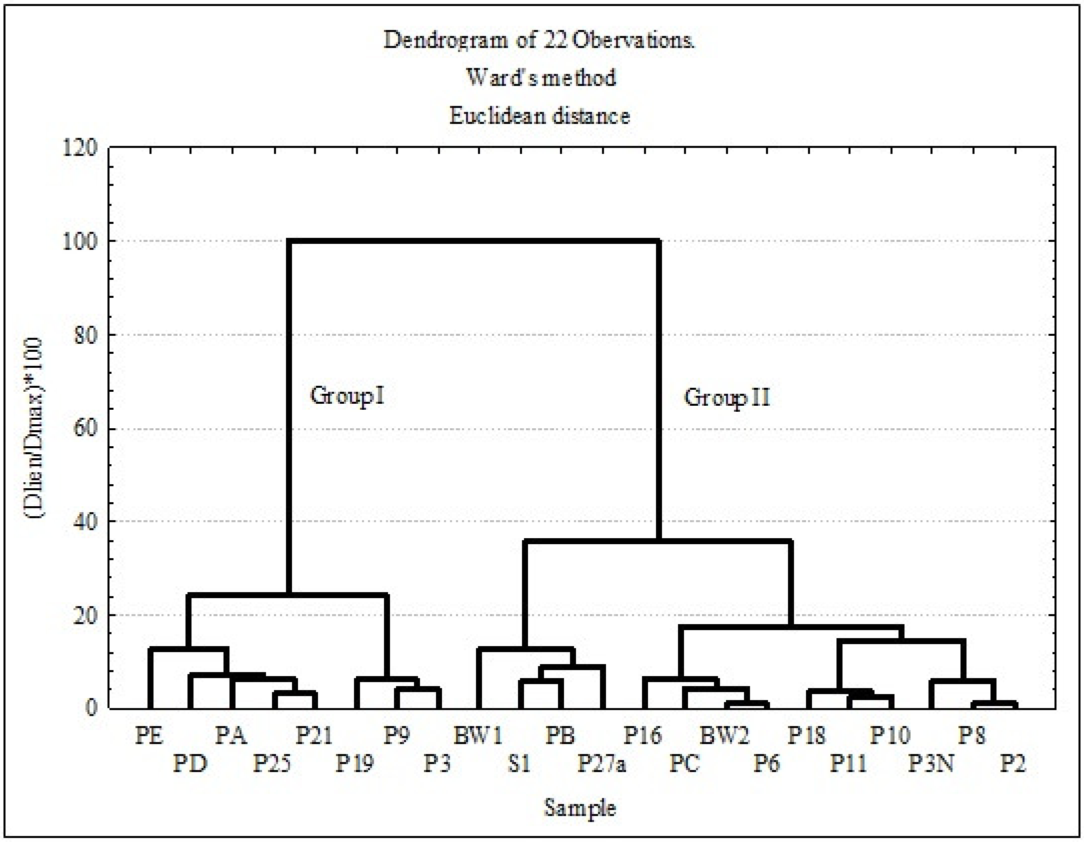

Figure-7
Dendrogram of groundwater samples in dry season

Table-4
Cluster groups and their members

Season	Group	Members (Location/sample code)	pH_Mean	pH_Range	Fe tot Mean	Fe tot Range
	I (n=6)	P9, P18, P19, P25, PC, PD	5.34	4.44 - 4.17	0.40	0.10 - 0.90
Rainy	II (n=7)	P8, P21, P27a, PB, S1, BH1, BH2	3.53	2.8 - 4.17	0.35	0.10 - 0.90
	III (n=9)	P2, P3N, P3, P6, P10, P11, P16, P_A, P_E	3.63	3.16 - 4.00	0.17	0.03 - 0.32
	I (n=8)	P3, P9, P19, P21, P25, P_A, P_D, P_E	6.09	5.49 -6.73	0.38	0.18 - 0.90
Dry	II (n=14)	BH1, BH2, S1, P2, P3N, P6, P8, P10, P11, P16, P18, P27a, PB, PC	4.51	4.00 - 5.37	0.27	0.15 - 0.90

Conclusion

The study has shown that most groundwater samples are acidic with iron concentrations above the permissible limit for drinking water. That is a potential health risk for the people. Treatment of these waters is indispensable before drinking. The acidity of water could be reduced by adding lime and reducing of iron concentration by reverse osmosis. Public authority had to consider the consumption of groundwater for drinking water in the study area as a problem of public health.

References

1. Giordano M., Global groundwater?, Issues and solutions, *Annu. Rev. Environ. Resour,* **34**, 153–178 **(2009)**
2. Siebert S.,Burke J., Faures J.M.,Frenken K.,Hoogeveen J.,Döll P. and Portmann F.T., Groundwater use for Irrigation-a global inventory, *Hydrol. Earth Syst. Sci.*, **14**, 1863–1880 (**2010**)
3. Hatton T. and Evans R., Dependence of ecosystems on groundwater and its significance to Australia, LWRRDC

Occasional Paper No 12/98.,

4. Mishra K.R., Pradip and Tripathi S.P., Groundwater quality of open wells and tube wells, *Acta Ciencia Indica*, XXXIIIC, **2,** 179 **(2002)**

5. Eruola A.O., Ufoegbune G.C., Eruola A.O., Awomeso J.A. and Abhulimen S.A., Assessment of Cadmium, Lead and Iron in Hand Dug Wells of Ilaro and Aiyetoro, Ogun State, South-Western Nigeria, *Res. J. Chem. Sci.***, 1(9)**, 1-5 (**2011**)

6. Amadi A. N., Olasehinde P. I., Yisa J., Okosun E. A., Nwankwoala H. O., Alkali Y. B., Geostatistical Assessment of Groundwater Quality from Coastal Aquifers of Eastern Niger Delta, Nigeria, *Geosciences*, **2(3)**, 51-59 **(2012)**

7. Raja G. and Venkatesan P., Assessment of groundwater pollution and its impact in and around Punnam area of Karur District, Tamilnadu, India, *E-Journal of Chemistry*, **7(2),** 473-478 **(2010)**

8. Kanade S. B. and Gaikwad V. B., A Multivariate Statistical Analysis of Bore Well Chemistry Data - Nashik and Niphad Taluka of Maharashtra, India, *Universal Journal of Environmental Research and Technology*, **1(2)**, 193-202 **(2011)**

9. Chilton J., Groundwater Water quality Assessment-A guide to use of biota: sediment and water in environmental monitoring, 2nd ed. UNESCO/ WHO/ UNEP **(1992)**

10. Twarakavi NK.C. Kaluarachchi JJ., Arsenic in the shallow ground waters of conterminous United States: Assessment, health risks, and costs for MCL compliance, *Journal of American Water Resources Association*; **42(2)**: 275–294 **(2006)**

11. Ranjan Rakesh, Water Quality Monitoring of Groundwater Resources around Sugar Factory, Near East-West Champaran Border, Bihar, India, *Res.J.Chem.Sci.,* **2(7),** 79-81 **(2012)**

12. American Public Health Association (APHA): Standard Methods for the Examination of water and Wastewater, 21st Ed., APHA, Washington, D.C. **(2005)**

13. Everitt B., Landau S. and Leese M., Clusters Analysis, 4th ed., Hodder Arnold Publisher **(2001)**

14. Yongming H., Peixuan D., Junji C. and Posmentier E.S., Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Central China, *Sci. Total Environ.,* **355 (1-3)**, 176-186 **(2006)**

15. Belkhiri L., Boudoukha A. and Mouni L., A multivariate Statistical Analysis of Groundwater Chemistry Data, *Int. J. Environ. Res.,* **5(2)**, 537-544 **(2011)**

16. Huang Y. C., Wu T. N. and Cheng P. J., Characterization of groundwater quality by multivariate statistical analysis: an example from Kaohsiung County, Taiwan. In Water and Wastewater 3025, The 6th International Conference on Natural Computation (ICNC) **(2010)**

17. Guler, C., Thyne, G.D., McCray, J.E. and Turner, A.K., Evaluation of graphical and multivariate statistical methods for classification of water chemistry data. *Hydro, Hydrogeology Journal,* **10,** 455-474, **(2002)**

18. Yidana S.M., Ophori D. and Yakubo B.B., A multivariate statistical analysis of surface water chemistry data - The Ankobra Basin, Ghana, *Jour. Environ. Management*, **86**, 80-87 **(2008)**

19. Cuneyt Guler and Thyne G.D., Statistical Clustering of Major Solutes: Use as a tracer for evaluating evaluating interbasin groundwater flow into indian wells valley, California. *Environmental & Engineering Geoscience*, **12(1)**, 53–65 **(2006)**

20. Bhattacharyya Rama, Kumar Manoj and Padhy Pratap Kumar, Index Analysis, Graphical and Multivariate Statistical Approaches for Hydrochemical Characterisation of Damodar River and its Canal System, Durgapur, West Bengal, India, *Int. Res. J. Environment Sci.*, **2(2),** 53-62 **(2013)**

21. Appelo C.H.J. and Postma D., Geochemistry, groundwater and pollution, A.A. Balkema Publishers, Rotterdam, 536 p.

22. Banton O. and Bangoy Lumony M., 1977, Hydrogéologie, Multiscience environnementale des eaux souterraines, Ed. Presses de l'Université du Québec, AUPELF, 460 p.

23. WHO. (2004). Guidelines for drinking water quality (3rd ed.). Geneva, Switzerland: WHO.

24. Mile I.I., Dagba B.I. and Jande J.A., Iron contamination of shallow wells in Makurdi urban area, Benue State, Nigeria, *Pak. J. Chem.* **2(2)**, 68-70 **(2012)**