Comparative Assessment of Groundwater Quality in Rural and Urban Areas of Nigeria

A.M. Taiwo, A.T. Towolawi, A.A. Olanigan,
O.O. Olujimi and T.A. Arowolo

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/59669

1. Introduction

Groundwater resource is a significant source for the provision of good quality drinking water to humans and animals. Access to potable water is one of the Millennial Development Goals (MDGs) in all developing nations of the world. This goal is yet to be achieved because an estimated two billion people worldwide lack access to potable water [1]. In Nigeria alone, about 52% of the population lack access to safe drinking water [2]. Groundwater quality differs from place to place and this may therefore affect its suitability for consumption [3]. For example, land-use has been found to affect the quality of groundwater [2]. Polluted groundwater resource may initiate water-borne diseases such as gastroenteritis, cholera, typhoid fever and giardiasis [4]. However, when groundwater is adequately protected and well managed, it could be a good source of drinkable water. In some parts of India, groundwater accounts for the supply of drinking water to about 88% of rural population where access to basic infrastructures for water treatment is lacking [5]. In Nigeria, groundwater does not only serve the need of rural communities only but also provide drinking water for urban dwellers where there is epileptic supply of pipe-borne water [6].

The major threats to groundwater quality include domestic, commercial and industrial wastes and increased agricultural use of fertilizers and pesticides [7]. These pollutants may infiltrate into aquifers through seepage and thereby polluting it. In the recent times, nitrate concentration of groundwater resources in most parts of Nigeria has increased due to rise in the construction of soak-away septic tanks in individual houses all over the country [6, 8]. Nitrate is dangerous to infants less than six months old. It causes a disease known as methemoglobinemia [9]. In the coastal areas, intrusion of saline water may be problematic to groundwater resource [8]. Microbiological pathogens can also pose a significant danger to consumption of groundwater. Nigeria has suffered some worst cases of cholera epidemic in recent times. In November 2001, a total of 724 cases and 52 deaths from cholera outbreak were reported in three communities in Nigeria (Kano, Kwara and Akwa Ibom states) [10]. Similarly, in December 2001, a total of 2050 cases and 80 deaths of cholera epidemic were recorded in Kano Metropolis [10]. In the developing countries, two million infants deaths are observed yearly due to consumption of unsafe drinking water [11]. This study therefore assessed the groundwater quality at both rural and urban areas in Nigeria in order to evaluate its suitability for consumption.

2. Material and methods

2.1. Geological description of the study areas

The two study areas can be found in the old Western Region of Nigeria. Figure 1 shows the geological map of Nigeria. An extensive discussion of the geology of Nigeria can be seen elsewhere in Jones and Hockey [12]. Two major geological formations characterises the south-western Nigeria. These include Basement Complex and Dahomey Basins. Under these two main formations are Abeokuta formation, Alluvium, Ewekoro formation, Ilaro formation and Coastal Plain Sands. According to Oyedele et al. [13], the south-western Nigeria's geology consists of rocks of older granite (pegmatite, granite-gneiss, grandiorite, migmatite and quartz diorite), charnockitic (pyroxene-diorite and metagabbro) and gneiss complex (quartzitite, biotite and biotite hornblende-gneiss mica-schist, amphibolite schist and granulitic gneiss).

2.2. Sampling and analysis

Groundwater were sampled from selected wells at rural (Forest Reserve near Benin) and urban (Ketu, Lagos) areas during rainy and dry seasons in 2011. Fifteen groundwater samples were sampled in the rural location while eight samples were collected in the urban location per season. Upon collection of the groundwater samples, parameters such as pH, temperature, colour, turbidity, total dissolved solids (TDS) and electrical conductivity (EC) were measured in situ using appropriate instruments (see Table 1).

Total suspended solids (TSS) were gravimetrically determined while total solids were calculated by summing TDS and TSS. Total hardness, alkalinity, acidity and chloride were measured titrimetrically and nitrate was determined by the sodium salicylate colorimetric method. Metals including Ca, Mg, Fe, Pb, Zn, Cu and Mn were measured using atomic absorption spectrometry (AAS). Prior to the determination of these metals, 100 mL of groundwater samples were digested with 10 mL concentrated nitric acid and heated for 30 minutes on a hot plate. After allowing to cool, the digested sample was transferred to a 100 mL volumetric flask and made to the mark. The digested samples were analysed with Atomic Absorption Spectrophotometer (Buck Scientific 200).

http://dx.doi.org/10.5772/59669

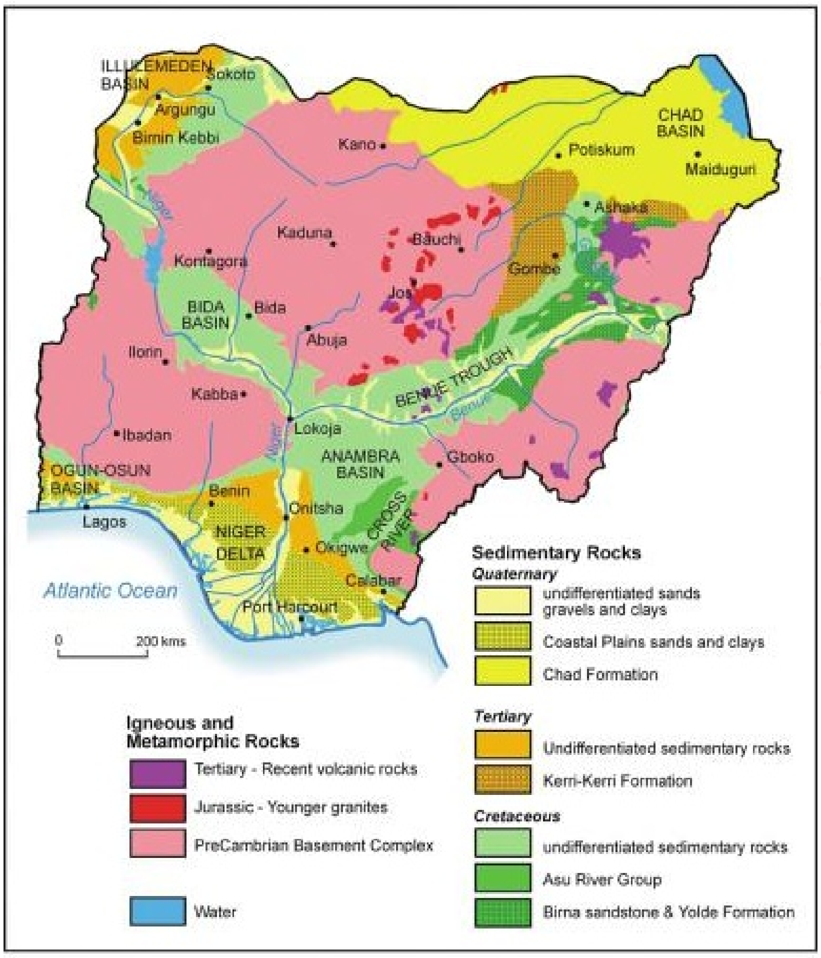

Figure 1. Geological map of Nigeria depicting Lagos and Benin where the groundwater wells were sampled [14].

Parameters	Methods of Analysis
pH/EC/TDS	Combined pH/EC/TDS meter (Combo HI 98130, Hanna, USA)
Temperature	Thermometer
Colour	Spectrometry
Turbidity	Turbidimetry
TSS	Gravimetry
Total Hardness	Titrimetry
Total Alkalinity	Titrimetry
Total Acidity	Titrimetry
Chloride	Silver nitrate [15]
Nitrate	Sodium Salicylate [16]
Metals	Atomic Absorption Spectrometry

Table 1. Analytical methods of analysis of groundwater samples

2.3. Statistical analysis

Data collected was analysed for descriptive statistics, analysis of variance and principal component analysis (PCA) using SPSS for Windows version 13.

3. Results and discussion

Figures 2-4 show the results (mean) of physical and chemical parameters measured in the sampled groundwater from the rural and urban sites. The results also indicated the seasonal variations at the two monitoring stations. The groundwater pH at both sites was generally less than 6.0 indicating slight acidic condition. This may pose a risk for consumption due to metal toxicity. Under a low pH condition, metals tend to go into solution thereby making it readily available for exposure [17, 18]. Jarup [19] highlighted deleterious effects of heavy metals contaminations. Most of the metals investigated in this study (except Fe) were observed to be below detection limits (0.01 mg/L for Pb, Zn, Mn and Cu of the Atomic Absorption Spectrophotometer. Temperature data of the groundwater samples were less than 30^{o}C.

Turbidity mean values were 19 ± 31 and 29 ± 54 NTU at the urban area during wet and dry seasons, respectively. These turbidity values at the rural site were 6.8 ± 2.8 and 3.7 ± 3.2 NTU for wet and dry seasons, respectively. The groundwater samples were very turbid at the urban site with up to 280 and 484% rise above the WHO permissible value of 5.0 NTU in drinking water [20]. A slight elevated turbidity value (35% higher than the WHO standard) was also observed in rural groundwater samples during wet season. Water turbidity usually denotes the presence of suspended substances, and may interfere with disinfection as well as harbouring microorganisms in water [21]. Bacterial growth could also be stimulated in high turbid water [22].

The mean values of colour of the groundwater samples at the urban site were 105 ± 169 and 126 ± 229 TCU during wet and dry seasons respectively while 19.53 ± 7.3 and 11.6 ± 8.7 TCU were recorded during wet and dry seasons in rural location. These colour mean values were significantly higher than the WHO standard of 15.0 TCU in drinking water by 30-740% except that of rural dry season. The obtained colour concentration at the urban site was extremely high and indicated pollution. FAO [23] reported that elevated colour concentration might suggest coloured organic substances and the presence of metals such as Fe, Mn and Cu. Although Cu and Mn were observed to be below detection limit in this study; Fe concentration was observed to be significantly higher concentrations than the WHO standard in groundwater samples collected at the urban site. According to the WHO, drinking water with colour above 15 CTU may attract aesthetic displeasures. It has also been established that colour in water may modify the toxicity of metals [24]. The extreme values of colour observed in the urban groundwater therefore suggest groundwater pollution at these monitoring sites thereby rendering the water unsafe for drinking.

The EC values also followed similar pattern like those of TDS, TS, colour and turbidity with higher concentrations observed at the urban site; but the values were within the permissible

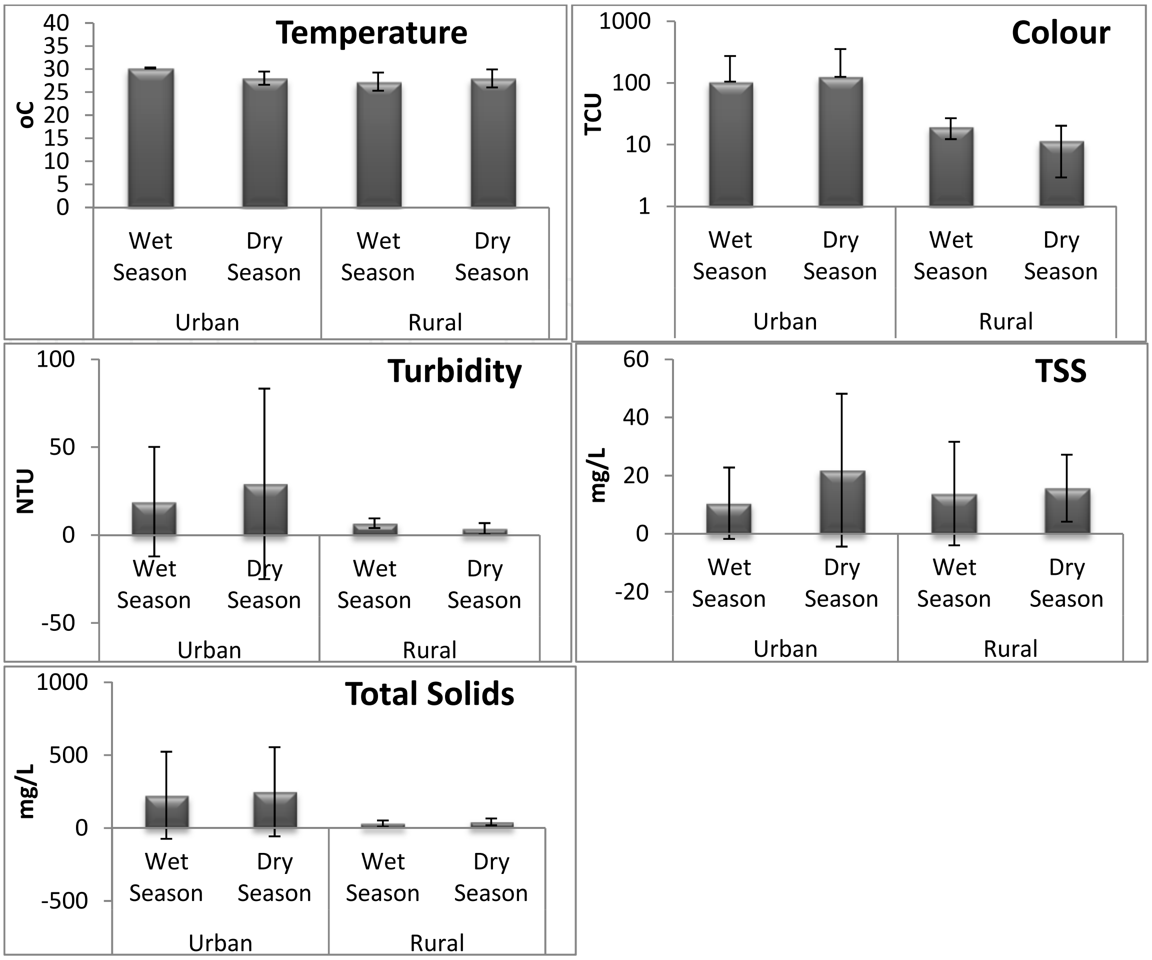

Figure 2. Comparison of the results of seasonal physical parameters of groundwater in urban and rural sites (Whiskers on the bars show the standard deviation values).

limit of 400-1250 µS/cm described by Mento [25]. Most of the studies carried out in Lagos have recorded elevated values of EC up to 43200 µS/cm [26]. A TSS mean value up to 22 ± 26 mg/L was observed during the dry season at the urban site (Figure 2). Since there's no permissible standard established for TSS in drinking water, it is difficult to ascertain the severity of the TSS values obtained in this study. For surface water protection, Roberts [27] has recommended a TSS value of 25-80 mg/L.TSS has been reported to harbour dangerous microorganisms [28]. The results of total hardness, alkalinity, acidity and chloride values (Figure 3) were generally high at the urban location; but were less than the WHO permissible standards. Nitrate data showed highest value at the rural site during the dry season (0.33 ± 0.41 mg/L); but below the WHO standard of 10 mg/L.

The level of iron in the groundwater samples at the urban site only was about 57 and 62 % higher than the WHO permissible level of 0.3 mg/L in drinking water [20] in samples collected in wet and dry seasons, respectively. Fe is an essential element in the body that forms the integral part of haemoglobin. However, at elevated concentration in the tissue, it can lead to conjunctivitis, choroiditis, and retinitis [29]. Elevated concentration of Fe in drinking water

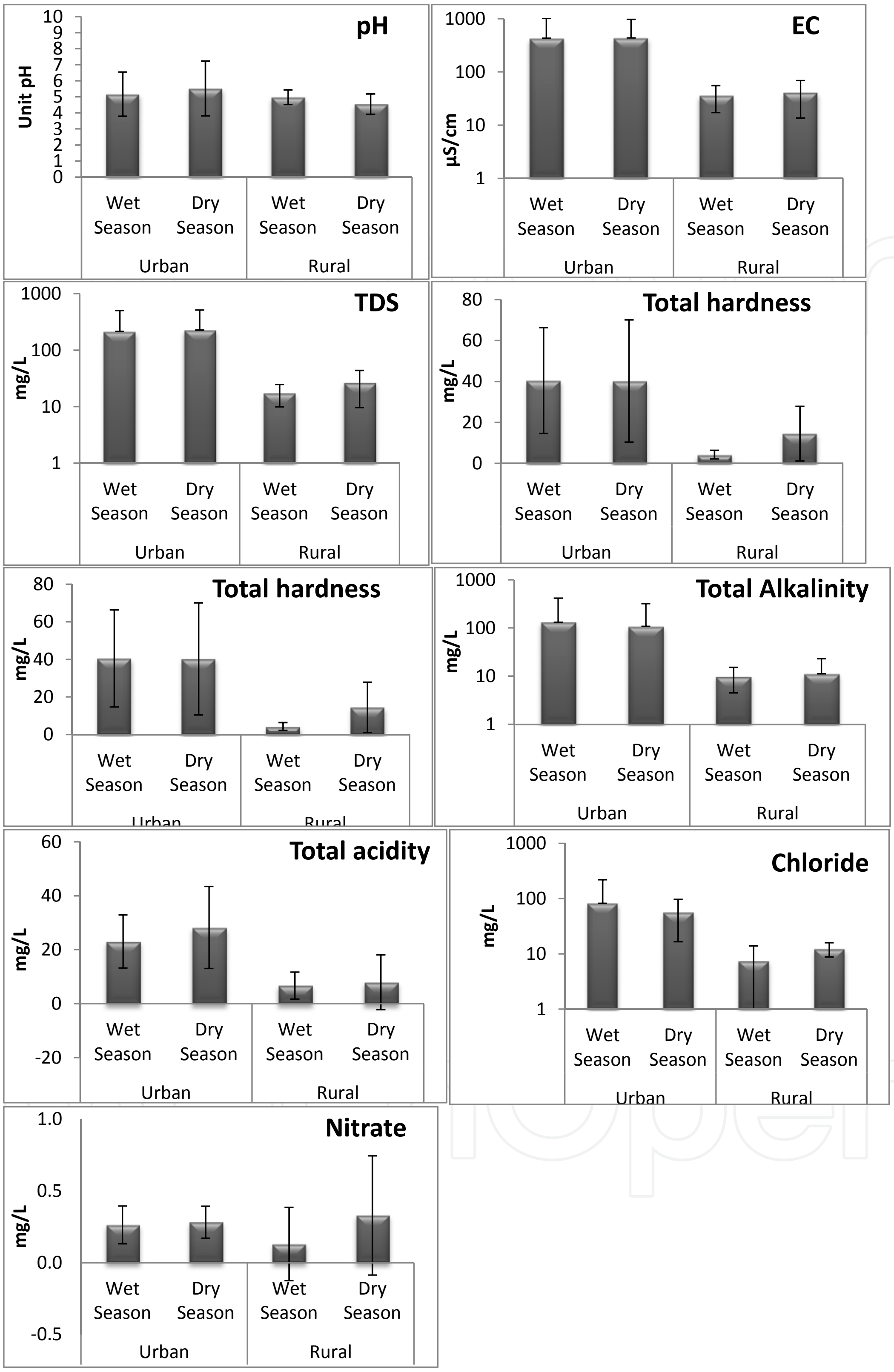

Figure 3. Comparison of the results of seasonal chemical parameters of groundwater in urban and rural sites (Whiskers on the bars show the standard deviation values).

http://dx.doi.org/10.5772/59669

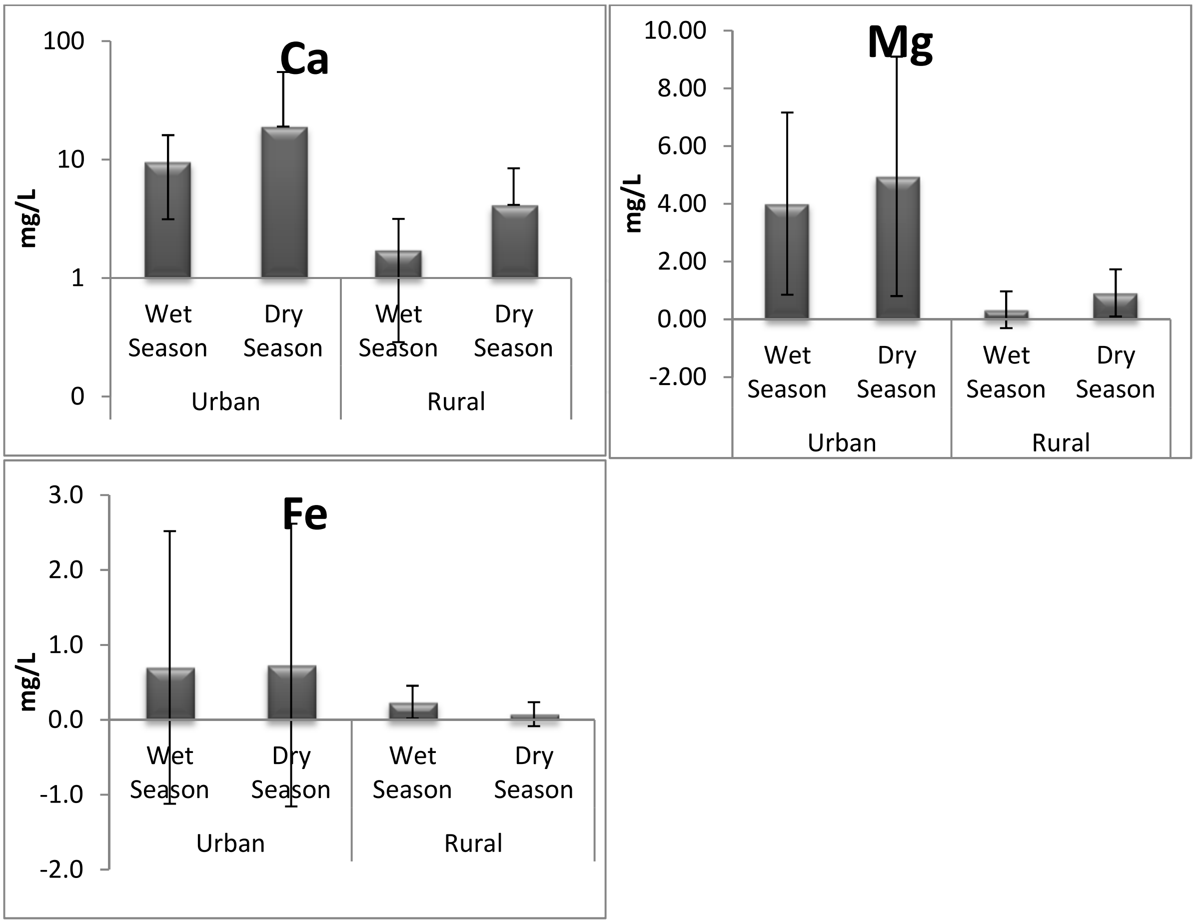

Figure 4. Comparison of seasonal levels of metals in groundwater in urban and rural sites (Whiskers on the bars show the standard deviation values)

may change its taste. The results obtained for Pb, Zn, Mn and Cu were below the detection limit.

Generally, most groundwater parameters (e.g. colour, turbidity, TSS, TS, TDS, EC, total alkalinity, total hardness, total acidity, Ca, Mg and Fe) showed a significant higher value at the urban site compared to the rural area (Table 2). This shows that the level of pollution of groundwater resources at the urban area is very high. However, the levels of industrial activities at the sampling locations in the urban site appeared to be minimal when this result is compared to that of Ayedun et al. [30] at an industrial site in Ifo. The results of this study is generally less than that of Adekunle et al. [31] for groundwater sampled in the rural area of Igbora, Oyo state, where the major contaminant of rural groundwater was organic waste [31].

Seasonal effects of groundwater quality were mostly observed for parameters such as turbidity, Ca and Mg at both sampling sites. There were instances where groundwater parameters were higher seasonally in one particular site. For instance, turbidity,TSS and total acidity were significantly higher during dry season in urban site while nitrate was higher during wet season in the rural site.

Parameter	F	Sig.	Parameter	F	Sig.
pH	3.560	.066	T-Hard	30.929	**.000**
Temp	7.028	**.011**	T-Alkal	6.212	**.017**
EC	16.296	**.000**	T-Acidity	36.552	**.000**
Color	7.945	**.007**	Cl	11.255	**.002**
Turb	5.832	**.020**	NO_3	.225	.637
TS	14.185	**.000**	Ca	5.995	**.018**
TDS	15.693	**.000**	Mg	32.315	**.000**
Fe	2.905	.095			

Temp-temperature, EC-electrical conductivity, Turb-turbidity, TDS-total dissolved solids, TSS-total suspended solids, TS-total solids, T-hard-total hardness, T-Alkal-total alkalinity, T-acidity-total acidity,

Table 2. ANOVA tests of groundwater parameters at the study areas

The rotated principal component analysis of groundwater samples collected at the urban site is presented in Table 3. The varimax PCA identified three factors with 86.6 % of the variance explained. Factor 1 which represents 58.4 % of the variance is characterized by significant loadings for EC, TS, TDS, TSS, total hardness, total alkalinity, Cl, NO_3, Ca and Mg. This factor might represent a mixed pollution sources from waste dump leachates, industrial effluents, agricultural run-off and seepage from soak-away or septic tanks [32]. Factor 2 (accountable for 20.6 % of the explained variance) is highly loaded for pH, colour, TSS, total acidity and Fe.

	Component			**Communalities**
	1	2	3	
pH	.524	**.712**	.075	**.787**
Temperature	.003	-.077	**-.811**	**.664**
EC	**.973**	.193	-.019	**.985**
Colour	.442	**.885**	.036	**.979**
Turbidity	.327	**.940**	.069	**.995**
TS	**.965**	.233	.031	**.986**
TDS	**.972**	.197	.014	**.984**
TSS	**.631**	**.654**	.254	**.891**
T-Hardness	**.866**	.310	.089	**.855**
T-Alkalinity	**.966**	.190	-.092	**.978**
T-Acidity	-.200	**.651**	.285	**.545**
Cl	**.828**	.041	-.425	**.868**
NO_3	**.733**	-.285	-.014	**.618**
Ca	**.705**	.245	**.490**	**.798**
Mg	**.967**	.063	.211	**.983**

	Component			Communalities
Fe	-.147	**.942**	-.140	**.929**
% variance	58.4	20.6	7.6	**86.6%**

(a)

	Component				Communalities
	1	2	3	4	
pH	-.084	-.046	-.736	-.006	**.551**
Temperature	.451	-.249	.115	-.554	**.585**
EC	**.646**	-.005	.470	.204	**.680**
Colour	.081	**.822**	-.011	.071	**.687**
Turbidity	.060	**.831**	.328	-.049	**.803**
TS	**.622**	-.028	.195	**.695**	**.908**
TDS	**.844**	-.019	.342	.179	**.863**
TSS	.158	-.025	-.023	**.890**	**.818**
T-Hardness	**.934**	-.005	.161	.105	**.910**
T-Alkalinity	**.645**	.495	-.397	.045	**.821**
T-Acidity	.230	-.019	**.747**	-.133	**.629**
Cl	.249	-.519	.361	.229	**.514**
NO_3	-.065	-.385	-.492	**.586**	**.739**
Ca	**.952**	.071	.162	.111	**.949**
Mg	**.850**	-.047	.003	-.203	**.765**
Fe	-.471	.435	-.074	.048	**.419**
% variance	34.4	15.2	13.2	9.6	**72.8%**

(b)

T-hard-total hardness, T-Alkal-total alkalinity, T-acidity-total acidity,

Table 3. (a). The principal component analysis of groundwater samples at the urban site. (b). The principal component analysis of groundwater samples at the rural site.

This component source might be linked to soil source. Factor 3 (represents lowest portion of 7.6 % of the explained dataset) is moderately loaded for Ca and anti-correlated with temperature might suggest contamination by mineral dust e.g. cement from construction activities. Ca has always been linked with construction activities [33].

The rotated PCA at the rural site has identified four components that explained 72.8 % of the total variance. Factor 1 has significant loadings for EC, TS, TDS, total hardness, alkalinity, Ca and Mg. The factor resembles factor 1 in the PCA conducted for urban site. This factor might best describe organic pollutant source. Organic pollutants from the oil palm processing factory located in the rural site might have influenced the rural groundwater quality resulting in water contamination. In the factor 2 are positive significance of colour, turbidity and moderate loadings for total alkalinity and Fe. This component might suggest soil runoff. Factor 3 is highly associated with total acidity and moderate significance for EC. This factor might be related to the palm oil waste source. Factor 4 shows loadings for TS, TSS and NO_3. This might represent sources from land use. According to Hooda et al. [34], nitrate pollution in the rural groundwater is controlled by factors such as land use, climate and soil. Run-off from soil can also raise the solid levels of groundwater.

4. Conclusion

This study compared the groundwater quality of an urban site and a rural site in Nigeria. Results showed higher values of most of the observed parameters at the urban site relative to samples collected in the rural location. This showed that the groundwater qualities of rural wells are less contaminated compared to the urban groundwater. The effect of seasonal variation was also observed. The rotated PCA was conducted on groundwater samples from both study areas. The major contaminants in groundwater in urban areas were mixed pollution sources e.g. leachates from waste, effluents from industries, agricultural land and seepage from soak-away or septic tanks, soil and mineral dust. The varimax PCA revealed the major sources of pollution to groundwater in the study area. These include: organic, palm-oil wastes soil and land use. This study recommends further studies on heavy metals and polycyclic aromatic hydrocarbons (PAHs) in groundwater from rural and urban areas. Thorough treatment is required for groundwater samples from the urban areas before it could be certified fit for consumption.

Author details

A.M. Taiwo, A.T. Towolawi, A.A. Olanigan, O.O. Olujimi and T.A. Arowolo*

*Address all correspondence to: tarowolo@yahoo.com

Department of Environmental Management & Toxicology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

References

[1] Lefort, R. (2006). Down to the last drop. UNESCO Sources.84, 7 pp.

[2] Orebiyi, E.O., Awomeso, J.A., Idowu, O.A., Martins, O., Oguntoke, O., and Taiwo, A.M. (2010). Assessment of pollution hazards of shallow well water in Abeokuta and Environs, Southwest, Nigeria. *American Journal of Environmental Sciences*. 6(1):50-56.

[3] Jain, C.K., Bhatia, K.K.S. and Vijay, T. (1995). Ground water quality monitoring and evaluation in and around Kakinada, Andhra Pradesh, Technical Report,CS (AR) 172, National Institute of Hydrology, Roorkee, 1994-1995.

[4] Alley, W. M. (1997). Regional groundwater quality. John Wiley & Sons. 364p.

[5] Kumar A. (2004). *Water Pollution*. Nisha Enterprises New Delhi Pp 33-35

[6] Gbadebo, A.M., J.A. Oyedepo, and A.M. Taiwo. (2010). Variability of nitrate in groundwater in some parts of southwestern Nigeria.*The Pacific Journal of Science and Technology* 11(2): 572-584.

[7] Ofodile, M.E. (2002). Groundwater study and development in Nigeria. University of Ibadan Press, Nigeria.

[8] Taiwo, A.M. (2012). Source identification and apportionment of pollution sources to groundwater quality in major cities in Southwest, Nigeria. *Geofizika* 29:157-174.

[9] McCasland, M., N.M. Trautmann, R.J. Robert and K.S. Porter (2007). Nitrate: Health effects in drinking water. http://psep.cce.cornell.edu/factsslides-self/facts/nit-heef-grw85.aspx

[10] WHO (2001). Cholera in Nigeria. http://www.who.int/csr/don/2001_11_27/en/. Accessed: 18/08/14.

[11] UNICEF. (2005). National Rural water supply and Sanitation investment programme. Final draft, pp: 1.

[12] Jones, A. A. and Hockey, R. A. (1964).The geology of part of southern Nigeria. *Geological Bulletin* 31, 101 pp.

[13] Oyedele, K. F., Ogagarue D. O and Esse, O. (2011). Groundwater potential evaluation using surface geophysics at Oru-Imope, South-Western Nigeria. *European Journal of Scientific Research*63: 515–522.

[14] Adelana, S. M. A., Olasehinde, P. I., Bale, R. B., Vrbka, P., Edet, A. E. and Goni, I. B. (2008). An overview of the geology and hydrogeology of Nigeria. In *Applied Groundwater Studies in Africa, IAH Selected Papers on Hydrogeology, edited by Adelana S. and MacDonald, A.* CRC Press/Balkema, Taylor & Francis Group, The Netherlands, 13, 171–199, Print ISBN: 978-0-415-45273-1, eBookISBN: 978-0-203-88949-7, doi: 10.1201/9780203889497.ch11.

[15] Vogel, A.I., 1976. A Textbook of inorganic analysis, 3rd Edition, Longman, London.

[16] Ademoroti, C. A. (1996). *Standard methods for water and effluents analyses*.Environmental Chemistry and Toxicology. Ibadan, Nigeria: Foludex Press Ltd.

[17] EPA (2003). Environmental chemistry, transport and fate. http://www.epa.gov/raf/metalsframework/pdfs/chaper3.pdf. Accessed 18/08/14.

[18] Taiwo, A. M., Gbadebo, A. M. And Awomeso, J.A. (2010a). Potability assessment of selected brands of bottled water in Abeokuta, Nigeria. *Journal of Applied Science and Environmental Management* 14 (3): 47-52. www.ajol.info/index.php /jasem/article/view/ 61464/49604.

[19] Jarup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin* 68(1): 167-182.

[20] World Health Organization (2008). Guidelines for drinking water quality, Geneva WHO 2008.

[21] http://vortex.weather.brockport.edu/~jzollweg/oakorchard/docs/waterquality.pdf.

[22] Awomeso, J. A., Taiwo, A. M., Morawo, O. A. and Moyosore., J. O. (2011). Possible Abstraction Sites along Oshun River-Lower Course in Ogun and Lagos State, Nigeria for Sustainable Production of Quality Potable Water. *Journal of Science and Technology* 31 (3): 58-67.

[23] FAO (2012).Water quality monitoring, standards and treatment. In: *Fishery Harbour Manual on the Prevention of Pollution-Bay of Bengal Programme.* FAO repository document. http://www.fao.org/docrep/x5624e/x5624e05.htm. Accessed 18/08/14.

[24] http://www.env. gov.bc.ca/wat/wq/BCguidelines/colour/colour_over.html

[25] Mento d I'exploitant de leauet del I'assainissesment. (1980). Lyonnaise Deseaux, p. 273-283.

[26] Awomeso, J. A., Taiwo, A. M. and Adenowo, J. A. (2010). Studies on the Pollution of Water Body by Textile Industry Effluents in Lagos, Nigeria. *Journal of Applied Sciences in Environmental Sanitation* 5 (4): 337-343.

[27] Roberts, R. J. (1978). Fish Pathology. Bailliere-Tindall, London, UK.

[28] Taiwo, A.M., A.O. Adeogun, K.A. Olatunde, and K.I. Adegbite. (2010b). Analysis of groundwater quality of hand-dug wells in peri-urban area of Obantoko, Abeokuta, Nigeria for selected physico-chemical parameters.*Pacific Journal of Science and Technology* 12(1):527-534.

[29] Satyanarayana, P., Raju, N.A., Harikrishna, K and Viswanath, K. (2013). Urban Groundwater Quality Assessment: A Case Study Of Greater Visakhapatnam Municipal Corporation Area (Gvmc), Andhra Pradesh, India. *International Journal of Engineering Science Invention* 2 (5): 20-31.

[30] Ayedun, H., Taiwo, A. M., Umar, B. F., Oseni, O. A. andOderinde, A. A. (2011). Potential Groundwater Contamination by Toxic metals in Ifo, Southwest Nigeria. *Indian Journal of Science and Technology* 4 (7); 820-823.

[31] Adekunle, I.M., Adetunji, M.T., Gbadebo, A.M. and Banjoko, O.B. (2007). Assessment of groundwater quality in a typical rural settlement in southwestNigeria. *International Journal of Environment and Public Health 4 (4)*: 307-318

[32] Ullah, R., Malik, R.N. and Qadir, A. (2009). Assessment of groundwater contamination in anindustrial city, Sialkot, Pakistan. *African Journal of Environmental Science and Technology* 3 (12): 429-446. http://www.academicjournals.org/AJEST

[33] Watson, J. G., Chow, C. (2007). Receptor models for particle source apportionment of suspended particles. *In: Introduction to Environmental Forensics*, 2nd*edn. Murphy, B. and Morrison, R. (Eds).* Academic Press: New York, p. 273-310.

[34] Hooda, P.S., Edwards, A.C, Anderson, H. A., Miller, A. (2000). A review of water quality concerns in livestock farming areas. *Scienc*e of the Total Environment 250: 143.