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SHORT COMMUNICATION

PHYSICO-CHEMICAL QUALITY OF SHALLOW WELL-WATERS IN GBOKO, BENUE STATE, NIGERIA

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ABSTRACT. Water quality and the problem of contamination in shallow wells have been assessed in Gboko. Ten wells were sampled and the water analysed for quality parameters and trace metals. Various standard methods were used for anions while trace metals were analysed using atomic absorption spectrophotometer. Results obtained in three seasons showed no significant variabilities ($p > 0.05$); an indication that the wells are fairly protected and do not receive considerable seepage. The water showed lower pH (5.7–7.8) in comparison to the WHO recommended range (6.5–8.5), with moderate permanent hardness (86.3–380.7) mg/L $CaCO_3$. Concentrations of most trace metals and anions were below the WHO standards for drinking water and other purposes. However, iron (0.29–1.79) mg/L and copper (1.39–1.44) mg/L were considered slightly elevated in comparison to the WHO maximum permissible levels of 1.0 and 2.0 mg/L, respectively. Chromium and lead were found in four wells situated in densely populated and in the vicinity of metal workshops, heavy motor traffic/commercial/motor station areas, and are indicative of localized anthropogenic contamination. Apart from these limitations, all the other chemical evidences show that the water is good and potable. The determined data are considered to be baseline.

KEY WORDS: Shallow wells, Water quality, Low pH, Localized contamination, Baseline data, Nigeria

INTRODUCTION

Gboko, a town in Benue State, in the central region of Nigeria, has a low urban status. The only visible urbanization is at the town centre, where the main market and some small and medium level businesses are located. The population is small, and concentrated at the town centre. Although there are many small scale food processing outfits and artisan works, the only industry of note is the Benue Cement Company, situated at about 10 km from the town centre. The town has largely an agricultural economy like most towns in Benue State, which has the acronym, "The Food Basket of the Nation".

There is no pipe-borne water supply in the town. The main sources of water are shallow wells found in almost every compound. Nevertheless, commercial water tankers supply some homes. Sanitation practices in the town as in most towns in Nigeria are poor. Domestic wastes (solid and effluent) are discharged indiscriminately around homes and in the business areas. Although almost every compound has either a pit toilet or water closet toilet, free ranging animals litter the environment with faecal wastes.

Water abstracted from adequately protected shallow wells compare well with those from boreholes if the soil is fine-grained [1]. Okoye and Adeleke [2] had reported that the quality of water from partially protected shallow wells in Akure showed comparable qualities with those of boreholes and pipe-borne supply. The fine-grained sand and similar structures give superb filtration, which removes pathogens including viruses, and the causes of colour, odour, taste and turbidity as the water slowly, percolates through the ground [3]. The quality limitations of ground waters obtained from adequately protected wells and boreholes result from the dissolution of rock minerals by dissolved carbon dioxide as the water passes through the rock

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deposits. This mineralization may increase the concentrations of cations and anions such as Ca^{2+}, Mg^{2+}, Mn^{2+}, Fe^{2+}, SO_4^{2-}, CO_3^{2-}, HCO_3^-, and Cl^- to pollution levels [3].

Mineralisation, poor sanitation practices, including the siting of water wells near and even downstream of pit toilet or soakaway pit, and indiscriminate disposal of all manner of solid and effluent wastes could be causes of concern to ground water quality [2], especially in shallow wells. Therefore, we set out to analyze water samples from selected wells in Gboko town in order to characterize the water and assess its quality. The data collected would also serve as basis for future monitoring of groundwater quality in the area, and would help in estimating the safety or otherwise of the water consumed in the area with regards to human health conditions.

EXPERIMENTAL

Sampling sites. Samples were collected from ten pre-destinated partially protected shallow wells within Gboko town (Table 1). In order to assess the general contamination status of the water the ten wells were selected from different parts of the town taking into consideration the population density and human activities in a particular area. All the wells had headwall and inner concrete lining. Two had no cover. Some have cemented surrounding.

Table 1. Description of sampling sites.

Sampling sites	No. of wells
Densely populated town centre	2
Remote farmland	1
Heavy traffic/commercial centre/motor park area	2
Mechanical/metal workshop area	1
Thinly populated area	2
Government reserved area (GRA)	2

Sample collection. Sampling was done six times in three seasons as follows: dry season (DS)–January and March; early rainy season (ERS)–April and June; and rainy season (RS)–August and October. The samples were drawn with a plastic bucket and poured into 2-litre polythene cans which were previously washed with detergent, leached with AnalaR grade 1:1 HCl (BDH, England) to remove any adhering trace metals on the surface and finally rinsed cupiously with distilled-de-ionized water. At the collection point, the cans were rinsed with well water before collecting the samples.

Sample analyses. All chemicals used were AnalaR grade (BDH, England). The pH, conductivity and alkalinity were determined immediately on arrival at the laboratory before the samples were preserved by freezing. The pH was determined with a Consort Digital P/07 pH meter, and conductivity with a Consort Digital K/20 conductometer (Consort, Belgium).

Various standard methods [4, 5] were used to analyse for the following: total dissolved solid (TDS)– gravimetry, total alkalinity (TA), carbonate and bicarbonate– acid-base titration; total hardness (TH), calcium and magnesium– EDTA titrations, and sulfate–turbidmetry as $BaSO_4$, using a spectroLab 21A spectrophotometer (PEC Medicals, USA). Chloride was determined by the Mohr method, and trace metals, namely; chromium, cadmium, copper, nickel, lead, zinc and iron were determined using atomic absorption spectrophotometer (ALPHA Series 4200 CHEM TECH ANALYTICAL Ltd, UK) with air-acetylene flame. All the samples for trace metal analysis were first concentrated by evaporating 500 mL of water sample to about 100 mL, followed by addition of 1 mL conc. HCl and digesting until volume was reduced to less than 25 mL, and later made up to the mark with distilled-de-ionized water in a 25 mL standard flask. Samples blanks were run for all analyses to assess accuracy.

RESULTS AND DISCUSSION

Table 2 shows the year average values of physico-chemical data at various wells (numbered 1–10). Their metal levels are presented in Table 3, while seasonal concentrations of all parameters are presented in Table 4. For comparison, the World Health Organisation [6] standards for drinking water quality are presented in Table 5. The pH range of 5.9-7.4 in the year (Table 2) is below the WHO permissible range (6.5-8.5). This is consistent with published studies which indicate that ground waters in Nigeria are predominantly acidic. Reported pH values include: 4.3-7 in Lagos [7]; 4.8-5.1 in Onitsha, and an average of 5.5 in Benin [8]; 5.5-7.2 in Akure [2] and 5.9-7.0, in Nsukka [9]. The buffering capacity was low with total alkalinity ranging from 3.6-6.5. This is also consistent with earlier studies as Umo and Okoye [9] observed for Nsukka ground water. Water with low buffering capacity is prone to rapid changes in pH, but in this case and also in Nsukka, the pH did not show seasonal variation, maintaining an overall mean of 5.9±0.5 (Table 2). Moreover, the water did not show any temporal turbidity after rains. These facts can only be observed in wells which do not receive considerable seepage of runoff water or effluent, indicating fair enough protection afforded by concrete inner lining, head wall and cover. Total dissolved solids were low and did not show any significant seasonal changes (Table 4). This was also reflected in the low values of conductivity and concentrations of ionic species, especially the anions. Carbonate was below detectable levels in all samples throughout the year, while bicarbonate showed a range of 3.48-6.84 mg/L (Table 2). The water showed moderate hardness, ranging from 86.3-380.7 mg/L, due largely to chlorides of calcium and magnesium, as this anion correlated well with the two metals ($p < 0.05$). Water could be considered to be very hard if hardness exceeds the WHO maximum permissible level of 500 mg/L. Very hard water is not good for drinking and is associated with rheumatic pains and gouty conditions. Such water does not lather with soap and produces deposits and scaling in pipes and steam boilers, hardens vegetables and would not allow it to cook well. When used for bathing it tends to harden the skin, or make the skin rough due to impregnation of insoluble calcium and magnesium soaps [4]. On the other hand soft water is associated with rickets in children [10]. Very soft water has hardness of between 50 and 60 mg/L [10]. Moderately hard water as found in this study is considered to be good dietically [11].

Table 2. Year average values of physico-chemical data of well waters in Gboko.

Wells	TH mg/L	TA mg/L	TDS mg/L	Conductivity µs/cm	pH	Cl^- mg/L	CO_3^{2-} mg/L	HCO_3^- mg/L	NO_3^- mg/L	PO_4^{3-} mg/L	SO_4^{2-} mg/L
1	352.8	4.2	248.1	605.1	6.3	107.3	Nd	3.48	0.067	0.55	13.3
2	274.8	4.7	56.6	116.2	7.4	115.7	Nd	4.86	0.044	0.54	16.3
3	222.2	5.3	110.0	210.6	6.5	97.3	Nd	4.19	0.043	0.71	8.4
4	125.9	5.6	45.1	124.1	6.0	117.2	Nd	4.18	0.051	0.660	3.6
5	380.7	4.9	67.6	142.7	6.5	77.5	Nd	5.07	0.034	0.83	2.6
6	301.2	6.5	298.4	524.3	6.5	117.0	Nd	4.13	0.050	0.55	14.0
7	181.1	3.8	38.9	103.0	5.9	98.7	Nd	5.31	0.045	0.59	5.7
8	212.6	3.6	107.7	221.1	6.1	105.0	Nd	6.84	0.044	1.01	6.8
9	190.6	5.1	119.4	202.9	6.0	88.5	Nd	4.37	0.021	0.74	3.4
10	86.3	3.6	26.6	52.5	5.8	97.0	Nd	3.99	0.054	0.98	16.8
Overall mean±sd	232.8± 89.8	4.7± 0.9	111.9± 86.9	230.3± 175.5	5.9± 0.5	102.1± 12.3	----	4.6± 0.9	0.045± 0.012	0.72± 0.17	9.1± 5.3

Nd = Not detectable; TH = total hardness; TA = total alkalinity; TDS = total dissolved solids.

Table 3. Metal concentrations (mg/L) in shallow well waters in Gboko.

Well	Ca	Mg	Cd	Cr	Ni	Fe	Pb	Zn	Cu
1	142.0	214.2	Nd	0.02	Nd	0.62	Nd	1.67	1.42
2	121.1	153.6	Nd	Nd	Nd	0.34	Nd	1.04	1.39
3	89.1	133.1	Nd	0.01	Nd	0.16	0.02	2.10	1.49
	49.6	76.3	Nd	Nd	Nd	0.28	0.01	2.14	1.51
5	153.4	222.5	Nd	Nd	Nd	0.42	Nd	1.59	1.50
6	109.3	186.9	Nd	Nd	Nd	0.21	0.02	2.35	1.39
7	74.9	106.2	Nd	Nd	Nd	0.42	Nd	0.98	1.30
8	83.0	129.7	Nd	0.01	Nd	0.22	0.03	2.39	1.49
9	80.3	110.3	Nd	Nd	Nd	0.24	Nd	1.11	1.32
10	32.9	53.3	Nd	Nd	Nd	0.21	Nd	0.95	1.34
DL	---	---	0.002	0.002	0.05	0.003	0.004	0.006	0.001
Ov. mean±sd	93.6±36	138.6±53.3	---	---	---	0.31±0.13	---	1.63±0.59	1.42±0.08

Nd = Not detectable; DL = detection limit; Ov. Mean = overall mean; Sd = standard deviation.

Table 4. Average seasonal concentrations (mg/L, except pH and conductivity) of analytes in shallow well waters in Gboko.

Parameter	Dry season	Early rainy season	Rainy season
Ca	83.2±42.2 (32.2-154.5)	107.7±35.6 (37.9-154.5)	89.8±50.5 (28.7-188.9)
Mg	124.5±63.3 (47.8-231.3)	168.8±63.8 (56.9-274.8)	83.2±42.2 (32.2-154.5)
Cd	Nd	Nd	Nd
Ni	Nd	Nd	Nd
Fe	0.29	0.51±0.17 (0.28-0.92)	1.79±0.54 (0.96-0.42)
Zn	1.33±0.64 (0.71-2.50)	1.58±0.57 (0.86-2.45)	1.79±0.54 (0.96-2.44)
Cu	1.41±0.08 (1.27-1.58)	1.39±100.5 (94.8-425.4)	1.44±0.12 (1.25-1.61)
Total hardness (mg/L $CaCO_3$)	208.2±106.8 (80.0-400.3)	281.9±100.5 (94.8-425.4)	208.3±102.7 (84.1-412.6)
Total alkalinity	4.2±1.2 (3.1-7.2)	5.3±1.7 (3.2-8.5)	4.7±1.6 (2.5-8.3)
Total dissolved solids	111.0±86.9 (28.7-315.3)	112.8±91.0 (26.8-425.4)	111.9 ± 91.8 (24.7-323)
Conductivity (µs/cm)	226.2±182.8 (53.4-675.0)	223.7±184.0 (49.6-652.5)	240.9±194.0 (54.5-757.8)
pH	6.3±0.5 (5.8-7.8)	6.3±0.5 (5.7-6.9)	6.3±0.5 (5.7-7.6)
Cl^-	93.2±10.1 (77.0-106.0)	106.5±14.7 (75.0-126.0)	106.8±12.9 (80.5-123.5)
CO_3^{2-}	Nd	Nd	Nd
HCO^-_3	5.3±8.8 (4.2-7.3)	3.93±1.66 (2.46-8.45)	4.70±1.02 (3.23-61.23)
NO_3^-	0.043±0.012 (0.027-0.067)	0.051±0.015 (0.022-0.078)	0.043±0.010 (0.021-0.056)
PO_4^{3-}	0.64±0.20 (0.41-0.93)	0.75±0.23 (0.46-1.28)	0.75±0.18 (0.49-1.06)
SO_4^{2-}	5.1±4.2 (1.0-14.5)	9.0±6.0 (2.0-20.5)	15.5±7.2 (3.9-24.5)

Nd = Not detectable.

Nitrate was below 0.1 mg/L all the year round. Phosphate and sulfate, respectively, had concentration ranges of 0.17-1.01 mg/L and 2.6-16.8 mg/L in the year. The most abundant anion is chloride with concentrations in the range of 77.5-117.3 mg/L in the year.

The major cations are calcium and magnesium ions. The two constitute the bulk of dissolved solids and are responsible for the moderate permanent hardness of the water. Calcium was in the range of 32.9-153.4 mg/L Magnesium had an overall average concentration of 138.6 mg/L (Table 3), and by WHO standards (Table 4), magnesium at concentration in excess of 150 mg/L, if sulfate is lower than 250 mg/L or 30 mg/L, if sulfate is up to 250 mg/L, is not considered high. Cadmium and nickel were below detectable levels in all the samples. Lead was detectable in four wells: namely; 3 and 6, which were located in heavy motor traffic areas; well 4, located in the commercial town centre, as well as in well 8, which was right inside the town's motor mechanic complex. Significant contribution of lead is expected from emission, use and spilling of leaded petrol and engine oil along the roads and in mechanical workshops, around where discarded lead-acid batteries are common sights. Also, blacksmithing near well 1, meat and fish storage facilities around well 3, and metal prickling in the mechanic village (well 8), could introduce many metals including chromium and lead into the water through leaching or direct contamination, as wells 1 and 8 had no covers and well 3 was a public facility. Chromium was detected in wells 1, 3 and 8 (Table 3).

No analyte showed significant seasonal changes ($p > 0.05$). However, in the rainy season, there were slight attenuations in the concentrations of the major cations, calcium and magnesium, and slight increases in the concentrations of trace metals (Table 3).

Iron and copper occurred at elevated levels with average concentrations being between the most desirable and the maximum permissible levels set by WHO. Zinc occurred in all the wells. The higher concentrations of the metal measured in wells 3, 4, 6 and 8, could be attributed to the fact that these wells are located within densely populated town centre, characterized by old houses with rusted zinc roofs, and in commercial and metal workshop areas.

Table 5. WHO standard values for drinking water (mg/L, except PH and conductivity) [6].

Parameter	Ingest desirable level	Maximum permissible level
Calcium	75	200
Magnesium	30 (if SO_4^{2-} = 250 mg/L)	150 (if SO_4^{2-} < 250 mg/L)
Cadmium	-	0.01
Chromium	-	0.05
Iron	0.1	1.0
Lead	-	0.05
Zinc	5.0	15.0
Copper	0.05	1.6
Total hardness($CaCO_3$)	100	500
Total alkalinity	-	-
Total dissolved solids	500	1000
Conductivity µs/cm	-	1,660
pH	7.0-8.5	6.5-9.2
Chloride	200	600
Carbonate	-	-
Bicarbonate	-	-
Nitrate	10	100
Phosphate	15.3 (EU)	
Sulfate	200	400

CONCLUSIONS

Inspite of the enhanced levels of iron and copper, analyte concentrations in the water were generally low, indicating that urban and industrial emissions, as well as fertilizers and insecticides, have not significantly affected the environment, or the quality of water in shallow aquifers in the area. The data procured are therefore baseline and reflect largely the geochemistry of the area. Consequently, well water in Gboko is of sufficient quality for drinking, domestic, and industrial uses. Even though the wells were shallow, chemical evidences in this study showed that they were fairly protected from infiltration of surface runoff and effluent wastes. The wells produce appreciably safe water; but for improved protection it has been recommended that a well should be made at least 6 meters deep with protection design which would include headwall, cover, concrete inner lining and cemented surrounding to maintain high quality water [2, 12, 13].

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