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Physico-chemical and Bacteriological Quality of Water from Shallow Wells in Two Rural Communities in Benue State, Nigeria

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Abstract

Ground water abstraction from shallow wells is widely practiced in the Obi and in Oju rural areas of Benue State, Central Nigeria, as a means of fighting guinea worm infestation associated with the surface water sources (streams) in these areas. To ascertain the physico-chemical and bacteriological quality of the water used by the population, water samples from 27 shallow wells in Obi and 19 Oju were taken and examined for key health-related quality parameters using routine methods. In Obi, the ground water colour ranged from 4.0-80.0 TCU, conductivity 55.2-1600.0 μS/cm, pH 6.1-8.6, TDS 38.6-1286 mg/L, turbidity 1.0-55.0 NTU, arsenic 0.001-0.210mg/L, copper 0.01-2.53mg/L, fluoride 0.08-1.82mg/L and nitrate 10.8-63.0mg/L, while in Oju, colour varied from 2.0-87.0 TCU, conductivity 107.4-1375 μS/cm, pH 6.4-8.53, TDS 75.2-1150 mg/L, turbidity 3.0-48.0 NTU, arsenic 0.001-0.023 mg/L, copper 0.01-2.10 mg/L, fluoride 0.01-1.54 mg/L and nitrate 10.2-59.7 mg/L. Some of these values in some instances exceed the WHO standard for drinking water. Alongside with the presence significant total coliform count in most of the wells (0-47/100 mL in Oju and 0-53/100 mL in Obi), the available water is considered largely unsafe for human consumption as obtained. It is concluded that, while ground water abstraction may be a safety measure against guinea worm infestation it, nevertheless presents other health challenges to the rural population in the area, as the quality of the ground water is generally low.

Keywords: Ground water, Shallow wells, Water quality, Rural community, Nigeria.

Introduction

The use of shallow ground water sources for drinking and other domestic purposes is a common feature for many low income communities in developing countries [1]. Typically, the well is a hole which is sunk, bored, driven or drilled into the ground to less than about 15 meters deep, from which water is extracted as needed. Due to the depth and structure of the shallow well, contamination with organic and inorganic compounds is a major concern [2]; contamination with chemical elements such as Pb, Cd, Cr, F, As, Cu and Mn can occur in such waters, with consequent health hazards to consumers. For example, after many years of using or drinking water from drilled wells in the Rift Valley area, Ethiopia, dental and skeletal fluorosis has become a serious problem [3]. This problem is not unique to Ethiopia, but in several other parts of the world as well, including China, India, Sri Lanka and Thailand [4]. Studies on the quality of ground water in Southwestern Nigeria revealed that wells in the suburbs of two major cities, Ibadan and Lagos, have very poor quality water including unacceptable concentrations of nitrate and ammonia nitrogen, ascribed to local waste disposal sites [5]. Okoye and Nyiatagher [6] reported better quality ground water in Gboko, a town with a relatively low urban status in Central Nigeria,

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where the underlying soil has fine-grained sand to provide adequate filtration for percolating feeder rain water [7].

As rural communities in Nigeria continue to rely on surface water sources and shallow wells for their water needs, it is important to know the quality of the water they use as a means of advancing their health in the face of grinding poverty. Up to the present however, there is little information on the quality of ground water in most rural communities in the country, attention been paid more to urban and sub-urban settlements. Available surface water sources in the Obi and Oju areas of Benue State (7^{o} 47$^{'}$, 10^{o} 0'E, and 6^{o} 25', 8^{o} 8'N) in Central Nigeria are very ephemeral; they stop flowing soon after the rainy season (April-July/August), leaving only isolated ponds for most of the dry season (August / September – March /April). These ponds are prone to guinea worm infestation with negative health effects on the inhabitants. There is complete absence of pipe-borne water, the alternative being hand-dug shallow wells. This study was therefore undertaken to investigate the quality of shallow ground water in the Obi and Oju rural areas of the State.

Experimental

The study was carried out in the Obi and Oju rural areas (covering about 200 km^2) of Benue State, in Central Nigeria. These are some of the very remote parts of the State, with virtually no industrial activities and so could serve as a primary model for the larger rural area. A field survey of shallow wells within the two areas was carried out and a total number of twenty-seven (27) shallow (hand-dug) wells in the Obi area and nineteen (19) in the Oju area were randomly selected for sampling.

Water samples were collected monthly in 2006, soon after the seasonal rains became well-established in May up to September, when the rains began to wind down, and the dry season set in. The samples were taken in 2-litre polythene bottles, previously acid-washed and rinsed with copious amounts of distilled water in accordance with Rump [8]. Samples for bacteriological evaluation were collected in clean, sterile bottles of 200 mL capacity. Care was taken to avoid any accidental contamination during the process. All samples were then packed in ice-boxes for transport to the laboratory.

Electrical conductivity (EC) and total dissolved solids (TDS) were measured using EC/TDS HACH CO150 meter. The pH was determined using Suntex TS-2 pH meter. Colour and turbidity of the samples were examined with HACH Data Logging Spectrophotometer 2010. Determination of arsenic, fluoride, nitrate and copper and bacteriological evaluation were done using methods described in Standard Methods for the Examination of Water and Waste Water [9].

Results

Groundwater quality in Obi area

The physico-chemical characteristics and bacteriological quality of shallow wells in Obi are shown in Table 1. The results indicate that colour ranged from 4.0-80.0 TCU with mean and standard deviation of 35.2±10.2. Conductivity varied from 55.2-1600 µS/cm, mean and standard deviation of 450±121. The pH of the shallow wells was observed to range from 6.1-8.6 (mean of 8.2±1.1). The total dissolved solids of the shallow wells examined ranged from 38.6-1286mg/L with a mean and standard deviation of 370±81.0. The turbidity of the shallow wells in the area ranged from 1.00-55.0 NTU, with a mean of 16.1±3.51. The concentration of arsenic in the water samples varied from 0.0011-0.210mg/L (0.011±0.002); copper 0.01-2.53mg/L (0.88±0.03) and fluoride 0.08-1.82mg/L (1.02±0.40), while nitrate concentration ranged from 10.80-63.00mg/L (34.4± 8.79) and the total coliform count ranged from 0-53 (18.7±15.2).

Groundwater quality in Oju area

In Oju (Table 1) colour ranged from 2.0-87.0 TCU with mean and standard deviation of 33.4±9.2. The conductivity varied from 107.4-1375µS/cm with a mean and standard deviation of 637±126. The pH of water from the shallow wells in this area was generally high and ranged from 6.4-8.5 (8.0±2.3). Total dissolved solids ranged from 75.2-1150mg/L (609 ±117), while the turbidity of the water samples varied from 3.0-48.0 NTU (14.3±3.81). The concentration of arsenic in the area ranged from 0.001-0.0230mg/L (0.015±0.001); copper ranged from 0.01-2.10mg/L (0.70±0.05), while the concentration of fluoride in the water samples examined ranged from 0.01-1.54mg/L (0.61±0.12) and nitrate 10.2-59.7mg/L (33.9±7.3) with a total coliform count of 0-47 (16.4±14.0).

Table 1. **Physico-chemical and microbiological quality of groundwater from shallow wells in Obi and Oju rural communities in Benue State, Central Nigeria* .**

Colour (TCU)	Conductivity (µS/cm)	Turbidity (NTU)	pH	TDS	As	Cu	F^-	$NO3^-$
				mg/L				
				Obi Rural Area				
40.0-80.0	55.2-1600	1.00-55.0	6.1-8.6	38.6-1286	0.001-0.210	0.01-2.53	0.08-1.82	10.8-63.0
(35.2±10.2)	(450 ±121)	(16.1±3.51)	(8.2±1.1)	(370±81.0)	(0.011±0.002)	(0.88±0.03)	(1.02±0.4)	(34.4±8.79)
				Oju Rural Area				
2.0-87.0	107.4-1375	3.0-48.0	6.4-8.5	75.2-1150	0.001-0.023	0.01-2.10	0.01-1.54	10.2-59.7
(33.4±9.18)	(637±126)	(14.3±3.8)	(8.0±2.3)	(609±117)	(0.015±0.001)	(0.79±0.05)	(0.61±0.12)	(33. 9±7.30)
				World Health Organization (WHO) Standards for Drinking-water (2006)				
-	≤1, 660	-	6.5-9.2†	-	0.01	2.00	1.50	50
				Total Coliform count /100 mL				
Oju	0-47 (16.3 ±14.0)		Obi			0-53 (18.7 ±15.2)		

*Range, mean ± standard deviation.
† Maximum permissible level (World Health Organization, WHO, *Guidelines for Drinking Water Quality*, 3rd ed., Vol. 1, Recommendation, Geneva; 2004 (cited Nov 19 2007), available from:http://www.indawaterportal.org//tt/wq/res/GDWQ2004web.pdf.; 7.0 – 8.5 is ingest desirable level).

Discussion

Pure water is a colourless, odourless liquid, with an insipid taste. Therefore, colour in water is suggestive of the presence of foreign, water-soluble substances (organic and inorganic). Thus the coloured appearance of water obtained from the shallow wells in the two areas suggest contamination, which may have its origins in dissolved products of the decay of dead natural vegetation as rainwater infiltrates to the groundwater table or it may be due to surface run-offs making input into poorly covered or lined wells [10, 11]. Howard *et al*, [12] found similarly significant colour in groundwater samples in Kampala, Uganda. Although the World Health Organization's Standards for drinking water [13] make no mention of this parameter, the occurrence of colour in water gives cause for concern as this parameter affects the aesthetic acceptability of water for most domestic uses.

Turbidity of water is an important parameter as it contributes to the aesthetics of water and leads to its acceptance or rejection for human consumption. The mean turbidity values of 16.05 NTU and 14.30 NTU for Obi and Oju, respectively exceeds the WHO standard [13]. High turbidity values, even in the absence of faecal indicator bacteria, imply reduced protection against contamination and it may also indicate that sanitary integrity has been compromised [12].

The electrical conductivity in the study area was generally acceptable. Ground water could have high conductivity due to the dissolution of some earth materials by infiltrating water. Similar trend in the conductivity was observed with the TDS measurements of the water samples in both Obi and Oju. High TDS obtained in a few cases may affect the taste of the drinking water and its consequent rejection by the consumer [14].

Extreme (low and high) pH values in water affect the health of consumers of the water and its disinfection [15]. An optimum range of 6.5-8.5 is recommended by WH0 [16]. The shallow wells in Obi and Oju were found, respectively, to have average pH values of 8.17 and 8.03, which is on the high side of the acceptable range. In a similar study, Okoye and Niagtagher [6] found lower pH values for water samples from shallow wells from Gboko, a more urbanized area not too far from the present study area in Benue State. This may be attributed to differences in the general geological formations in the two areas; while the Gboko area rests predominantly on basement complex rocks, the area in this study is largely on shale and limestone formations. (Fig. 1) shows a relatively stable pH regime across the months sampled, with the possible exception of the Oju area, indicating a good buffering capacity of the well waters, even as the other parameters suggest inputs from raining events during the period. Okoye and Nyiatagher [6] found a similar stability in pH across the seasons they took their water samples; they considered this as indicating fair enough protection afforded by the concrete inner lining, head wall and cover of the wells, attributes which the wells in Oju and Obi rarely had. It is, therefore, more likely that the geological formation in the area contributes to the buffering capacity of the water in the wells there. This notwithstanding, the case of Oju suggests a break-down in the buffering capacity at the peak of the rains (Fig. 1).

Arsenic is one metalloid element that is known to be toxic to humans even at low concentrations. The mean concentration of arsenic in shallow wells in Obi and Oju were 0.011 and 0.015 mg/L, respectively. These mean concentrations hover at the WHO recommended upper limit of 0.01mg/L of arsenic in potable water [13]. Arsenic can be released into ground water from natural arsenic bearing rocks [17] or may originate from agricultural practices [18]. The study area is largely rural, where inhabitants are engaged in extensive arable agriculture in which herbicides and other agricultural chemicals including some arsenicals are used in large quantities. Therefore, presence of arsenic in the ground water may be traced to agricultural activities in the area, in addition to the geology [18]. Excessive copper in drinking water could engender gastrointestinal disorders, and renal and, possibly, liver failure in consumers; at low concentrations it may cause nausea and diarrhoea. The mean copper concentration in Obi (0.88 mg/L) and Oju (0.79 mg/L) are within limits considered safe (2.0 mg/L) by WHO [13]; so are the fluoride levels (1.02 mg/L in Obi and 0.61 mg/L in Oju). However, very low fluoride concentration (<0.5mg/L) may result in dental carries in children under the age of 7 [19], thus the rural population in the Obi/Oju area are probably at risk with regard to development of dental caries, for this age group.

The mean nitrate concentration in the water at Obi (34.44 mg/L) and Oju (33.89 mg/L) were, generally, within the WHO recommended standard [16]. All the same, some shallow wells in the study area had nitrate content that exceeded this standard. Nitrate commonly occurs naturally in ground water, but high concentration might be associated with animal and human waste, open septic or sewage systems and fertilization of farms [20]. The high nitrate concentration in some of the water points may be ascribed to any or a combination of the above mentioned factors, considering the occupation of the population (agriculture) and a generally poor sanitation culture.

The presence of significant levels of coliform bacteria in the water samples from both areas may be attributable to the shallowness of the wells, in combination with a compromise of the sanitary integrity of the wells [21]. The presence of roaming animals close to the wells was observed on the field. In addition, indiscriminate open defecation by humans is common practice in these areas and this could be a source of faecal coliform contamination of the wells from surface run-offs. This is buttressed by the monthly pattern of the total coliform count as indicated in (Fig. 1). Here, the coliform count is highest at the peak of the raining season (July-August). As with the coliform count, most of the parameters show a strong parallel to the known raining intensity/pattern in the area, suggesting that much of the quality of the well waters is influenced by run-offs or infiltrating rain water.

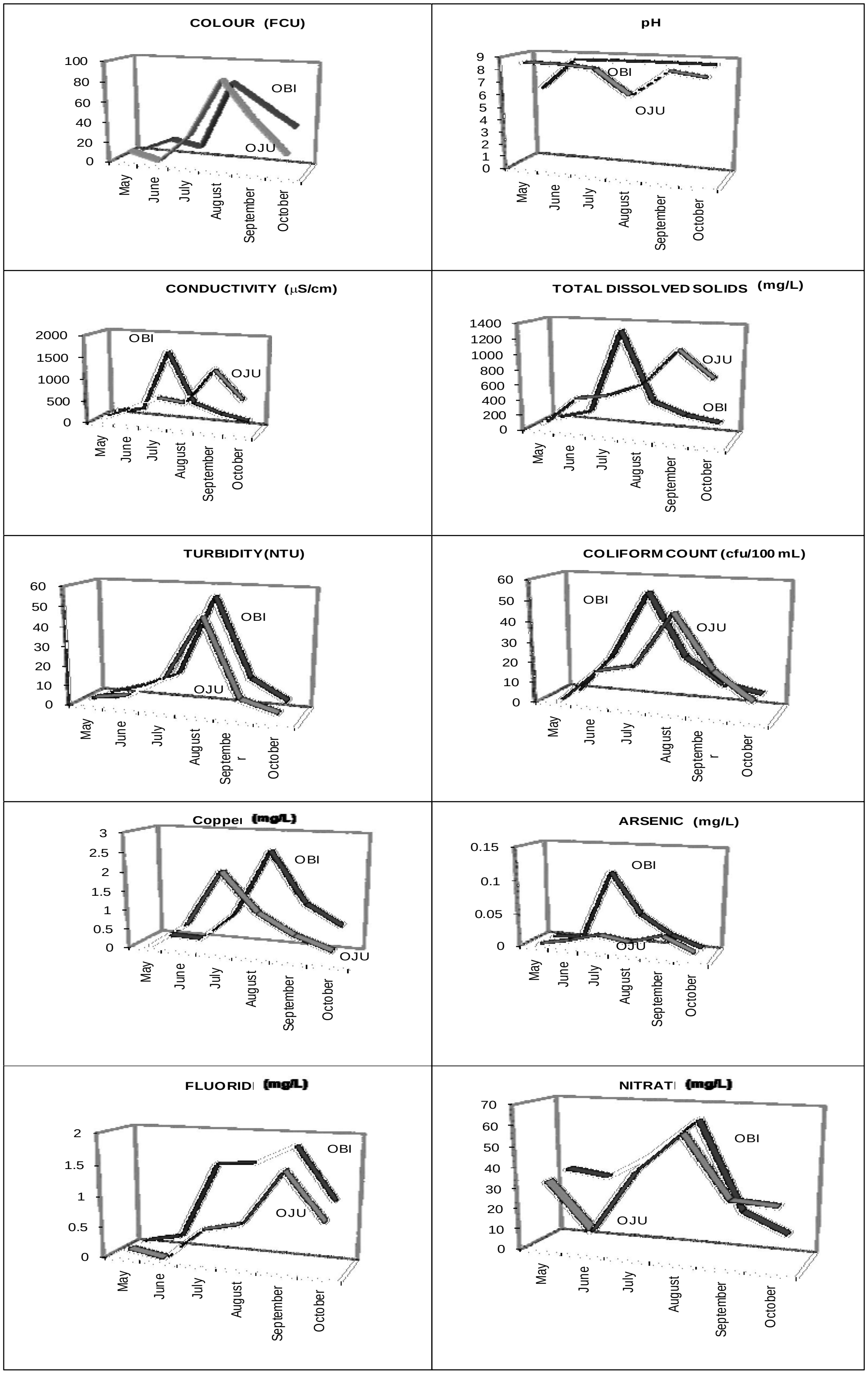

Figure 1. **Shows the monthly average for the parameters in both Oju and Obi rural areas.**

Conclusions

This study affords the following conclusions:

- Water from shallow wells in the Obi and Oju rural areas in Central Nigeria have rather poor quality with regard to colour, turbidity and pH somewhat, especially in the Oju area.
- The quality of the water seems to be influenced by the seasonal raining events (run-offs and infiltration)
- The presence of significant counts of coliform bacteria is indicative of inadequacy of the depth of the wells or a breach of sanitary integrity of the wells.
- Other quality parameters investigated (EC, TDS, Cu and as content) are within the WHO standards on the average or are at the borderline of permissible limits, making the water only fairly acceptable for many domestic uses.
- However, there is the potential that the communities may be at risk of dental caries in the young, owing to the level of fluoride.
- There is need to disinfect and treat the water for colour, turbidity and probable pH adjustment for the water to be completely acceptable for domestic use, including drinking.

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