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Physicochemical Studies of Potable Water Resources within the Kubwa Vicinity of Bwari Area Council, Abuja

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Authors' contributions

This work was carried out in collaboration between all authors. Authors UMU, UD and DMS designed the study. Authors UMU, OOP and OJO collected all data and performed the statistical analysis. Authors UMU and SCJ did the literature search. Authors UMU, OOP, OJO and SCJ wrote the first draft of the manuscript. Authors UZ and DMS wrote the second draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To examine the quality of both borehole and groundwater in selected sites within the Kubwa district of Bwari Area Council, Abuja, Nigeria with regards to drinking water quality parameters and the measure of microbial load.
Study Design: Collection and assessment of the water samples from 5 different borehole and

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groundwater sites for which the pH, Conductivity, Temperature, Turbidity, TDS, TSS, Total hardness, Alkalinity, DO, BOD, Cl^-, PO_4^{3-} and bacteriological analysis were measured.
Place and Duration of Study: The experiment was conducted at the Chemistry and Biotechnology Advanced Research Centres of the Sheda Science and Technology Complex, Abuja, Nigeria between February and October, 2015.
Methodology: Water samples were collected from the sampling sites and assessments were determined based on the APHA water and wastewater standard procedures. The heavy metal analysis was determined with the aid of Atomic Absorption Spectrophotometer (*iCE* 3000). Total microbial load was determined via pour plate method using nutrient agar, MPN indexing, MacConkey broth and Eosin Methylene Blue (EMB) agar.
Results: Results revealed that pH ranged from 6.89 - 7.15 (borehole), 6.64 - 6.95 (well water), Conductivity (µs/cm) range between 0.95 - 1.32 and 0.68 - 0.89 for borehole and well water respectively. TDS, TSS and total hardness ranged between 256-322 mg/l, 178-194 mg/l, 0.22-0.31 mg/l for all tested borehole samples while 313-327 mg/l, 226-245 mg/l, 0.28-0.34 mg/l for well water. These parameters are found to be within the permissible limits in case of all tested samples. The bacteriological analysis showed that the total bacterial count in well water was relatively high compared to that of borehole water. Also, the borehole water samples had an average of 4.0×10^2 cfu/100 ml while that of well waters ranged from 1.1×10^3 cfu/100 ml to 2.1×10^3 cfu/100 ml of the water samples. The borehole water samples had an average count of 1.2×10^2 cfu/100 ml faecal coliform while in well water samples, the faecal coliform (*E. coli*) count ranged from 2.0×10^2 cfu/ml to 6.0×10^2 cfu/100 ml. All tested parameters were compared with the WHO standards for drinking water and the results of the tested samples fell within the WHO permissible limits.
Conclusion: the levels of physic-chemical parameters; Temperature, pH, conductivity, turbidity, total dissolved solids and alkalinity contents in the borehole and well samples did not exceed the permissible acceptable world health limits.

Keywords: Borehole; groundwater; Kubwa district; physicochemical analysis.

1. INTRODUCTION

Water is a finite resource that is both invaluable and vital, and it occupies about 70% of the earth's surface [1]. It is a well acceptable fact that sufficient supply of potable water is a basic need for all humanity on earth. In other words, water is a key determinant of sustainable health and general well-being of humanity. In addition to human consumption and health requirements, water is also needed for agriculture, industrial, recreational and other purposes. Ideally, water is colourless and tasteless in its pure form. But, there is no such thing in nature as "pure" water. Nearly all water contains contaminants, even in the absence of nearby pollution-causing activities. Many dissolved minerals, organic carbon compounds, and microbes find their way into drinking water as water comes into contact with air and soil [2]. The two main sources of water are the groundwater and the surface water. Groundwater (source of water for wells and boreholes), which is generally of better quality than surface water owing to the soil's natural filtering capacity, may be vulnerable to contamination, and the event can occur sporadically. Also, due to increased human population, industrialization, very poor sanitation condition, use of fertilizers in agriculture and other anthropogenic activities, drinking water from sources are highly polluted with different harmful contaminants [3]. In most developing countries like Nigeria where dangerous and highly toxic industrial and domestic wastes are disposed of by dumping them into rivers and streams, water becomes an important medium for transmitting a wide variety of diseases [4-6]. When pollutant and contaminant levels in drinking water are excessively high, they may affect certain household routines and/or be detrimental to human health, and the health of the population influences all other activities [7]. The presence of most harmful contaminants, however, is not always obvious and such contaminated water may not cause health-related symptoms immediately. As a result, the only way to ensure that water supply is safe is to have a periodic laboratory water analysis done on the drinking water to check the quality. If a full range of chemical analyses is undertaken on water sources and repeated thereafter at fairly long intervals, chemical contaminants are unlikely to present an unrecognized hazard [8]. The Kubwa sites chosen for this investigation are presently suffering from irregular supply of potable water. So, in such conditions, the residents resort to make use of the available boreholes, wells and streams around. Hence, the present work is aimed at determining the physicochemical properties, bacterial load and heavy metals accumulation of these water resources from Kubwa in Bwari Area Council, Abuja, Nigeria.

2. MATERIALS AND METHODS

Bwari, the study area, lies between latitudes 9 05' 00'' and longitudes 7 32' 00'' and situated in the Federal Capital Territory. Portable (borehole) samples were collected in polyethylene bottles from Phase 2 site 2, Byazhin across, phase 4 and Gbazango extensions during the dry season; between February to June, 2016 from the respective sampling spots mentioned above. Each sample was taken at a depth of 30cm by slowly lowering each sample container into the water before opening up its cork by hand. The depth was determined with the aid of a calibrated measuring stick. Following this, the containers were closed up and pulled out carefully. The water samples were collected monthly from February to October, 2015. Four samples of each water source (well water and borehole water) were collected in four different places of each study area (Phase 2 site 2, Byazhin Across, Phase 4, Gbazango Extension) making a total of 32 water samples for the analysis. The monthly grab samples were collected in well-labeled polyethylene containers which were prewashed and soaked in 1M HNO_3 for 24 hours and later rinsed with deionised water [9]. The samples were transported to the laboratory in a cooler of ice to ensure rapid cooling and were protected from direct sunlight during transportation. They were further preserved in the refrigerator prior to analyses.

2.1 Physicochemical and Heavy Metals Analyses

The temperature of the water samples were determined in-situ using the mercury-in-glass thermometer. pH was determined using a Pocket Digital pH Meter and electrical conductivity was measured at 25ºC using conductivity meter (Systronics-304). Turbidity is an expression of optical property and was measured using a nephelometer. All these were recorded at the site of sample collection. Other parameters carried out in the laboratory include: chloride by Argentometric method, total hardness by titrimetric method, total dissolved solids by gravimetric methods, alkalinity by titrimetric method, total suspended solids by filtration method, dissolved oxygen by titrimetric method, phosphate by spectroscopic method and biological oxygen demand by APHA method. The heavy metals (Cd, Pb, Mn, Fe and Zn) were determined with the aid of Atomic Absorption Spectrophotometer (AAS) iCE 3000 at 228.8, 283.3, 279.5, 248.3 and 213.9 nm respectively according to APHA method [9].

2.2 Bacteriological Analysis

The total bacterial count was determined by pour plate technique using standard methods [10]. Nutrient agar medium was used for the enumeration of bacteria in the samples. Total coliform count was determined by MPN index method by employing 3-3-3 regimen using macConkey broth and positive result was indicated by the production of acid and gas on incubation at 37ºC for 48 hours. Faecal coliform count was determined using Eosin Methylene Blue (EMB) agar, in which *E. coli* strains appeared as greenish metallic sheen colonies and this was confirmed by the organism's ability to ferment lactose at 44.5ºC [11].

2.3 Statistical Analysis

All the determinations were conducted in triplicates and data generated were analyzed statistically by one-way analysis of variance (ANOVA) technique using (SPSS) 16.0.

3. RESULTS AND DISCUSSION

From Tables 1 and 2, the pH of the borehole waters ranged from 6.89 - 7.15 with a mean value of 6.99 while that of well waters ranged from 6.64 - 6.95 with a mean value of 6.78 which are within the WHO standard range of 6.50 to 8.50. This pH range is close to neutrality and most of biochemical and chemical reactions are influenced by the pH. This suggests the suitability of these water samples for drinking and other purposes. During the present investigation, there was no great difference between the temperature of the well and borehole water, which can be explained on the basis of depth of water. The temperature of any water body affects the rate of proliferation of microorganisms [12]. The temperature range of 28.63 - 29.05ºC (in the case of borehole water samples) and 28.69 - 28.82ºC (for well water samples) could be said to be suitable for the growth of heterotrophic bacterial species when present in the sample.

The values of electrical conductivity obtained from the borehole water samples ranged from 0.95 - 1.32 µs/cm while that of the well waters ranged from 0.68 - 0.89 µs/cm. These values were below the recommended WHO standard and were better health wise [13]. The turbidity results obtained were in the range of 0.35 - 0.41 NTU for borehole and 0.75 - 0.89 NTU for well water samples which are all below the WHO standard value of 5.0 NTU. Dissolved solids are solids that are in dissolved state in solution. All natural waters contain dissolved and suspended organic and inorganic substances [14]. The mean TDS value of 282 mg/l was recorded for borehole while 319.5 mg/l was obtained for well water samples. Turbidity in water sample is a function of TDS as well as TSS. There is also a linear relationship between TDS and conductivity. The greater the TDS, the greater the conductivity [15]. These values are within WHO standards for potable water.

The total hardness is the sum of calcium and magnesium concentrations, both expressed as $CaCO_3$ in mg/L [13]. Hardness level for the borehole sample was 0.25 mg/l while that of the well water sample was 0.31 mg/l which were below WHO standard of 500 mg/l. This showed that these water samples are soft water [16]. The average alkalinity values of 12.02 and 11.32 mg/l were recorded for borehole and well water samples respectively. These values were below the highest desirable level of 200 mg/l recommended by WHO and were accepted.

Oxygen dissolved in water is a very important parameter in water analysis as it serves as an indicator of the physical, chemical and biological activities of the water body. Biological Oxygen Demand (BOD) is the amount of oxygen required by microorganisms for stabilizing biologically decomposable organic matter under aerobic conditions [17]. The BOD range of 1.41 - 1.79 mg/l was recorded for borehole water samples, while 1.55 - 1.86 mg/l was recorded for the well water and were within the WHO recommended standard of 10 mg/l.

The presence of chlorides in natural waters can mainly be attributed to dissolution of salt deposits in the form of ions (Cl^-). Otherwise, high concentrations may indicate pollution [18]. The mean values of 0.26 and 0.20 mg/l were recorded for borehole and well waters respectively. Phosphates occur in natural waters as orthophosphates, condensed phosphates and naturally found phosphates. Their release via the weathering of rock materials like apatite, present in some boreholes may account for the detection of phosphates in the water sample [18]. The mean phosphate values for borehole and well water samples were 0.09 and 0.07 mg/l respectively. These physicochemical parameters of the water samples were compared with the WHO standards for drinking water and the results of the tested samples fell within the WHO permissible limits [19].

There was much considerable variation in the bacteriological quality of the borehole and well water samples. The total bacterial count in borehole water samples ranged from 2.5×10^1 to 3.0×10^1 cfu/ml, while that of well water ranged from 1.10×10^3 to 1.40×10^3 cfu/ml with the borehole samples having count within the limit of 100 cfu/ml allowed for potable water [20].

Table 1. Results of some physicochemical parameters of the borehole samples

Parameters	**Site A**	**Site B**	**Site C**	**Site D**	**Mean**	**Range**	**WHO**
pH	6.89	7.02	7.15	6.91	6.99	6.89 - 7.15	6.5-8.5
Conductivity (µs/cm)	0.95	1.21	1.32	1.11	1.15	0.95 - 1.32	0-40
Temperature (ºC)	28.63	29.05	28.91	28.86	28.86	28.63 - 29.05	28
Turbidity (FTU)	0.41	0.37	0.35	0.39	0.38	0.35 - 0.41	5
TDS (mg/l)	256	322	279	271	282	256 - 322	500
TSS (mg/l)	178	194	185	189	186.5	178 - 194	-
Total hardness (mg/l)	0.31	0.25	0.23	0.22	0.25	0.22 - 0.31	500
Alkalinity (mg/l)	12.36	11.54	11.98	12.21	12.02	11.54 - 12.36	500
DO (mg/l)	5.48	5.32	5.31	5.45	5.39	5.31 - 5.48	>6
BOD (mg/l)	1.79	1.41	1.62	1.73	1.64	1.41 - 1.79	0.05
Cl^- (mg/l)	0.26	0.33	0.37	0.09	0.26	0.09 - 0.37	250
PO_4^{3-} (mg/l)	0.07	0.15	0.08	0.05	0.09	0.05 - 0.15	

Where site A, site B, site C and site D = Phase 2 site 2, Byazhin Across, Phase 4 and Gbazango Extension respectively

Table 2. Results of some physicochemical parameters of the well water samples

Parameters	Site A	Site B	Site C	Site D	Mean	Range	WHO
pH	6.95	6.64	6.71	6.83	6.78	6.64 - 6.95	6.5-8.5
Conductivity (µs/cm)	0.88	0.76	0.68	0.89	0.80	0.68 - 0.89	0-40
Temperature (ºC)	28.74	28.82	28.76	28.69	28.75	28.69 - 28.82	28
Turbidity (NTU)	0.87	0.89	0.79	0.75	0.83	0.75 - 0.89	5
TDS (mg/l)	313	327	322	316	319.5	313 – 327	500
TSS (mg/l)	245	231	226	243	236.25	226 – 245	-
Total hardness (mg/l)	0.29	0.34	0.28	0.31	0.31	0.28 - 0.34	500
Alkalinity (mg/l)	10.47	12.25	10.75	11.82	11.32	10.47 - 12.25	500
DO (mg/l)	6.48	4.97	6.51	5.74	5.91	4.97 - 6.51	>6
BOD (mg/l)	1.55	1.83	1.55	1.86	1.70	1.55 - 1.86	0.05
Cl^- (mg/l)	0.24	0.17	0.19	0.21	0.20	0.17 - 0.24	250
PO_4^{3-} (mg/l)	0.06	0.09	0.07	0.05	0.07	0.05 - 0.09	-

Table 3. Bacteriological analysis results

Sites	Sample	Total bacterial count (cfu/100ml)	Total coliform count (cfu/100ml)	Faecal coliform count (cfu/100ml)
Site A	Borehole water	4.3×10^5	1.1×10^3	1.0×10^2
Site B	Borehole water	1.7×10^3	3.0×10^2	2.0×10^2
Site C	Borehole water	3.9×10^5	6.0×10^2	1.0×10^2
Site D	Borehole water	4.8×10^5	7.0×10^2	1.0×10^2
Site A	Well water	4.52×10^6	1.4×10^3	3.0×10^2
Site B	Well water	3.04×10^6	1.1×10^3	6.0×10^2
Site C	Well water	4.28×10^6	2.1×10^3	4.0×10^2
Site D	Well water	6.61×10^5	1.9×10^3	2.0×10^2
WHO Limits			0.0×10^0	0.0×10^0

Table 4. Result of the heavy metals concentrations of the water samples (mg/l)

Sites	Sample	Cd	Pb	Mn	Fe	Zn
Site A	Borehole water	0.0439	0.2472	0.027	0.0811	0.2502
Site B	Borehole water	0.0621	0.1946	0.029	0.0642	0.4161
Site C	Borehole water	0.0353	0.3261	0.041	0.0731	0.2738
Site D	Borehole water	0.0412	0.2523	0.032	0.0832	0.2319
Mean		**0.0456**	**0.2551**	**0.032**	**0.0754**	**0.2930**
	WHO	**0.001 – 0.1**	**0.001 – 0.1**	**0.001 – 0.1**	**1**	**15**
Site A	Well water	0.0425	0.00	0.0194	0.0336	0.00
Site B	Well water	0.0441	0.00	0.0205	0.0318	0.00
Site C	Well water	0.0715	0.00	0.0131	0.0199	0.00
Site D	Well water	0.0523	0.00	0.0152	0.0257	0.00
Mean		**0.0526**	**0.00**	**0.0171**	**0.0278**	**0.00**
	WHO	**0.001 – 0.1**	**0.001 – 0.1**	**0.001 – 0.1**	**1**	**15**

The total coliform count of the borehole waters analyzed recorded an average of 4.0×10^{-2} cfu/100 ml while that of well waters ranged from 1.1×10^{-3} cfu/100 ml to 2.1×10^{-3} cfu/100 ml of the water samples. Also, all the borehole water samples had an average count of 1.2×10^{-2} cfu/100ml faecal coliform while in well water samples, the faecal coliform (E. coli) count ranged from 2.0×10^{-2} cfu/ml to 6.0×10^{-2} cfu/100ml (Table 3). The presence of *coliforms* in well water samples is of great concern and this showed evidence of faecal contamination of such samples [17].

The mean values of the heavy metals determined were: Cd (0.0456), Pb (0.2551), Mn (0.032), Fe (0.0754), Zn (0.2930) for borehole samples and Cd (0.0526), Pb (0.00), Mn (0.0171), Fe (0.0278), Zn (0.00) for well water samples (Table 4). This showed that Pb and Zn were not detected in well water samples. But all the values obtained for the heavy metals in all the samples were within the WHO drinking water standards.

4. CONCLUSION

The results of these study showed that the Kubwa water is presently to a large extent safe for human consumption but there is need for proper maintenance of the water resources through appropriate control measures and continuous monitoring to ensure a lasting safe supply to the people.

The water quality parameters namely pH, DO and turbidity for all the water samples are well within the permitted levels. Most of the water samples exhibited EC and TDS values above the permitted values, while the alkalinity, chlorides and hardness values are higher than permissible levels only in some samples. Data obtained in this study suggests that a form of treatment has been incorporated to the borehole which accounts for the coliform levels detected. Improving the groundwater quality in peri-urban and urban areas of Abuja at the studied sampling locations would be considered safe for domestic usage after standard handling, transporting and distribution in healthy and environmentally safe procedures if counterpart treatment facilities are introduced to portable water sources. Furthermore, extensive and continuous sample collection coupled with acceptable data analysis would aid in ensuring the general safety of surface water.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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