Quality Evaluation of Hand Dug Wells Using Water Quality Index

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Abstract
This research evaluate water quality from hand dug wells in Kubwa village in Abuja, Nigeria. Water samples were collected from five (5) hand-dug wells within Kubwa Village, and analysed for drinking ; Physical, chemical and biological parameter come from the analysis of ground water. Twenty six (26) parameters were analysed in each of the hand well using American Public Health Association (APHA) standard laboratory method. The parameters investigated included Turbidity, Temperature, pH, Total Dissolved Solids (TDS), Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Chloride (Cl^-), Fluoride(F^-), Zinc (Zn), Nitrite (NO_2), Bi-Carbonate (HCO_3), Sulphate (SO_4), Nitrate (NO_3), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chromium (Cr), Iron (Fe), Alkalinity, Carbonate, Total Hardness(TH), Electrical Conductivity(EC), E-Coli and Total Coliform (TC). Weighted Arithmetic Water Quality Index method were used to obtain a single value for each well interpreted. An analyses of the results indicates that all water samples (W1, W2, W3, W4 and W5) were found to be unsuitable for drinking purpose using the Nigerian Standard for Drinking Water Quality (NSDWQ) as well as the World Health Organisation (WHO) standards to calculate the WQI as their WQI values were all above 100. The range of percentage difference of water quality index (WQI) determined using NSDWQ and WHO standards for the same water samples were determined to be 159.23% to 313.23%. Therefore, it has been established that apart from laboratory investigation and comparison of values of parameter obtained from laboratory against set water quality standards and weighted arithmetic water quality index is a good tool for summarizing and communicating the overall quality of given water.
Keywords: Groundwater, Water Quality, Water Quality Index, Water Quality Parameters

Introduction

Ground water is an important natural resources to human since it serve as an alternative to surface water for drinking. Groundwater is a source of drinking water, which is used by large population due to unavailable safe surface water. Owamah *et al.,* (2013) revealed that sub- Sahara Africa which constitute about 40% of the world population lack access to portable drinking water. Ground water are usually used for domestic, industrial and agricultural purposes. High demand for water is due to rapid population growth and industrialization (Ramakrishnaiah *et al.,* 2009). Water is an indispensable resources for life support (Sojobi *et al.,* 2014). The provision of potable water to rural and urban population is necessary to prevent water-borne diseases (Okorafor *et al.* 2012). The quality and quantity of available water have implications on the health status of a community. According to the UN report, more than 5 million people die annually from diseases caused by drinking contaminated water and lack of adequate sanitation. Increase in human population has exerted enormous pressure on the provision of safe drinking water especially in developing countries

(Domènech and Saurí, 2011). Hence, the continuous monitoring of groundwater becomes mandatory to minimize and have control on the pollution causing agents. On like surface waters which are easily prone to contamination from diverse sources, ground waters on the other hand are more reliable for domestic and agricultural irrigation needs (Okeola *et al.*, 2010; Haruna *et al*, 2008; Shymala *et al.*, 2008). The aim of this work is to evaluate water quality of hand dug wells in Kubwa Village Abuja using water quality index.

Materials and Methods

Description of the Study Area

The Kubwa Community is located Abuja the city capital of Nigeria. The Kubwa community has been in existence since 1990 as a satellite town in Abuja. It is part of the Bwari Area Council which is one of the six (6) area councils. It has annual rainfall ranges from 1,100mm to 1,600mm, which is between March to November. Kubwa is underlain by rocks of various types and an undulating terrain. The Gwagi people were the original residents.

The environments of the water sources were surveyed to examine the sanitary condition of the environments to locate wells. Twenty six (26) water quality parameters were analysed according to APHA standard laboratory procedures as provided in the standard methods for the examination of water and waste water, (APHA, 2005). Weighted Arithmetic Water Quality Index (WAWQI) method was adopted for the determination of the water quality index. Water samples were collected from hand dug wells within the study area. New high-density PET screw-capped containers of 1.5 L capacity were used to collect the water samples. The PET containers and stoppers were thoroughly washed with distilled water three times and once with the water to be sampled before collecting the actual sample. At the same time, samples for microbial analysis were collected using autoclave-sterilized sample bottles from the same locations. The water samples were transported to the Laboratory. The water samples were preserved in an ice bag to keep the water content intact until analyses were carried out.

The samples analysed were Total Dissolved Solids (TDS), Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Chloride (Cl^-), Fluoride(F^-), Zinc (Zn), Nitrite (NO_2), Bi-Carbonate (HCO_3), Sulphate (SO_4), Nitrate (NO_3), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chromium (Cr), Iron (Fe), Alkalinity, Carbonate, Total Hardness(TH), Electrical Conductivity(EC), E-Coli and Total Coliform (TC). Detailed Information of the Hand-Dug Wells (Sample Sources) are presented in Table 1.

Table 1: Detailed Information of the Hand-Dug Wells (Sample Sources)

Well Water Sample	Lining Material	Well Cover Material	Height Above EGL	Well Diameter	Approximate Depth	Distance of Well Closet Septic Tank/ Soak Away Pit
			mm	mm	Mm	mm
W1	Nil	Wood	0	1350	4830	200
W2	RC Rings	Flat Steel Sheet and Wood Cover	200	1000	4000	≤ 4000
W3	RC Rings	RC Slab and Wood Cover	170	900	5000	≤ 2500
W4	RC Rings	RC Slab and Plastic Cover	245	750	10000	≤ 4000
W5	RC Rings	RC Floor Slab and Flat Steel Cover	0	700	10000	≤ 4000

Source: Field Work and Preliminary Investigation (2015)
NOTE: EGL is Existing Ground Level and RC is Reinforced Concrete

Data Analysis

Microsoft Office Excel 2010 software package was used to statistically analyse the data. The mean values of the parameters analyse were computed for the water samples.

Calculation of Water Quality Index (WQI)

The groundwater samples were analysed for the twenty-six parameters and WQI was calculated using suitable number of parameters out of these twenty-six with both the NSDWQ 2007 and WHO water quality standards for the purpose of comparison. The weighted arithmetic water quality index (WAWQI) was calculated as follows:

1. The five groundwater samples were analysed for twenty-six (26) common parameters namely Na, K, Ca, Mg, Cl, HCO_3, SO_4, NO_3,DO, BOD,COD, Cr, Fe, TH, *p*H, TDS, EC, *E-Coli*, TC, Alkalinity, Turbidity, Fluoride, Zn, NO_2, Carbonate and Temperature.
2. The more hazardous a given groundwater pollutant, the lower its drinking water standard, and the unit weight WI for the *i*th parameter PI is assumed to be inversely proportional to its recommended guideline standard S*i* (*i*=1, 2, 3....n); where n is the number of parameters.
3. Equation 1 shows the relationship between unit weights and the water quality standards

$$wi = \frac{K}{Si} = \frac{1}{Si} \quad (1)$$

where,
wi is the unit weight
k is the constant of proportionality which is equal to unity.

4. Except for pH, equation 2 below shows the relationship between the water quality rating (*qi*) for the *i*th parameter PI, averages of the

observed data (V*i*) and maximum permissible value in water quality standards (S*i*).

$$i = 100\left(\frac{Vi}{Si}\right) \qquad (2)$$

5. For pH and DO, the quality rating *q*pH and *q*DO can be calculated from equation 3 since Vo = 0 except in certain parameters like pH and dissolved oxygen

$$qpH = 100\frac{(VpH - 7.0)}{(8.5 - 7.0)} \qquad (3)$$

6. Ultimately, the water quality index is calculated by taking the weighted arithmetic mean of the quality ratings *qi* as shown in equation 4

$$WQI = \left[\frac{\sum(qi.wi)}{\sum wi}\right] \qquad (4)$$

where:

WQI = water quality index

Σ = summation

qi = quality rating for the *i*th water quality parameter

wi = unit weight for the *i*th parameter

Note: Except *p*H and DO, unit weights of the other parameters were calculated as the inverse of their guideline values.

7. The WQI obtained are now interpreted in accordance with the Water Quality Rating as per Weight Arithmetic WQI method presented in Table 2.

Table 2: Weight Arithmetic Water Quality Index Rating

WQI Value	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

Source: Neerja *et al.*, (2012)

Results and Discussion

Table 3 and Table 4 shows all physical parameters for the five (5) water samples, and the results of the laboratory test were within allowable limit of NSDWQ and the WHO Standards. While, Results shown in Table 6 indicate that some parameters exceeds the maximum allowable limits under the NSDWQ standards. The parameters that exceeds the maximum allowable limits under the WHO standards are Iron (Fe) which occurred in wells W1 to W5 and Dissolved Oxygen (DO) also occurred in W1 to W5. All other chemical/inorganic parameters were within acceptable maximum allowable limit for both the NSDWQ and WHO standards as shown in Table 5.

Dissolved Oxygen (DO) Concentration in all the water samples were above the maximum acceptable limit of 5mg/L as prescribed by WHO. The results also shows presence of *E.coli* bacteria in samples W1, W3 and W4 indicates that the water samples are not safe for drinking. The unsuitability of the well water samples for drinking purposes also agrees with the findings of Odiba *et al.,* (2014), on a research Wukari Town, Taraba State, Nigeria. The differences in the values of the water quality index for the five wells might be attributed to the fact that some of the wells were located close to septic tanks, some without cover and some do not extend above the natural ground or floor level as indicated on Table 6. These findings agree with that of Yisa *et al.,* (2012) who carried out similar study in Maikunkele area of Bosso Local Government Area of Niger State.

Table 3: Mean and Range of parameters for the five hand dug well water Sample

S/No	Parameter	Notation	Unit	Groundwater Samples					Mean for Study Area	Range	
				W1	W2	W3	W4	W5		Minimum	Maximum
1	Sodium	Na	Mg/L	65.00	38.00	67.00	38.00	46.00	50.80	38	67
2	Potassium	K	Mg/L	43.00	20.00	22.00	13.00	14.00	22.40	13	43
3	Calcium	Ca	Mg/L	21.60	21.60	18.40	16.00	13.60	18.24	13.6	21.6
4	Magnesium	Mg	Mg/L	8.78	2.44	4.88	3.42	2.93	4.49	2.44	8.78
5	Chromium	Cr	Mg/L	0.05	0.01	0.03	.02	.01	.024	.01	.05
6	Iron	Fe	Mg/L	.45	.25	.38	.22	.31	.322	.22	.45
7	Zinc	Zn	Mg/L	.89	.46	.88	.67	.79	.738	.46	.89
8	Fluoride	F	Mg/L	1.35	1.09	.98	1.07	1.06	1.11	.98	1.35
9	Chloride	Cl	Mg/L	23.40	15.10	21.20	16.90	19.00	19.12	15.1	23.4
10	Bi-Carbonate	HCO_3	Mg/L	30.00	13.00	28.00	25.00	27.00	24.60	13	30
11	Carbonate	CO_3^{2-}	Mg/L	0.00	0.00	0.00	0.00	0.00	0	0	0
12	Sulphate	SO_4	Mg/L	45.00	21.00	30.00	25.00	26.00	29.40	21	45
13	Nitrate	NO_3	Mg/L	0.19	0.09	0.11	0.08	0.05	0.104	0.05	0.19
14	Nitrite	NO_2	Mg/L	0.19	0.09	0.11	0.08	0.05	0.104	0.05	0.19
15	Dissolved Oxygen	DO	Mg/L	6.97	6.95	5.25	6.14	6.80	6.422	5.25	6.97
16	Biochemical Oxygen Demand	BOD	Mg/L	0.00	0.00	3.00	2.00	0.00	4.2	0	3
17	Chemical Oxygen Demand	COD	Mg/L	0.00	0.00	13.00	8.00	0.00	1	0	3
18	Turbidity	Tur.	NTU	1.87	1.87	1.78	1.47	1.65	1.728	1.47	1.87
19	Temperature	T	^0C	27.40	27.50	27.40	27.40	27.40	27.42	27.4	27.5
20	Total Alkanity		Mg/L	30.00	13.00	28.00	25.00	27.00	24.6	13	30
21	Total Hardness	TH	Mg/L	90.00	64.00	66.00	40.00	46.00	61.2	40	90
22	pH	pH		6.92	6.21	6.57	6.53	6.58	6.562	6.21	6.92
23	Total Dissolved Solids	TDS	Mg/L	352.00	160.00	287.00	208.00	257.00	252.8	160	352
24	Electrical Conductivity	EC	µS/cm	525.00	239.00	428.00	310.00	383.00	377	239	525
25	*Escherichia Coli.*	E.Coli.	Cfu/mL	101.00	0.00	126.00	68.00	0.00	59	0	126
26	Total Coliform	TC	Cfu/100mL	250.00	110.00	230.00	176.00	25.00	158.2	25	250

Table 4: Results of Physical Parameters for five hand dug well water samples

S/N	Parameters	Notation	Unit	Ground water samples					NSDWQ 2007	WHO
				W1	W2	W3	W4	W5	Thresholds	Thresholds
1	Turbidity	Tur	TUR	1.87	1.87	1.78	1.47	1.65	5	5
2	Temperature	T	℃	27.40	27.50	27.40	27.40	27.40	Ambient	40
3	pH	pH	-	6.92	6.21	6.57	6.53	6.58	6.5-8.5	6.5-8.5
4	Total Dissolve Solid	TDS	mg/L	352.00	160.00	287.00	208.00	257.00	500	1000
5	Electrical Conductivity	EC	µS/cm	525.00	239.00	428.00	310.00	383.00	1000	250

Table 5: Results of Chemical/Inorganic Parameters for Water Samples

S/No	Paramater	Notation	Unit	Groundwater Samples					NSDWQ 2007	WHO
				W1	W2	W3	W4	W5	Thresholds	Thresholds
1	Sodium	Na	Mg/L	65.00	38.00	67.00	38.00	46.00	200	200
2	Potassium	K	Mg/L	43.00	20.00	22.00	13.00	14.00	NA	
3	Calcium	Ca	Mg/L	21.60	21.60	18.40	16.00	13.60	75	75
4	Magnesium	Mg	Mg/L	8.78	2.44	4.88	3.42	2.93	0.2	50
5	Chromium	Cr	Mg/L	0.05	0.01	0.03	.02	.01	0.05	0.1
6	Iron	Fe	Mg/L	.45	.25	.38	.22	.31	0.3	0.1
7	Zinc	Zn	Mg/L	.89	.46	.88	.67	.79	5	2
8	Fluoride	F	Mg/L	1.35	1.09	.98	1.07	1.06	1.5	1
9	Chloride	Cl	Mg/L	23.40	15.10	21.20	16.90	19.00	250	250
10	Bi-Carbonate	HCO_3	Mg/L	30.00	13.00	28.00	25.00	27.00		600(WHO 1996)
11	Carbonate	CO_3^{2-}	Mg/L	0.00	0.00	0.00	0.00	0.00		
12	Sulphate	SO_4	Mg/L	45.00	21.00	30.00	25.00	26.00	100	250
13	Nitrate	NO_3	Mg/L	0.19	0.09	0.11	0.08	0.05	0.2	10
14	Nitrite	NO_2	Mg/L	0.19	0.09	0.11	0.08	0.05	0.2	3
15	Dissolved Oxygen	DO	Mg/L	6.97	6.95	5.25	6.14	6.80	7.5	5
16	Biochemical Oxygen Demand	BOD	Mg/L	0.00	0.00	3.00	2.00	0.00	2	6
17	Chemical Oxygen Demand	COD	Mg/L	0.00	0.00	13.00	8.00	0.00	1000	10
18	Total Alkanity		Mg/L	30.00	13.00	28.00	25.00	27.00		120(WHO 2001)
19	Total Hardness	TH	Mg/L	90.00	64.00	66.00	40.00	46.00	150	200

Table 6 indicates that samples W1, W3 and W4 exceed the maximum permissible limits of *Escherichia Coli* as recommended in NSDWQ and WHO standards. It also indicates that all water samples exceed the maximum permissible limits of *Total Coliform* under the NSDWQ as well as the WHO standards. Based on these findings, all the water samples are considered unsuitable for direct domestic consumption (drinking) without appropriate treatment. From the results in Tables 6 and 7 it indicates that calculating the WQI using the NSDWQ and WHO guidelines shows that all water samples (W1 to W5) are unsuitable for drinking purposes as their values exceed 100. The two water quality standards are therefore comparatively said to yield the same results in respect of interpretation of WQI for the given groundwater samples. However, the percentage difference in the WQI obtained using the NSDWQ and WHO guidelines ranges from 159.23% to 313.23%.

Table 6: Results of Biological/Bacteriological Parameters of Water Samples

S/No	Parameter	Notation	Unit	Groundwater Samples					NSDWQ 2007	WHO
				W1	W2	W3	W4	W5	Thresholds	Thresholds
1	*Escherichia Coli*	*E-Coli*	Cfu/mL	101.00	0.00	126.00	68.00	0.00	0	0
2	*Total Coliform*	TC	Cfu/100m	250.00	110.00	230.00	176.00	25.00	10	0

Table 7: Classification of Water Samples based on the WQI Rating table for NSDWQ and WHO guidelines.

WQI Rating	Rating of Water Quality	Grading	NSDWQ	WHO Guidelines
0 - 25	Excellent Water Quality	A		
26 - 50	Good Water Quality	B		
51 - 75	Poor Water Quality	C		
76 - 100	Very Poor Water Quality	D		
Above 100	Unsuitable for drinking purpose	E	W1, W2, W3, W4, W5	W1, W2, W3, W4, W5

Conclusion

It has been established that Weighted Arithmetic Water Quality Index (WAWQI) is an invaluable tool for summarizing and communicating the overall quality of a given water sample apart from laboratory investigation. It gives a single value for understanding and interpretation to professionals and decision makers. Thus, it can be considered as a confirmatory test of the results of direct comparison of the concentration of parameters in water samples against set maximum permissible limits of various water quality standards in the study area.

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