ASSESSMENT OF GROUND WATER QUALITY IN LOW INCOME HIGH DENSITY AREAS OF KADUNA METROPOLIS

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ABSTRACT

Water is essential for life and bloodstream of the green economy. Lack of access to clean drinking water adversely affects the public health on many developing countries like Nigeria. Population growth, expanding cities and accelerating economic activity create unsustainable pressure on our water resources. Kaduna metropolis is a city undergoing rapid expansion in economics growth and urbanization. One of the challenges of this growth is pressure on public water supply. As in most developing countries, public water supply in Kaduna is erratic and inadequate for local consumers. Consequently, majority of the local population relied on underground water for domestic and commercial applications. The quality of underground water in the metropolis is rarely assessed. This study investigated underground water quality in high density low income areas of the metropolis. A combination of Physico-chemical and bacteriological parameters were used to analysed the quality of ground water samples collected from hand dug wells and bore holes across the metropolis. Generally, over 65% of samples were contaminated by coliform. Results indicate higher bacterial counts in hand dug wells than bore holes. While the pH of the samples varied widely, physico-chemical analysis showed over 90% of water samples were in conformity with Nigerian Standard for Drinking Water Quality (NSDWQ). Although underground water in the metropolis may be suitable for commercial and industrial applications, human consumption is only recommended after treatment to eliminate coliform risk. Protection of shallow wells and boreholes is strongly adviced.

Keywords: *Kaduna metropolis; Water quality; Water standards*

INTRODUCTION

Many cities in developing countries are facing severe water uncertainties, such as floods and droughts. Developing countries such as Nigeria are increasingly faced with the challenge of providing portable water to rapidly growing urban population. Public water supply in urban centres such as Kaduna metropolis are under intense pressure due to low investment, irregular maintenance of existing infrastructure, poor morale of personnel and negative public attitude to social services. Although the public is expected to pay for water services, deprivation and low households income are major impediments to fulfilling this obligation. Consequently, low income families especially those in high density areas are regularly cut-off from the mains. The result is exploitation of underground water for drinking and other domestic applications. The irregularity of public water supply is also responsible for the use of underground water in most industries and households across the metropolis.

Water resources management in Nigeria is regulated by the Nigerian Water Resources Management Policy, 2006 (R3) and National Water Supply and Sanitation policy, 2000 (R4). The NWRMP is concerned with management and development of water resources, water quality monitoring and

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pollution control. According to NWSSP, access to safe drinking water and sanitation is a right of all Nigerians. The document recommends free water supply to the poor (R4). Nigeria is endowed with about 52 billion cubic metres of groundwater, annually (NWSSP, 2000). Despite the abundance of groundwater the average national water supply coverage was about 57% (about 60% for urban areas, 50% for semi-urban areas, and 55% for rural areas) (ref). Urban systems require treatment plants, distribution systems, elevated tanks, piped systems, house connections, yard taps and public standpipes. Each public standpipe is generally intended to serve 250 people. Access to sanitation nationwide was estimated at 42% (R1). Diseases associated with unclean water and inadequate sanitation accounted for more than 70% of child mortality and morbidity in Nigeria (Ince et al, 2010).

Groundwater quality comprises the physical, chemical, and biological qualities of ground water. The physical qualities include temperature, turbidity, colour, taste, and odour. Generally, the quality of groundwater in Nigeria is better than that of surface water in terms of public health, but much of the groundwater is corrosive, and some areas have iron, nitrate or fluoride concentrations above WHO guideline values. (NWSSP, 2000). As ground water is mostly colourless, odourless, and without specific taste, its quality is mostly determined by its chemical and biological properties. Naturally, ground water contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred to as dissolved solids. Some dissolved solids may have originated in the precipitation water or river water that recharges local aquifers. Except for natural organic matter originating from top soils, dissolved solids are inorganic constituents. Dissolved solids in groundwater may be minerals, nutrients, and trace elements, including trace metals. Trace elements occur in such low concentrations that they are not a threat to human health. In fact many of the trace elements are considered essential for the human metabolism.

Groundwater pollution (or groundwater contamination) is an undesirable change in groundwater quality resulting from human activities. Human activities can alter the natural composition of ground water through the disposal or dissemination of chemicals and microbial matter at the land surface and into soils, or through injection of wastes directly down the soil profile. Some trace constituents that are associated with industrial pollution, such as arsenic and chromium, may also occur in completely pristine ground water at concentrations that are high enough to make that water unsuitable for drinking.

Public water supply for Kaduna Metropolis is abstracted from river Kaduna and supplied mostly to low density high income areas of the metropolis. Most settlements in low income high density areas use groundwater from wells and boreholes for domestic and industrial applications. Though water supply in urban centres is the responsibility of states and local governments, large scale water projects are only possible with federal assistance. Public water supply even where obtainable is erratic, spatial and may be contaminated through inadequate treatment, leakages or decayed infrastructure. Thus groundwater is the major water source for consumption, sanitation and hygiene. Underground water sources are poorly protected especially in low income high density areas where they are usually crowded by water vendors and the deprived at peak water demand periods of dry seasons. This combined with poor waste management and sanitation strategies are responsible for contamination of groundwater. The aim of this study is to assess the quality of groundwater in high density low income areas of Kaduna metropolis and recommend a functional strategy for improved groundwater quality.

MATERIALS AND METHODS

Sampling point coordinates were obtained using Garmin *GPSmap* 60CSx receiver. The depths of wells were obtained using intelli**measure**^{TM} laser made by Stanley. Depths of boreholes were obtained from owners/drillers. Water samples were collected from three (3) hand dug wells and bore holes from each of the selected high density low income areas of Tudun Wada, Kakuri, Barnawa and Kawo. Sampling points were randomly chosen. Water samples for physico-chemical studies were collected from selected borehole and shallow well stations 1, 2 and 3 in each locality. A total of six samples were collected fortnightly from each site using the depth method (surface and mid-depth) for well water collection. All

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samples were collected aseptically. Water samples collected were stored at 4^{o}C in clean sterile plastic bottles prior to analysis.

Physical tests: Colours of water samples were individually observed, the nature of particles present were noted. For odour, water samples were vigorously shaken and a portion of the water was poured into a clean separate beaker with each sample tested with the tongue. Temperature was measured using infra red laser thermometer (Model).

Chemical tests: pH, conductivity, Biochemical Oxygen Demand and other chemical parameters were determined using Hanna multi-parameter ion specific meter.

Total aerobic bacteria: total aerobic plate count was done using the poor plate method. Counts were recorded as colony forming units per ml

Coliform: presence of coliform was enumerated using the most probable number (MPN). These includes i) presumptive test ii) confirmed test and iii) completed test

All pure isolates were gram stained and tested for catalase, indole, motility, citrate utilization and methyl red (methyl red Voges-Proskauer test). Figure 1 illustrates a public borehole and a private shallow well.

Figure 1 Public borehole and a private well

Table 1 Ground water sampling points

S/No	Locality	Depth (m)	Elevation (m)	Latitude	Longitude	Ownership
	Tudun Wada					
	Bore holes					
1	*Sampling point 1*	22	596	N 10^{o} 30. 593'	E 007^{o} 24. 942'	Public
	Sampling point 2	18	610	N 10^{o} 30. 841'	E 007^{o} 24. 781'	Public
	Sampling point 3	25	607	N 10^{o} 30. 609'	E 007^{o} 24. 635'	Public
	Shallow wells					
	Sampling point 1	3.64	616	N 10^{o} 31. 059'	E 007^{o} 24. 110'	Private
	Sampling point 2	7.21	619	N 10^{o} 30. 695'	E 007^{o} 24. 191'	Public
	Sampling point 3	6.35	618	N 10^{o} 31. 059'	E 007^{o} 24. 319'	Private
2	**Kakuri/Makera**					
	Bore holes					
	Sampling point 1	16	611	N 10^{o} 27. 880'	E 007^{o} 24. 206'	Public
	Sampling point 2	16	598	N 10^{o} 28. 055'	E 007^{o} 24. 457'	Public
	Sampling point 3	17	614	N 10^{o} 28. 247'	E 007^{o} 24. 651'	Public

	Shallow wells					
	Sampling point 1	7.58	618	N 10^{o} 27. 932'	E 007^{o} 24. 692'	Private
	Sampling point 2	7.79	626	N 10^{o} 27. 404'	E 007^{o} 24. 834'	Private
	Sampling point 3	4.47	597	N 10^{o} 28. 946'	E 007^{o} 24. 858'	Public
3	**Barnawa**					
	Bore holes					
	Sampling point 1	21	600	N 10^{o} 28. 859'	E 007^{o} 25. 879'	Public
	Sampling point 2	17	598	N 10^{o} 28. 928'	E 007^{o} 26. 054'	Private
	Sampling point 3	20	616	N 10^{o} 28. 394'	E 007^{o} 25. 892'	Private
	Shallow wells	6.74	605	N 10^{o} 28. 929'	E 007^{o} 25. 153'	Public
	Sampling point 1	4.64	601	N 10^{o} 28. 843'	E 007^{o} 25. 879'	Public
	Sampling point 2	4.79	598	N 10^{o} 28. 961'	E 007^{o} 26. 074'	Public
	Sampling point 3					
4	**Kawo**					
	Bore hole					
	Sampling point 1	26	617	N 10^{o} 34. 894'	E 007^{o} 27. 231'	Private
	Sampling point 2	23	611	N 10^{o} 34. 793'	E 007^{o} 27. 709'	Private
	Sampling point 3	26	622	N 10^{o} 34. 171'	E 007^{o} 27. 709'	Private
	Shallow wells					
	Sampling point 1	3.52	630	N 10^{o} 34. 660'	E 007^{o} 26. 871'	Private
	Sampling point 2	4.68	624	N 10^{o} 34. 848'	E 007^{o} 26. 957'	Private
	Sampling point 3	4.10	622	N 10^{o} 34. 830'	E 007^{o} 27. 013'	Private

NB: Public: Government build; open access; in mosques/churches/schools; free water **Private**: Build by Citizens, limited access, in family compounds, water may be charged

RESULTS AND DISCUSSION

Generally, physical analysis of borehole and shallow well water samples in Kaduna metropolis showed that most sample were colourless, odourless and tasteless. Boreholes water samples from T/wada showed the highest average temperature of $36.8^{0}C$ while borehole samples from Kawo recorded the lowest average temperature of $28.1^{0}C$. The highest average temperature from well water samples was recorded in Kakuri. Generally water samples from boreholes showed higher temperature values than those from shallow wells. While the pH of water samples from shallow wells were higher than those boreholes. Shallow well ware samples from Barnawa recorded the highest average pH of 6.8. The highest average turbidity of 44 was recorded from well water sample of T/wada, though generally well water samples were more turbid than those from boreholes. The microbial analysis showed that mean total coliform count were generally higher in water samples from shallow wells than those from boreholes. The highest counts were recorded in shallow well water samples from T/wada and Kakuri (21 MPN/ml and 18 MPN/ml respectively). The total aerobic count also revealed higher microbial load in water samples from shallow wells than boreholes. The highest average total aerobic count for boreholes was recorded in T/wada (7.6×10^{2} cfu/ml), while the highest from shallow wells was 7.8×10^{3}cfu/ml from Kakuri.

Results of the Physico-chemical tests for water samples from boreholes shown in Table 2 indicates high degree of alkalinity and hardness especially in samples from Kakuri and Kawo quarters. This may be due to geology of these settlements. Bore holes from calcite rich bedrock release carbonate (HCO_3^{-}) and bicarbonate ions (CO_3^{-2}) which in solution tend to increase *TDS* and *Con*. Dissolved oxygen is used to indicate portability of surface and ground water sources. The low levels of dissolved Oxygen is probably due the high concentrations of dissolved and suspended solids, which combined are responsible for elevated conductivity values in the samples. Generally the physico-chemical values indicate the portability of water from boreholes (Table 2) than those from shallow wells (Table 3). Thus, Water from boreholes of T/wada and Barnawa will be more suitable for domestic applications than those of Kakuri and Kawo. This is more as result of geology than diversity of human activities.

Table 2 Average values of Physico-chemical parameters (Boreholes)

Location	Con ($\mu S.cm^{-1}$) (1000)	TDS (mg/l) (500)	TSS (mg/l) (30)	DO (mg/l) (NS)	TA ($mgCO_3/l$) (NS)	TH ($mgCO_3/l$) (NS)
T/wada	80	440	10	1.1	458.79	234.36
Kakuri	114	630	50	0.4	599.23	476.16
Barnawa	74	420	10	1.6	74.9	252.96
Kawo	30	570	10	2.1	561.78	483.6

Key: Con = Conductivity; TDS = Total Dissolved Solids; TSS = Total Suspended Solids; DO = Dissolved Oxygen; TA = Total Alkalinity; TH = Total Hardness; characters in parenthesis are Nigerian Standard for Drinking Water Quality (NSDWQ) Limits; NS = Not Specified

The values of Physico-chemical parameters were observed to be higher in shallow wells than boreholes. This may be due to pollution or contamination from human activities as pollutants are more like to contaminate water tables than aquifers. Consequently higher values/concentrations will be expected from older and denser quarters of the metropolis. Kawo and Barnawa with DO values of 2.1 and 2 mg/l should have cleaner water than T/wada and Kakuri, however the reality is confusing as no single parameter is sufficient indicator of portability as indicated in Tables 2 and 3.

Table 3 Average values of Physico-chemical parameters (Wells)

Location	Con ($\mu S.cm^{-1}$) (1000)	TDS (mg/l) (500)	TSS (mg/l) (30)	DO (mg/l) (NS)	TA ($mgCO_3/l$) (NS)	TH ($mgCO_3/l$) (NS)
T/wada	357	1670	30	1.7	1789.76	956.24
Kakuri	421	2150	145	1.4	1960.23	876.1
Barnawa	189	1347	25	2	350.21	489.34
Kawo	98	1080	40	2.1	1248.72	987.82

Key: Con = Conductivity; TDS = Total Dissolved Solids; TSS = Total Suspended Solids; DO = Dissolved Oxygen; TA = Total Alkalinity; TH = Total Hardness; characters in parenthesis are Nigerian Standard for Drinking Water Quality (NSDWQ) Limits; NS = Not Specified

The test for minerals such as calcium, magnesium, chlorine and iron revealed that boreholes in all the low income high density areas of the metropolis studied are rich in the first three (Figure 2) and low in ferric ions. This is because Ferric ions are not stable and are easily oxidised in air to ferrous state with a red or brownish precipitate. A few boreholes showed this transformation in T/wada, which is clean water turning brownish red in minutes. Water

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from such boreholes is discarded even though it may be suitable for human consumption though with little or no application in cooking and laundry. Figure 2 illustrates the relative abundance of mineral in waters obtained from boreholes in low income high density areas of Kaduna metropolis.

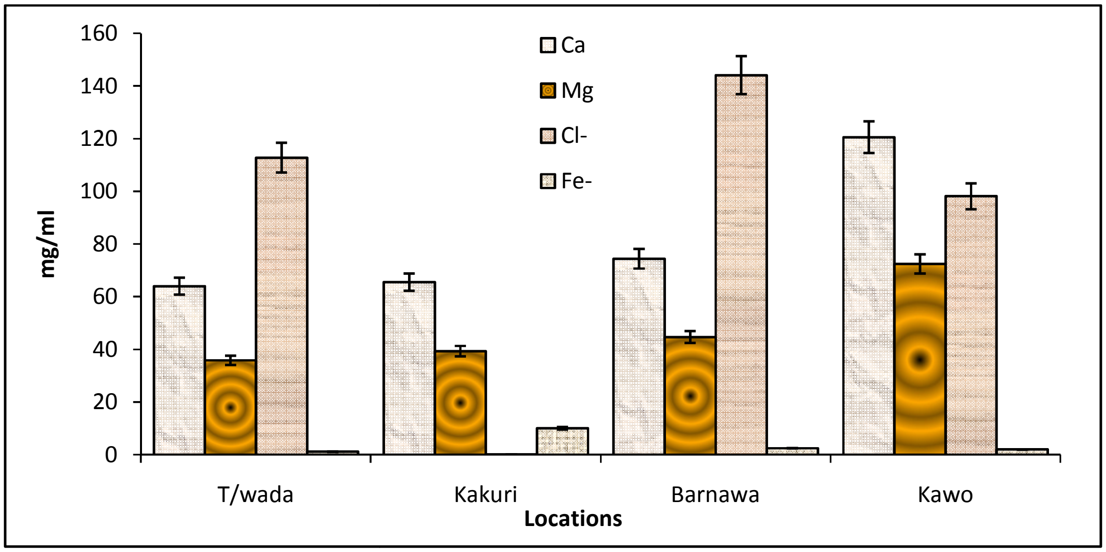

Figure 2 Minerals from borehole water samples in Kaduna metropolis (Ca = Calcium; Mg = Magnesium; Cl^- = Chlorine ion; Fe^- = Iron ion; n=6)

Organic pollution of ground water in areas studied was investigated using two parameters, namely oil and grease and chemical oxygen demand. Organic pollution in boreholes is generally low as they are more protected than shallow wells. Figure 3 shows organic pollution in shallow wells in the areas studied.

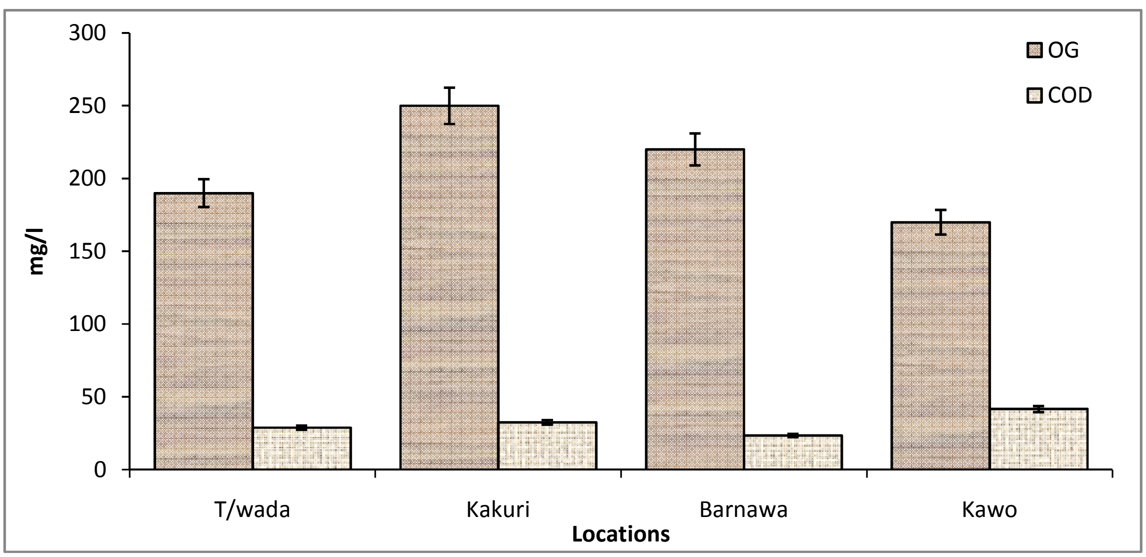

Figure 3 Organic pollution in shallow wells in Kaduna Metropolis (OG = Oil and Grease; COD = Chemical Oxygen Demand; n=6)

Among the four quarters studied the highest OG and COD of 250 and 32.61 mg/l were observed in water samples from the shallow wells of Kakuri. This may be due to high concentration of industries whose effluents may have contributed these values.

Result of total aerobic count is shown in Figure 4. The high total bacterial count observed in water samples from shallow wells may be due to improper communal and individual hygiene and lack of adequate protection and safeguards which might have exposed the wells to contamination from people drawing water from them. Contamination may also be from surface impurities and debris which are easily washed into shallow well, especially the unprotected ones.

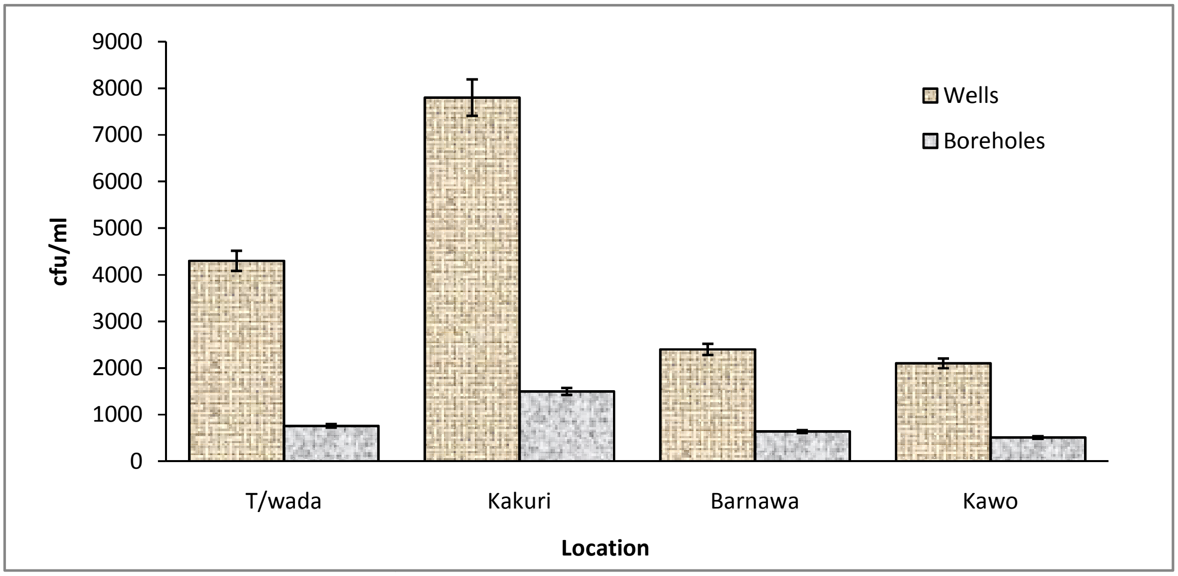

Figure 4 Mean bacterial colony count (n=6)

The confirmatory and completed tests indicated the presence of coliform in both shallow wells and boreholes. These suggest the presence of coliform and other pathogenic bacteria. Consequently, the biochemical test carried out on isolates showed the presence of *Escherichia coli* especially in Public boreholes, none was isolated from private boreholes. This may be due limited public access. Other bacteria isolated from public boreholes include *Klebsiella spp*, *Staphylococcus spp* and *Enterobacter spp*. With few exceptions, most water samples from shallow wells were contaminated with *Escherichia coli*. These isolates have grave implications on public health and safety.

CONCLUSIONS AND RECOMMENDATIONS

Based on physical and chemical analyses ground water can be use for any application other than drinking. For portability however, some form of physical or chemical treatment is require for aesthetics. The microbiological analyses showed that most samples from both boreholes and shallow wells are contaminated with potential pathogens with serious consequences on public health and safety. This was attributed to lack of adequate protection for most ground water sources especially the public ones. Protection and treatments of ground water is strongly recommended especially where one of the intended applications is human consumption. Health and environmental education is also required to raise the level of communal and individual hygiene.

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