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PARAMETERS OF WATER QUALITY IN HAND DUG WELLS (HDW) FROM HARDO WARD, BAUCHI METROPOLIS, NIGERIA

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ABSTRACT

The study analysed the water quality of Hand dug wells (HDWs) from Hardo ward, Bauchi metropolis, Nigeria for the Physical, Chemical and Bacteriological parameters. The study used standard laboratory techniques for the water quality analysis and the results were evaluated based on the benchmark standards of the World Health Organisation (WHO) and Nigerian Standard of Drinking Water Quality (NSDWQ). A random sampling method was used to select20 HDWs for the water quality analysis. Excel 2007 software was used for data analysis and the results were presented in Figures and Tables. The results of water quality from HDWs were found to fall within or below or in excess of the safety limits of drinkable water based on the benchmark standard set by the WHO and the NSDWQ. The study concluded that the quality of water from HDWs in Hardo ward were not suitable for drinking. The study recommended regular monitoring of ground water quality and a further research to determine the sources of ground water pollution in the study area.

Keywords: water quality analysis, parameters, drinking water, hand dug wells, Bauchi Nigeria.

INTRODUCTION

The quality of water used for drinking or any domestic purpose is an important factor in public health. Poor quality water can cause a disease outbreak and according to world health organization about 40% of the diseases in the world are due to consumption of polluted groundwater [1] and in developing countries about 75% of diseases are induced by polluted water WHO [2]. Water is most abundant occupying about 75% of the earth's surface, but access to potable water that is safe for drinking and sanitation is a global issue [3]. According to [4] about 1 billion people lacked access to adequate supply of potable water across the world and [5] observed that in most developing countries access to good quality water is lacking. In this situation of acute shortages of potable water [4] urban dwellers resort to groundwater sources for domestic water supply including water for drinking. In Nigeria, about 70% of the population relied on groundwater as the most important source of drinking water [1] and for the majority of the lower income residents water is obtained through the construction from hand dug wells. These sources are often susceptible to pollution as [6] observed that in the low income, high densityresidential areas of cities in the developing countries hand dug wells are highly susceptible to several sources of pollution. This implied the need to assess water quality from HDW in order to determine their safety for drinking.

In Nigeria, studies [7; 8; 9; 10] have observed water pollution in HDW due to factors such as poor location of wells, land use and construction standards of the wells. Similarly, [11; 12] have indicated the need to monitor ground water quality from hand dug wells in Nigeria due to the shallow depth and vulnerability to several sources of pollution. Furthermore, the ground water pollution may only be noticed when the water is consumed and negative impacts becomes obvious. Therefore, a regular water quality assessment is necessary to detect early signs of water pollution [6].

In Bauchi metropolis adequate supply of portable water is lacking [13]. Thus, residents in the low income residential areas such as Hardo ward resorted to sourcing water from hand dug wells due to affordable cost. In Hardo ward, hand dug wells are the most common sources of domestic water supply for drinking and other domestic uses and in most houses a pit latrine is used for sewage disposal. In addition, the area lacks adequate infrastructure for surface water drainage sand solid waste disposal. Furthermore, some of the HDWs are poorly constructed (Figure-1) while some others are located close to pollution sources such as the pit latrines. Therefore, the water from HDWs in Hardo ward should be assessed to ascertain their quality for drinking.

Figure-1. A Typical hand dug well in Hardo ward (Source: Field Survey 2014).

WATER QUALITY ASSESSMENT PARAMETERS

The quality of ground water is a function of either natural or human processes or both. Thus, both human and natural processes such as the weathering of bedrock materials, fluvial processes and leaching of organic matter, wind deposits and biological processes are potential sources of water pollution. These factors determine the quality of water [14]. Therefore, water quality assessment is generally based on the physical, chemical and biological parameters.

Physical and chemical parameters

The chemistry of soils and the rock geological formation in any area has a great influence on the quality of water because it determines the concentration of cations and anions in the water. Nitrate remains a major concern in groundwater contamination because of its high solubility and health implication particularly in pregnant women and infants [8]. Used physical, chemical and the bacteriological parameters for the water quality assessment in 10 wells from Makurdi Town, Nigeria, where the results showed water pollution effect by both faecal bacteria and non-faecal bacteria. Similarly, [15] used COD, total water hardness, total solids, turbidity and other water quality parameters of pollution effects from slaughtering slab on groundwater quality in Ilorin city, Nigeria.

Bacteriological parameters

Parameters such as Total Bacteria Counts, Total Coliform Count, Enterobactersp, Thermo Tolerant Coliform or E. coli, Faecal, Streptococcus, Clostridium Perfringens spore among others, are the most common bacteriological parameters found in ground water sources. However, the universal indicator organisms have been the Coliforms, specifically Escherichia coli, which normally originate from human and animal faeces. Their presence in any water is a proof that faecal contamination has occurred and that pathogens may be present [16]. Scholars like [17] used bacteriological analysis to evaluate water quality from 80 wells in Enugu where the results showed evidence of sewage contaminations.

Water quality standards

The standards of drinking water are based on the presence of objectionable tastes, odour, colour and the presence of substances with adverse physiological effects. However, many quality standards are recognized across the world for evaluating the safety limits of water for drinking (Davis and De West, 1966 in [18]. This study used the benchmark of [19] and the [20] to assess water quality of the HDW in Hardo ward for drinking based on physical, chemical and biological parameters.

METHODOLOGY OF THE STUDY

The study area

The study area Hardo ward is one of the high density and low income residential areas in the Bauchi metropolis (Bogoro and Babanyara, 2011) with about 15,736 populations (NPC, 2006 in Bogoro and Babanyara, 2011). Hardo ward occupies about 42.47 hectares of traditional layout within the old Bauchi city area surrounded by the ancient wall. The area is predominantly inhabited by the native population. Hardo ward is at an altitude of 644m and located between latitude 10.3120°N and 10.32°N and a longitude 9.83°E and 9.843°E and the average rainfall is about 1.0914mm per annum, while the daily humidity increases to 94% in the middle of the rainy season and drops drastically to less than 10% during the Harmattan period in the dry seasons (Belee, 2004 in [22]). In the study area, hand dug wells are the most common sources of water for domestic purposes including water for drinking. The area is an unplanned traditional layout where houses are built not to modern design standards, but mainly to provide shelter for the low income population. The area lacks adequate facilities for surface water drainages and waste disposal. In addition, most houses use a pit latrine for sewage disposal. More so, some of the wells are poorly constructed and are often without covers (Figure-1) and some are located close to pollution sources.

Study scope and sampling procedure

The scope of the study is to assess quality of water from HDWs selected within Hardo ward in the Bauchi ancient city, Nigeria. A random sampling technique was used to select 20 HDWs for the study and water samples were collected during the rainy season month of October, 2014. Two samples were collected from each well: one each of the physical and chemical analysis and the other one for bacteriological analysis. The water samples were stored in a one litre plastic bottle, made free of air bubbles and the bottles were sealed and labelled: $HDWn_1$-n_{20}. The bottles were then stored in a cooler before being transported to the laboratory for analysis. This is to prevent any rise in temperature, which may encourage either the growth or death of Bacteria and subsequently affect reliability of the results.

Methods of analysis

The standard laboratory analysis was used in collaboration with the benchmark standard of WHO and the NSDWQ to assess water quality from HDW in Hardo ward based on physical, chemical and bacteriological parameters. The variables examined under the three parameters include: The physical parameters of Temperature, Colour, taste, odour, Turbidity, Total dissolved solids and Electrical Conductivity; the Chemical parameters were pH, Total Hardness, Total alkalinity, Calcium, Magnesium, Total iron, Copper, Fluoride, Zinc,

Nitrate, Nitrite; and the bacteriological parameters are total coliform or faecal coliform.

RESULTS OF WATER SAMPLE ANALYSIS

Table-1. The results of water quality analysis of HDWs in Hardo Ward (Field Surveys, 2014).

Physical properties						
S/N	**Parameters** (mg/l)	**Range** (m)	**Mean**	**SD**	**WHO**	**NSDWQ**
1	Temperature	27.2 –28.9	27.935	0.413299	NS*	NS*
2	Electric conductance	940-1692	1382.9	242.2321	1000	1000
3	TDS	470-822	690.95	120.7623	500	500
4	PH	7.1-7.9	7.51	0.259351	6.0-8.5	6.0-8.5
5	Turbidity (NTU)	0.26-2.69	0.9135	0.649553	5	5
6	TSS	2.0-8.0	4.75	1.970172	NS*	NS*
S/N	Parameters (mg/l)	Range (m)	Mean	SD	WHO	NSDWQ
Chemical properties						
1	Total Hardness	225-365	292.45	47.07270	150	150
2	Magnesium Hardness	28-250	134.95	66.75917	100	100
3	Calcium Hardness	98-312	157.5	60.27263	50	50
4	Total Iron	0.0-0.15	0.054	0.044651	0.3	0.3
5	Fluoride	0.1-2.3	0.688	0.530358	1.5	1.5
6	Nitrate	16.8-95.7	42.255	24.59164	50	50
7	Nitrite	0.017-0.718	0.25781	0.181987	3.0	0.02
8	Sulphate	41-60	51.75	6.086006	0.5-1.5	100
9	Chloride	289-453	381.3	45.85458	200	502
10	Phosphate	0.1-1.8	0.661	0.496301	200	200
11	Copper	0.0-0.04	0.01	0.012978	0.3	1.0
12	Zinc	0.0-0.15	0.0155	0.030860	3.0	3.0
Bacteriological Properties						
S/N	Parameters (mg/l)	Range (m)	Mean	SD	WHO	NSDWQ
1	Total ColiForm	4.0-95	36.85	26.64637	0.0	10

NS* - Not specified, SD=standard deviation, WHO= World Health Organisation,
NSDWQ= Nigerian standard of drinking water quality

Physical parameters

Temperature: The temperatures of water samples obtained from the hand-dug wells in Hardo ward ranged between 27.2°C and 28.9°C, respectively. Although, both NSDWQ and WHO have not defined temperature values for drinking water, all the values exceeded the normal room temperature of 22°C. This can be acceptable because it could be due to the weather condition of the area at the period of sample collection.

Electrical conductivity (EC): This measures ability of water to conduct electric current which is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. Results of analysis showed that the EC values ranged between 940µs/cm and 1692µs/cm. Only water samples from 3 HDWs namely: HDW, 11, 12 and 15 showed EC values (of 976µs/cm, 940µs/cm and 988µs/cm respectively) which fall below the maximum permitted limit of 1000µs/cm recommended by the WHO and NSDWQ. In all the 17 other samples the EC values are above 1000µs/cm. This may occur due to the high degree

of total dissolved solid (TDS) in water samples as revealed in this study, because EC is directly proportional to TDS.

Total Dissolved Solids (TDS): The WHO standard recommended a value of 1500mg/l as safe water for drinking; but the NDSWQ recommended maximum limit of 500mg/l of water as safe drinking in Nigeria, therefore the only water samples with TDS values below 500mg/l were considered safe for drinking. From the result of analysis the TDS values were between 470mg/l and 822mg/l with a mean of 690.95mg/l. This means that the TDS values in some sample were below the maximum limits while some others were above the maximum limit of 500mg/l recommended by NSDWQ. Only results of water samples from 3HDW: 11, 12 and 15 recorded values' 488mg/l, 470mg/l and 494mg/l, respectively, and were considered safe for drinking in Nigeria, based on TDS as recommended by the NDSWQ. The high TDS values in the study area might be a result of dissolution of weathered materials from the rock formation in the study area or from pollution through leaching from Pit latrines into the hand dug wells due to the un-protective nature of the hand dug wells in Hardo ward.

PH: In all, the water samples the PH values ranged from 7.1-7.9 which are within the standards of WHO and NSDWQ in Nigeria.

Turbidity: The turbidity measures the degree to which the water loses its transparency due to the presence of suspended particles. Turbidity affects the acceptability of water for drinking and also its demand for other uses (EPA, 2001). The turbidity analysis of all the sampled water from the HDW showed values ranging from 0.26-2.69 which is lower than (5 NTU) the maximum safety limits of NSDWQ and WHO. Therefore, water from HDW in Hardo ward is fit for drinking in terms of turbidity values.

Colour: Colour in water is a reflection of the presence of suspended matter. The greater is the suspended matter in water the greater will be the colour. However, colour often arise naturally due to the presence of colloidal particles such as Iron/Manganese in water. The water samples from 17 out of the 20 HDW were found to be colour free, but only in 3 samples from HDW 3, 6 and 14 that the water colour deviated slightly from the normal quality for drinking. Therefore, water from all the HDWin Hardo ward were considered safe for drinking in terms of colour.

Chemical parameters

Total hardness: Hardness refers to the total concentration of calcium and magnesium in water; it is also a measure of the capacity of water to precipitate soap. Soap is precipitated mainly by calcium and magnesium present in polyvalent cation and they are often in complex forms frequently with organic constituents (Jayalakshmi, *et al.*, 2011). The values of Total Hardness recorded in the water samples from the HDW in Hardo ward are above the 150mg/l permitted safety limit for drinking water in Nigeria by the NSDWQ. However, no specific value was mentioned by the WHO as the threshold limit for Total Hardness in water. The high values of total hardness in the water samples can result from the leaching of dissolved calcium and magnesium into hand dug wells which is possible given the pronounced use of pit latrines for sewage disposal in addition to substandard construction of wells and a poorly maintained set back standards of distance between wells and pit latrines as was observed in Hardo ward during the survey. Thus, water from HDW in Hardo ward may cause hard scales and rust on cooking utensils and other metal objects when heated. This will reduce the efficiency and life cycle of heating equipment's. It may also make soap to curd in water instead of lather which affects washing/laundry and it can also cause tooth decay.

Manganese: Manganese occurs naturally in both surface and ground water sources. However, human activities are also agents for manganese contamination in water (WHO, 2011). The NSDWQ and WHO recommends permissible limits of 0.5mg/L and 1.5mg/L of Manganese levels respectively for drinking water. However Manganese was not detected in samples from all the HDW analysed in Hardo ward.

Calcium hardness: Calcium is an element that is found naturally in abundance within the earth's crust. It is also an important and abundant element in the human body. Adequate intake of calcium is essential for normal growth and good health. Calcium is the most important element causing hardness in water. Water samples from HDW in Hardo ward showed values for calcium concentration are above maximum permitted limit of 314mg/l recommended by NSDWQ and WHO. The presence of excess calcium in water causes temporary hardness, but it can be removed easily by boiling.

Total Iron content: Iron in the groundwater is normally present in the soluble ferrous (Fe2+) form. It is easily oxidized to the insoluble ferric (Fe) state upon exposure to air. Underground water normally contains Fe2+ due to insufficient oxygen in the aquifer. The values of Fe in all the water samples from the HDW in Hardo ward ranged between 0.00mg/l and 0.15mg/l; showing values are below the recommended limits of 0.30mg/l by the WHO and NSDWQ. Therefore, water from all sampled HDW are safe for drinking based on Fe concentration.

Fluoride: Fluoride content in drinking water is of great concern because its concentration in optimum value is beneficial to human health while concentration in excess has negative impact on health. It has been established that fluoride of concentration in values between 1.00 mg/l and 1.5mg/l is of optimum benefit because it can prevent tooth cavities, especially among children and the consumption of water with fluoride exceeding this limit can cause dental and skeletal fluorosis. The results of the analysis of fluoride content in most of the water samples (17 out of 20) are either less than 1mg/l or in excess of 1.5mg/l, which in both instances fall outside the optimum range for safe human consumption. Only the water samples from 3 HDW (2, 5 and 8) have a fluoride content of 1.26mg/l, 1.19mg/l and 1.01mg/l, respectively, which falls within the recommended safety limits of 1mg/l and 1.5mg/l by the WHO and NSDWQ and are considered safe for drinking in terms of fluoride concentration.

Nitrate: The higher levels of nitrate in water can result from pollution by animal waste, or by seepage of human sewage or by the excess use of fertilizers. Nitrite is of concern to human health because it causes the haemoglobin in the blood to change to met-haemoglobin which reduces the amount of oxygen carried by the blood. This result of insufficient oxygen supply in body cells leading to a malfunction condition called met-hemoglobinemia [23]. In addition, Nitrite can react with secondary amines in the human stomach to form the highly carcinogenic N-nitroso compounds [24]. The result of the analysis in 15 out of 20 water samples from HDW in Hardo ward showed values below the permitted limit of 50mg/l recommended by NSDWQ. Therefore, only water from 5 HDW (1, 3, 6, 12 and 20) with nitrate values above 50mg/l are not safe for drinking without proper treatment based on nitrate contaminants.

Nitrite: From the results, water samples from all the HDW have nitrite content below the recommended value of 3mg/l by WHO. But water samples from 10 (or 50%) of the HDW have nitrite concentration exceeding the limits of 0.2mg/l recommended by NDSWQ for water quality in Nigeria. Therefore, only the quality of water from HDW: 1, 5, 7, 10, 11, 12, 14, 16, 19 and 20 which have values below 0.2mg/l are considered safe for drinking.

Sulphate: Sulphate minerals are widely distributed in nature, and the sulphate anion is a common constituent of unpolluted water. Sulphate may arise from leaching of mostly sedimentary rocks, which is then deposited as gypsum. The results obtained revealed that the sulphate concentrations in all the water samples from HDW were below the maximum limit of 200mg/l recommended by NSDWQ and WHO. Therefore, it can be concluded that the water from the sampled HDW meet the requirement for drinking in terms of sulphate concentration.

Chloride: Chlorides are usually found in the form of salts of sodium, potassium, and calcium (NaCl, KCl, and $CaCl_2$). The concern with chlorides in water is more to do with quality of taste than with health. From the results, all the water samples from HDW have the concentration of chloride above the permissible limits of 250mg/l and 200mg/l set by NSDWQ and WHO respectively. Therefore, the entire water samples from the HDW did not meet the chloride requirement for safe drinking.

Phosphate: In all, the water samples the values of phosphate ranged from 0.1-1.8 with a mean of 0.66 which are within the standards of both the WHO and the NSDWQ.

Copper (Cu): Copper is an essential element in human metabolism, and its deficiency results in a variety of clinical disorders, including nutritional anaemia particularly in infants. The concentrations of Cu in all the water samples from HDW ranged between 0.01-0.04mg/l which falls within the safety limits set by the WHO and NSDWQ.

Zinc; Zinc was the only heavy metal family detected in the water sample analysis. The Zinc concentrations in the sampled HDWs were all within standard limits of 5mg/l as recommended by both WHO and NSDWQ.

Heavy metals: This is any metallic chemical element that has a relative high density and is toxic or poisonous. Heavy metals are natural components of the earth's crust that cannot be easily degraded or destroyed. Heavy metals are ingested into the human body through water, food or air. Long term accumulation of heavy metals in the human body initiates a slow and progressive process of physical, muscular and neurological degeneration. However, the heavy metals like Lead, Arsenic, Cyanide and Chromium were not detected in the water quality samples. Therefore, the qualities of water from HDW in Hardo ward are safe for drinking based on heavy metal concentrations.

Bacteriological analysis

Coliform bacteria are described by grouping based on their common origin or characteristics, as either Total or Faecal Coliforms. The Total group includes Faecal Coliform bacteria such as Escherichia coli (E coli) and other Coliform bacteria that are naturally found in the soil. Faecal Coliform bacteria exist in the intestines of human beings and animals and are released through waste discharges into the soil (WHO, 2003). Coliform bacteria

are used as indicators of as water quality because their presence in drinking water may indicate a possible presence of harmful, disease causing organisms. Their detection in drinking water is also relatively simple and economical [25]. The bacteriological analysis of water samples showed that all the HDW contained Coliform bacteria mostly with concentrations above the maximum limits recommended by both NSDWQ and WHO. According to the WHO standards no Coliform should be detected at all in any 100ml of drinking water. However, the NSDWQ recommend 10cfu/100ml as the maximum permissible limits for the total coliform concentration for safe drinking water quality in Nigeria. Therefore, the results of water samples from 17/20 (85%) of HDW are with values above 10cfu/100ml which are not safe for drinking while water samples from 3 HDW (namely: HDW 13, 15 and 18) which showed values below 10cfu/100ml were considered safe for drinking based on the NSDWQ standard.

CONCLUSIONS AND RECOMMENDATION

The results of the analysis showed a variation in water quality parameters. In some parameters, the water samples from hand dug wells in Hardo ward are within safety limits while in many parameters the water quality either falls below or in excess of the standards set by the national standard for drinking water quality (NSDWQ) and the World Health Organisation (WHO). Therefore, the study concluded that water from HDWs in Hardo ward are not safe for drinking and the water should be treated before drinking. The study recommended regular assessment of ground water quality and a further research to determine the sources of ground water pollution in Hardo ward in order to design measures for improving water quality in HDWs in the study area.

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