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Pollution Status of Selected Hand Dug Well Water Within North Bank, Makurdi

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Abstract

Access to portable water supply is one of man's biggest challenges. Ground water is threatened with pollution and diseases such as cholera and typhoid are caused as a result of water pollution. This study assessed the pollution status of hand dug wells in North bank, Makurdi, focusing on physicochemical parameters, biological parameters and heavy metals. Water samples from twelve hand-dug wells located in four areas of North bank were collected and analyzed using standard analytical procedures and the values obtained were compared with the WHO and NSDWQ permissible standards for drinking water. The Palintest methods and Atomic Absorption Spectrophotometer (AAS) were used for the analyses. Results showed physiochemical parameters such as temperature ranged from 34.57 – 35.5 °C and this is above the permissible limit, pH: 6.43 – 7.00, conductivity: 268.33 – 568.33 µS/cm, total dissolved solids: 135.00 – 284.00 mg/L. YGW had the highest chloride 50.33 mg/L while HDW and FHW have the lowest with 22.67 mg/L, total hardness: 111.67 – 301.00 mg/L, which is above the permissible limit, nitrate: 15.37 – 38.60 mg/L. All the samples contain copper, lead, cadmium and zinc while nickel was found in all the samples except at ICW. Nickel ranged from 0.03 – 0.26. Chromium was below detection limit in all the samples. Cadmium, nickel and lead are above the permissible level. The study showed significant anthropogenic influences on well water quality, indicating the risk of waterborne diseases in the area. Regular monitoring and protection of hand dug wells are important to ensure safe drinking water.

Keywords: Well water, Physicochemical parameters, Heavy metals, AAS, Palintest methods

Introduction

Water is an essential resource for living systems [20]; it is a key determinant for sustainable human health as well as general wellbeing [15]. Water contains minerals which are important for human beings as well as plant and aquatic life [27].

Groundwater is vital natural resources that are found available in rocks and soil under the earth surface, this groundwater usually concentrates underground in sinkhole. It was estimated that about 97% of world freshwater that is potentially available for human use constitutes groundwater and it is an important source of drinking water in various places around the world [17].

The quality of water remains a key challenge in Nigeria due to its significant reliance on surface and groundwater for drinking, irrigation, and industrial use [19]. Over 66 million Nigerians lack access to safe water near their homes, forcing them to spend hours daily queuing and trekking long distances to fetch water, often without knowing its quality [15].

Many residents are forced to rely on wells due to the government's inability to provide accessible and affordable water [9]. In many arid and semi-arid areas of Africa, well water is one of the means of coping with water deficiencies in areas where rainfall is scarce or highly seasonal and surface water is extremely limited [22].

Groundwater resources are commonly susceptible to pollution which may degrade their quality [32]. The quality of groundwater is dependent on either natural or human factors or an interaction of both. These factors can determine the groundwater quality. Although, groundwater aquifers are sources of quality water due to the purifying of the soil layers [18].

All natural waters contain many dissolved substances. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of insufficient treatment and disposal of wastes from humans and livestock, industrial discharge and overuse of limited water resources [6].

Testing water quality in dug wells is vital since many people in African communities rely on them for drinking water [30]. This study aims to assess the pollution status of hand dug wells in North bank, Makurdi, and identify potential health risks

Plate 1: Opened, Semi-closed and Closed Hand-dug Wells in North Bank, Makurdi (Source: Field Survey)

Materials and Methods

Materials

Reagents of analytical grade were used for this study. Water samples were analyzed with Palintest photometer (7100), Wagtech conductivity/TDS meter, and HACH 2100P turbidity meter at the laboratory of the Benue State rural water supply and sanitation agency (BERWASA) and AAS at the Federal Ministry of Agriculture and Rural Development, Zaria, Kaduna State.

Study Area

Makurdi town, the headquarters of the local government also serves as the state capital. Its geographical coordinate is latitude 7.74° N, longitude 8.51° E. It has area of 820 Km^2 and density of 494.5Km^3. North bank, also known as Makurdi North, is located at the North Bank of River Benue.

North bank was selected as the study location due to its high population density and agricultural activities. The area's dependence on hand dug wells for domestic water supply and potential pollution from agricultural runoff make it an ideal site for assessing pollution status of hang dug wells.

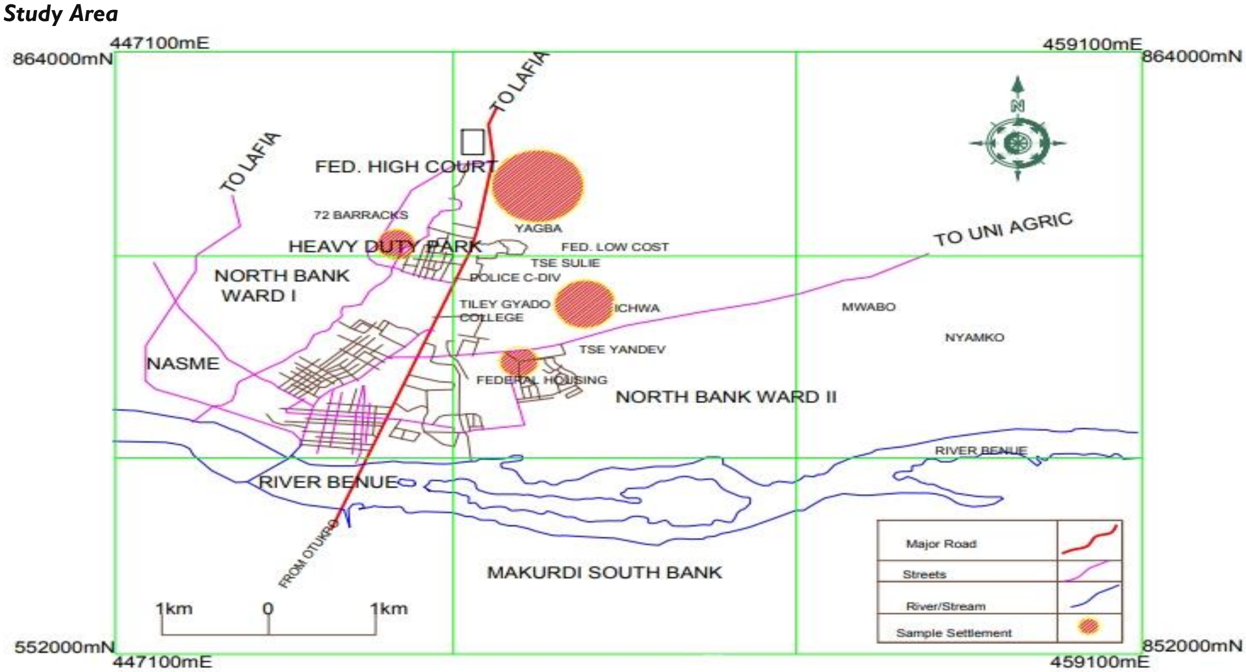

Plate 2: Map of Makurdi Showing the Locations of Sampled Hand-dug Wells in the North bank Area

Sampling

The water samples were randomly collected from twelve hand-dug wells, one sample per well, sited in four settlements (Heavy duty park, Federal Housing Estate, Ichwa and Yagba) of North bank, Makurdi. The water samples were collected using rope tied to plastic fetcher, dipped into the wells and drawn out into labeled polyethylene bottles that were properly washed and rinsed with distilled water. The samples were then taken to laboratory at Benue State rural water supply and sanitation agency (BERWASA) for analysis. The water samples temperature and pH were taken in-situ. Sampling was done during the raining season between 7:30 am and 10:30 am.

Atomic Absorption Spectrometry (AAS)

AAS is an analytical procedure for the quantitative measurement of chemical elements, based on the absorption of light by the free metallic ions that have been atomized from a sample [21]. The principle of AAS is dependent on how light is absorbed by atoms. It works by using a light source, such as a hollow-cathode lamp or an electrode-less discharge lamp that emits light at specific wavelengths corresponding to the element being. First, the sample is turned into a gas, where the atoms become free, a process called atomization. Once the atoms are in this state, they absorb the light at those specific wavelengths. The amount of light absorbed is directly related to the concentration of the element in the sample. This relationship is described by the Beer-Lambert law, which says that the more atoms there are, the more light is absorbed [36].

Table 1. Sampling Codes and Description

S/N	Sample code	Description
1	HDW1-3	Heavy Duty Wells
2	FHW1-3	Federal Housing Wells
3	ICW 1-3	Ichwa Wells
4	YGW1-3	Yagba Wells

Water Quality Analysis

Water quality assessment covers Temperature, pH, Turbidity Conductivity, Total dissolved solids (TDS), Total suspended solids (TSS), Chloride, Nitrate, Sulphate, Flouride, Total hardness, Alkalinity, Dissolved oxygen, Biochemical oxygen demand, Chemical oxygen demand and heavy metals.

On-site measurements were taken immediately after sample collection. Temperature was recorded with a mercury thermometer, and pH was measured using a Hanna pH meter (pHep). Other parameters were analyzed using specific meters: dissolved oxygen (Hanna HI 9146), electrical conductivity and total dissolved solids (Wagtech conductivity/TDS meter), total suspended solids (TSS meter sensor), and turbidity (HACH 2100P). Total solids were calculated as the sum of TSS and TDS. Palintest methods, which use tablet-form reagents to produce a color change, were used to determine total hardness, nitrate, fluoride, and chloride levels.

The testing process involves adding specific tablets to the water sample. The reactions produce a specific coloration in the water sample. The intensity of this colour, which correlates with the parameter being tested, is then measured using a Palintest photometer [37].

To guarantee the elimination of impurities from the samples and prevent interference in heavy metal analysis, each water sample was digested with concentrated nitric acid. 10 mL concentrated HNO_3 was added to 50 mL of water in a 250 mL conical flask. The mixture was evaporated to half of its volume by hot plate then allowed to cool and finally diluted with double deionized water in 50 mL volumetric flask. Standard solutions of Zn, Ni, Cd, Cu, Cr and Pb were prepared from their salts in aqueous solutions containing 2 % of nitric acid, with serial dilution of the standard solutions into a series of 50 mL volumetric flasks. Calibration curve for each metal was prepared by plotting the absorbance of standards against their concentrations. The acidified water samples were analyzed for the presence of Zn, Ni, Cd, Cu, Cr and Pb respectively using atomic absorption spectrophotometer (Varian AA240) [11].

Quality Control

Analyses were done in triplicate on the samples to calculate a mean which was used to determine the trueness of the results at the end of the analysis [6]. Quality control practices involving reference material was adopted. Portable water samples from registered/certified dealer were used as analytical control samples.

Statistical Test of Significance

All values were reported as mean ± standard deviation (SD). The mean values of the parameters obtained for the various sampled wells were presented in charts in comparison with WHO and NSDWQ standards for drinking water. Significant difference was tested at 95% confidence level ($P<0.05$). All data analyses were performed using Microsoft excel 2010 and the statistical package for social sciences (SPSS) [16] [33].

Results and Discussion

The summary of results of physicochemical properties and heavy metal analysis of twelve well water samples from four different locations in North Bank, Makurdi are shown in tables 1 and 2 respectively. The results were compared with WHO and NSDWQ standards for drinking water.

Table 2: Summary of Result of Physicochemical Parameters of Well Water from the Study Area

Parameters	HDW	FHW	ICW	YGW	P- Value	WHO	NSDWQ
Temperature(°C)	35.50±0.5	34.57±0.7	34.87±0.2	34.97±0.0	0.17	27.00	Ambient
pH	6.43±0.3	6.90±0.1	7.00±0.2	6.50±0.2	0.24	6.5-8.5	6.5-8.5
Turbidity (NTU)	1.16±0.3	0.63±0.5	0.54±0.3	6.18±0.4	0.32	5	5
Conductivity (µS/cm)	268.33±17.9	405.00±106.9	568.33±259.7	499.00±56.0	0.37	1000	1000
TDS (mg/L)	135.00±8.9	203.00±80.7	284.00±130.9	250.33±28.5	0.56	500	500
TSS (mg/L)	50.33±6.0	46.67±5.9	43.33±2.9	50.00±3.0	0.35	500	-
Chloride (mg/L)	22.67±11.9	22.67±9.1	48.00±14.1	50.33±16.2	0.17	250	259
Nitrate (mg/L)	38.60±10.7	15.37±19.9	24.87±18.5	32.57±15.5	0.07	50	50
Sulphate (mg/L)	7.67±8.1	12.00±11.3	41.00±18.3	15.67±17.7	0.08	250	100
Flouride (mg/L)	0.26±0.1	0.62±0.2	0.62±0.2	1.28±0.1	0.03	1.5	1.5
Phosphate (mg/L)	0.39±0.1	0.55±0.0	0.20±0.0	1.89±0.2	0.02	5.0	-
Carbonate (mg/L)	60.00±20.0	66.67±11.6	73.33±11.5	80.00±20.0	0.16	-	-
Total Hardness	111.67±22.5	185.00±66.2	301.00±196.7	151.67±2.9	0.12	500	600
Alkalinity (mg/L)	10.80±1.2	12.60±0.4	12.67±0.6	12.13±1.4	0.48	500	-
DO (mg/L)	2.03±0.1	2.37±1.1	2.03±0.2	2.50±0.6	0.34	5	-
BOD (mg/L)	1.37±0.3	1.33±0.2	1.20±0.1	1.40±1.1	0.32	5	6
COD (mg/L)	2.73±0.6	2.67±0.3	2.40±1.1	2.80±0.2	0.81	-	10

Key: HDW = Heavy Duty Well, FHW = Federal Housing Well, ICW = Ichwa Well, YGW = Yagba Well, P-Value at 95 % CL (P < 0.05), WHO = World Health Organisation, NSDWQ = Nigerian Standard for Drinking Water Quality, TW = Table Water, WB = Water Board.

Table 3: Summary of Result of Heavy Metals of Well Water from Study Area

Heavy metals (mg/L)	HDW	FHW	ICW	YGW	WHO	NSDWQ
Cu	0.26±0.06	0.28±0.02	0.19±0.02	0.23±0.03	2.000	1.000
Pb	0.61±0.30	0.26±0.36	0.60±0.23	0.19±0.28	0.01	0.01
Zn	0.05±0.06	0.12±0.09	0.23±0.04	0.18±0.08	3.000	5.000
Ni	0.24±0.21	0.03±0.31	BDL	0.22±0.17	0.02	0.02
Cd	0.03±0.02	0.05±0.04	0.04±0.02	0.02±0.02	0.003	0.003
Cr	BDL	BDL	BDL	BDL	-	-

BDL = Below Detection Limit.

Temperature

The temperatures of water samples obtained from the hand-dug wells in ranged between 34.57 °C at FHW to 35.50 °C at HDW. The mean values of temperatures of the water samples were statistically insignificant at $p<0.05$. Elevated temperatures of well water can lead to high risk of bacteria growth and decreased dissolved oxygen. Temperature is one of the most important factors which has a profound influence on both the living and non-living components of the environment, thereby affecting organisms and the functioning of an ecosystem. Temperature generally influences the overall quality of water [32].

pH

This is the scale for determining the level of acidity and alkalinity of a solution. The pH of the hand dug wells in North bank was generally within the acceptable limit of WHO and NSDWQ, with the highest value of 7.00 at ICW, and lowest value of 6.43 recorded at HDW. The value at HDW is due to the discharge of acidic products into Well water by agricultural and domestic activities (application of fertilizer, animal manure and use of detergents near hand dug wells). pH is generally considered to have no direct impact on human; however prolonged consumption could lead to mineral deficiencies [2].

Turbidity

Turbidity values of all the water samples ranged from 0.54 to 6.18 NTU, and it's in agreement with WHO and NSDWQ except at YGW where the value is 6.18 NTU. The value at YGW could be as a result of proximity of the wells to pit latrines.

Turbidity is the measure of the clarity or cloudiness of water. Turbidity in water occurs as a result of the presence of very finely divided solids which are not filterable by routine methods [10].

Conductivity

Electrical conductivity (EC) is a measure of total salt content in water. It is a determination of levels of inorganic constituents in water [32]. In this study the conductivity ranges from the minimum value of 268.33 µS/cm at HDW to maximum value of 568.33 µS/cm at ICW. It was observed that the mean value of conductivity of the water samples were statically insignificant at $p<0.05$. The values of this study were found to be within the permissible limits for both WHO and NSDWQ.

Total Dissolved Solids

The values recorded for TDS from the four locations were found to be within the permissible limit for both WHO and NSDWQ with the minimum value of 135 mg/L at HDW and maximum mean value of 284 mg/L at ICW. [29], recorded values that ranged from 550-1344 mg/L for hand dug well in Oyo state. Water can dissolve a wide range of inorganic and some organic minerals or salts. These minerals produced un-wanted taste [23].

Total Suspended Solids

The Total suspended solids of water samples in this study ranged from 43.33 mg/L at ICW to 55.33 mg/L at HDW. [37], obtained higher values that ranged between 28.0-815 mg/L from hand dug wells in Makurdi. All values obtained for this study are within the WHO standard of 500 mg/L. High TSS leads to turbidity and it is an indication of pollution [4].

Chloride

Chloride concentration in this study ranged from 22.67 mg/L at HDW to 50.33 mg/L at YGW. These values are below the WHO and NSDWQ standard of 250 mg/L for drinking water. It was also observed that the mean values of chlorides of the water samples were statistically insignificant at $p<0.05$.

Chloride is harmful not to human at low concentration but could alter the taste of water at concentration above 250 mg/L. The presence of chlorides in natural water could be attributed to pollutions from sewage, minerals and industrial effluents. Geochemical conditions could also make chlorides to present in varying conditions [14] [26].

Nitrate

The nitrate range of the well water samples was 15.37 mg/L to 38.60 mg/L. The values obtained in this study are within the WHO and NSDWQ standards of 50 mg/L for drinking water. The nitrate in the water samples from North bank could originate from the use of agricultural fertilizers, human and animal waste.

High concentration of nitrate causes methemoglobinemia in infants less than six months and other ailments such as diarrhea and respiratory diseases [35].

Sulphate

The concentration of sulphate in water samples from the study area ranges from the minimum of 7.67 mg/L at HDW to the maximum of 41.00 mg/L at ICW. No major negative impact of sulphate on human health is reported. The values recorded for this study are much lower than those obtained by [12], 48-190 mg/L. All the values fall within the WHO and NSDWQ permissible range for drinking water. Sources of sulphate in hand dug wells are agricultural runoff and geological formations. High sulphate can cause unpleasant taste.

Fluoride

The concentration of fluoride in this study are in the range of 0.26 mg/L, 0.62 mg/L, 0.62 mg/L and 1.28 mg/L at (HDW, FHW, ICW and YGW) respectively. Water samples from 3 sampling area (HDW, FHW and ICW) are below the required standard for fluoride in water while YGW is within the acceptable limit of 1.5 mg/L stated by both WHO and NSDWQ and is considered safe for drinking. The values at YGW could be as a result of geological formations.

Fluoride content is of great concern in water. Low concentration of fluoride is beneficial to human health while high concentration above the recommended value has negative impact such as dental and skeletal fluorosis [18].

Total Hardness

Hardness is one of the most important properties of ground water for domestic use. In this study, the values for total hardness of the water samples recorded was 111.67 mg/L at HDW which indicate that the water is moderately hard, 151.67 mg/L at YGW which also indicate that the water is hard. The values 185.00 mg/L and 301.00 mg/L recorded at FHW and ICW indicates that the water in this location is very hard. [25] classified total hardness of water in the following ranges; 0 – 60 mg/L soft, 61 – 120 mg/L moderate, 121 – 180 mg/L hard and > 181 very hard. The values from YGW, FHW and ICW fall outside the acceptable standard of NSDWQ and WHO. The values obtained for this study could be as a result of agricultural runoff (fertilizer), rock and soil dissolution. Hardness increases the boiling points of water due to the presence of salts of calcium and magnesium [24].

Alkalinity

Alkalinity in the samples ranged from 10.80 mg/L at HDW to 12.67 mg/L at ICW, with the average mean of 12.05 mg/L. [28], reported values that ranged between 19.31-27.60 mg/L for water of Iyesi, Ogun State. Alkalinity in the hand dug wells could be due to various factors including: the proximity of garbage dumps to the wells and agricultural activities such as use of pesticides and fertilizers. Alkalinity is the sum total of components in the water that tend to elevate the pH to the alkaline side of neutrality [13].

Dissolved Oxygen

The values of DO record for each of the sources analyzed are 2.03, 2.37, 2.03 and 2.50 for HDW, FHW, ICW and YGW respectively. [40] obtained higher values, 5.98-6.20 mg/L water samples of New Calabar. The values for this study are within acceptable limit of 5.0 mg/L and so, are acceptable for drinking.

Biochemical Oxygen Demand

BOD is the measure of oxygen in water that is required by aerobic organisms. The values of BOD recorded for this study range from 1.37 mg/L to 1.4 mg/L. [7] reported lower values that vary from 0.10-1.27 mg/L for groundwater resources from Industrial areas of Anambra. The values for this study fall within the permissible limit of 5 mg/L. Low BOD value is an indicator of good quality water, while high BOD value indicates polluted water [8].

Chemical Oxygen Demand

COD values for this study ranged from 2.40 mg/L to 2.80 mg/L It falls within the permissible limit and is similar to the findings of [34] who reported lower COD values in Ebubu Community, Eleme, Rivers State. [3] reported higher values that varied between 30-50 mg/L for water samples from Daranna Community. Latrines and septic tanks that have close proximity can leak into hand dug wells and increase COD level. High COD indicates the presence of greater amount of organic matter and this causes a reduction in the level of dissolved oxygen within the water.

Heavy Metals in Water Samples

The results obtained for metals in water samples collected from the different locations North Bank, Makurdi are presented in Table 2. The mean concentration of cadmium in this study ranges from the minimum value 0.02 mg/L at YGW to the maximum value of 0.05 mg/L at FHW with an average value of 0.035 mg/L. The concentrations of cadmium in all the water samples were above the WHO and NSDWQ permissible limit for drinking water. This could be as a result of rock weathering. [34] reported that excess cadmium can lead to health effects like cardiovascular diseases, cancer and hypertension.

Zinc content in the well samples ranged from 0.05 mg/L at HDW to 0.23 mg/L at ICW, with an average mean value of 0.145 mg/L which is less than the WHO and NSDWQ maximum permissible limit of 3.00 mg/L for drinking water. The presence of zinc is due to the use of pesticides and fertilizers around the hand dug wells. [1] obtained 0.01-4.5 mg/L for water samples collected from different locations within a mining site in Tsofo, Birnin-Gwari. Zinc concentration above the permissible limit can cause skin irritations, vomiting, nausea and anaemia.

The result of this study revealed that the samples at FHW had the lowest value (0.03 mg/L) of nickel, while HDW has the highest with 0.24 mg/L. [38] reported lower values that varied from 0.005-0.055 mg/L for water samples from

Dutsin-ma. All the samples have nickel level above the WHO and NSDWQ standard of 0.02 mg/L for drinking water. This could be as a result of leaching from plumbing pipes and fittings.
Copper recorded for this study ranged from 0.19 mg/L at ICW to 0.28 mg/L at FHW with an average mean of 0.24 mg/L. All the samples have Cu level below the WHO and NSDWQ standard for drinking water. Copper in small quantity is important to both plants and animals. However, excessive consumption of Cu causes health problems like anemia, liver and kidney damages, stomach and intestinal irritation [31].
Lead concentrations in this study ranged from 0.19 mg/L at YGW to 0.61 at HDW. These values are above the NSDWQ and WHO permissible level of 0.01 mg/L for drinking water. High concentrations of Pb observed especially at HDW could be as a result of proximity of mechanic workshops (Battery recycling) to the wells and the use of leaded petrol by vulcanizers and cars. It could also be as a result of proximity of these wells to dumpsite and footpath which are sources of metals.

Conclusion

This study has provided data on the level of physiochemical properties, heavy metal concentrations and pollution levels of wells within North bank, Makurdi. This study revealed that the wells, based on physiochemical properties are good, but Temperature and Total Hardness surpassed the WHO and NSDWQ permissible limit for drinking water.
Three heavy metals (Cd, Ni and Pb) are above the permissible level. The occurrence of these metals in quantities higher than the permissible limit, presents serious health risks to consumers, including neurological disorders, kidney damage and cancer, making the water unsafe for consumption.
Based on the findings of this study, relevant government agencies and non-governmental organisations should always educate the people on proper sanitation and the dangers of consuming contaminated water. Analysis like this should be carried out always to ascertain the quality of water consumed in this area.

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