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ASSESSMENT OF DRINKING WATER QUALITY IN RURAL NORTHERN NIGERIA: A CASE STUDY OF DIGGI VILLAGE IN KEBBI STATE

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Abstract

The United Nations Millennium Development Goals (MDGs) target, and recently, World Health Organizations' SDG goal, was to achieve access to safe and affordable drinking water for all. An important strategy to achieve these goals was to obtain up-to-date information of water sources and their quality, especially the rural areas. This study assesses and provides such information on the typical sources and quality of drinking water available in a northern Nigeria rural community, most of which still lack infrastructure for effective treatment and distribution. Water samples from three wells and two boreholes were collected, analysed in-situ and in the laboratory for quality – physico-chemical, heavy metals and bacteriological parameters using appropriate methods. The pH was within acceptable limit (5.64 – 7.77) except in the well located at Illela. Although the conductivity (12.6-435.0 µs/cm), TDS (7.45-261 mg/l), alkalinity (10.0-12 mg/l) and chloride (1.9-45.9) values were lower than the recommended WHO ranges, the values could affect acceptability of the water. The well in Kofar Yamma recorded high lead values (0.09 mg/l) as well as chromium (0.08 mg/l) and arsenic (0.06 mg/l). The five water sources have very poor microbiologic quality with records of E. coli in all the samples. Boiling, chlorination and better hygiene practice was recommended for the village community.

Keywords: MDG goals, SDG goals, Drinking water, Quality, Heavy metals.

Introduction

Water is a very vital natural resource to life. Humans can only survive for a few days without water. It is essentially needed in the body for normal physiological functions such as respiration, perspiration and digestion (Robayo-Amortegui et al., 2024). Potable water, or drinking water, defined with respect to its intended use, is one fit for consumption by humans and other animals (Tchobanoglous *et al*., 2003). The usual sources of drinking water for most villages in developing countries are usually nearby streams, rivers and hand dug wells which are mostly untreated and associated with various health risks (Iduseri et al., 2021). Most of these sources are usually untreated before consumption which predisposes such people to various water related diseases. Such water related diseases are usually pronounced and peculiar with the source of the water, its possible source of pollution, and the health status of the people of the community. Efforts in achieving safe and portable water for all made the United Nations (UN) to declare the 1980s as the International Drinking Water Supply and Sanitation Decade and compelled the World Health Organisation (WHO) to review the guideline for drinking water quality four times, the last of which was in 2011. The seventh goal of United Nations Millennium Development Goals (MDGs) target 7c was to "half, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation". To this, the world achieved a great success by the UN reports that "between 1990 and 2015, 2.6 billion people gained access to improved drinking water sources" (WHO/UNICEF, 2015). However, over 748 million people still lack access to improved drinking water, and about 1.8 billion people use a source of drinking water that is faecally contaminated (Bain *et al*., 2014).

The World Health Organisation, seeking to improve on the achievement of the MDG goal, developed a post-2015 MDGs strategy including Water Quality and Health Strategy from 2013 – 2020 (WHO, 2013). The United Nations, improving on the MDG goal 7c seek to achieve "by 2030, universal and equitable access to safe and affordable drinking water for all" in the Sustainable Development Goal (SDG) target 6.1. One of the key strategies to achieve these goals will be to obtain reliable and up-to-date information about sources of water and quality of water in various parts of the world, especially the rural areas where lack of portable water is more common. In 2015, the joint report by the World Health Organization and United Nations International Children's Emergency Fund (WHO/UNICEF, 2015) concluded that Nigeria was making 'limited or no progress' in the MDG goals especially on water and sanitation with about 25 percent of the population still practicing open defecation.

Paucity of infrastructure for effective treatment and distribution of water accounts for the incidence of high morbidity and mortality rate associated with water borne diseases in developing countries (Ganiyu et al., 2021) including Nigeria. One of the most important environmental problems in the present age is water contamination. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of waste disposal from humans and livestock, industrial discharges, over-use of limited water resources and inadequate treatment of these water sources. The need to assess the quality of water from some of these sources has become imperative because they have a direct effect on the health of individuals. This study seeks to assess the sources and quality of drinking water that are available in Diggi Village in Kebbi State, a typical northern Nigeria rural community.

Methodology

Kalgo Local Government was created in 1996 out of Bunza Local Government and has a population of 85,403 by 2006 census (National Population Commission [NPC], 2006) with a total land area of 1,173km^2. The headquarters is Kalgo Town, about 11 kilometers from Birnin Kebbi (the state capital) in Kebbi State, Nigeria. There are two major tribes in the local government namely Hausa/Fulani and Zabarmawa. The major occupations of the people of Kalgo local government are weaving, fishing and farming and the major crops cultivated are rice, millet and sorghum. Diggi, where the samples were taken is one of the important villages in the local Government Area (Figure 1) serving as a subregional administrative headquarters in the local government.

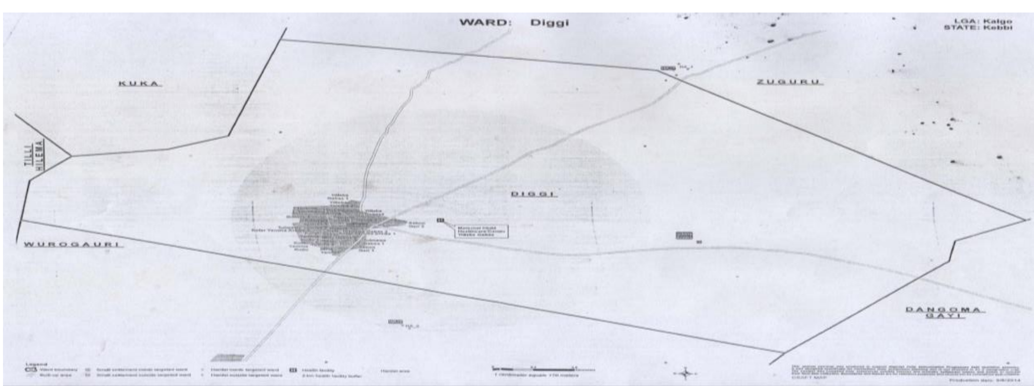

Figure 1: Map of Diggi village in Kalgo Local Government Area, Kebbi State, Nigeria

At each sampling location, composite surface water samples were collected and stored in clean polyethylene bottles that have been pre-washed with HNO_3 and thoroughly rinsed with deionised water. Samples for heavy metals analyses were acidified in-situ with 5ml HNO_3. Non-conservable parameters such as pH, temperature and electrical conductivity were determined in-situ. The pH of water sample was measured with a pH meter previously calibrated with buffer solutions. Conductivity was measured with a conductivity meter calibrated with potassium chloride solution. Temperature was measured with a thermometer. Alkalinity was determined by titrating a known volume of water sample with 0.02M HCl. Total dissolved solid (TDS) was determined gravimetrically by evaporating a known volume of water to dryness in a pre-weighed crucible on a steam bath. The total suspended solid (TSS) was determined by filtering a known volume of sample through a thoroughly dried filter paper and the residue weighed. Total hardness was determined by titrating with EDTA using Eriochrome black T as indicator and chloride analysis was done colorimetrically. Table 1 and Figure 2 shows the location of the sources of the water samples used in this study with their GPS coordinates.

Table 1: The water sources in Diggi village

Location of water source	GPS Coordinates	Water source	Legend
Sabon gari	N 12^0 21.209' E 004^0 01.712'	Well	W1
Illela	N 12^0 21.356' E 004^0 01.519'	Well	W2
Kofar Yamma	N 12^0 21.338' E 004^0 01.356'	Well	W3
Hillabe	N 12^0 21.339' E 004^0 01.697'	Borehole	B4
Kanwuri	N 12^0 21.450' E 004^0 01.442'	Borehole	B5

Figure 2: The five water sources in Diggi village

Bacteriological analysis

The microbial quality of the drinking water samples was assessed by making use of the multiple tube fermentation test (American Public Health Association (APHA), 2005). Total coliforms were estimated by using the 5-tube most probable number (MPN) method. MacConkey broth was used for the presumptive tests. Inoculated tubes of MacConkey broth were incubated at 44°C for 24 hours. Positive presumptive tests were confirmed using Eosin Methylene Blue agar. Colonies with characteristic growth were reinoculated into tubes of MacConkey broth. Growth characteristics in MacConkey broth as well as reactions to indole, methyl red, Voges Proskauer and citrate utilization tests were used as confirmation of presence of *E. coli.* The most probable number (MPN) of the coliforms in 100ml of the water samples was estimated by the positive tubes as directed in the MPN table (APHA, 1992).

Heavy metals analysis

Heavy metal was determined by digesting a known volume of water sample with analytical grade HNO_3. This was filtered into a 20ml standard flask, made up to mark with distilled-deionizer water and stored in a nitric acid pre-washed polyethylene bottle in the refrigerator prior to analysis. Atomic Absorption spectrophotometer was used for the analysis of the following heavy metals according to Cunningham and Lundie (1993); Lead (Pb), Mercury (Hg), Chromium (Cr), Iron (Fe), Arsenic (As). Each sample was analysed in triplicate and the mean result reported.

Results and Discussion

The physico-chemical parameters of the water sampled from the wells and boreholes are presented in Table 2. In all the water samples collected from the well, except in W3, the pH values (5.64 – 7.77) were within the WHO acceptable standards. Conductivity, total hardness and alkalinity values for all the five samples were below the provisional limit set by the WHO. These parameters are not considered to be of health concern but may affect the acceptability of drinking water. The TDS values were well below acceptable limit as high value (>500mg/l) could cause scaling of water pipes, water kettles, boilers and other household appliances (El-Naggar et al., 2015). The pH, temperature and chloride values obtained in this study were similar to those observed in Zaria, another northern Nigeria town, by Chigor *et al*. (2012) who reported pH (5.77 -7.32), temperature (15-33°C) and chloride (7.5–181 mg/l).

Table 2: Physico-Chemical properties of water samples

Parameters	**W1**	**W2**	**W3**	**B4**	**B5**	WHO*	NSDWQ**
pH	7.77	6.78	5.64	6.85	7.36	6.5 – 8.5	6.5-8.5
Temperature (˚C)	22.3	21.5	25.6	23.4	20.9		
Conductivity (µs/cm)	12.60	24.9	215	52.5	435	900–1200	1000
Total Dissolved Solids (mg/L)	7.45	149.2	129.3	31.1	261	600–1000	500
Total Suspended Solid (mg/L)	6.23	147.6	128.3	29.7	258.2	30	30
Turbidity (NTU)	5.3	3.2	2.6	3.7	4.8	5	5
Total Hardness ($CaCO_3$) mg/L	57.8	60.4	59.5	59.5	58.6	200	150
Chloride mg/l	1.9	5.8	23.4	29.9	45.9	250	
Alkalinity (as $CaCO_3$) mg/l	11	10	11.5	12	10.3	100	

* World Health Organisation (WHO, 2011)
** Nigerian Standard for Drinking Water Quality. Nigerian Industrial Standard (NSDWQ, 2007)
NTU = Nephelometric Turbidity Unit

Turbidity in water is caused by suspended particles or colloidal matter of organic or inorganic origin, which prevents light transmission through water. It can be noticed by the naked eye above 4.0 NTU and reduces the effectiveness of disinfection at this level. Disinfection process for drinking water is more effective when the turbidity value of the water is less than 1 NTU (Liu, 2005). Comparatively, the turbidity values in this study were below those found in drinking water by Chigor *et al*. (2012) and Adeoye *et al*. (2013) who reported turbidity values of 1.4–567 and 0.06 -9.00 NTU respectively. The TDS, Total hardness, Turbidity, Alkalinity and Chloride values

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reported in the water sources in this study were below those reported by Ezeribe *et al* (2012) in the well water samples in some villages in Northern Nigeria.

Table 3: Heavy metals analysis of water in Diggi village

Parameters	Unit	W1	W2	W3	B4	B5	W.H.O*	NSDWQ **
Iron (Fe)	mg/l	0.11	0.07	0.16	0.06	0.13		0.3
Lead (Pb)	mg/l	0.00	0.00	0.09	0.00	0.00	0.01	0.01
Chromium (Cr)	mg/l	0.16	0.02	0.08	0.03	0.05	0.05	0.05
Arsenic (As)	mg/l	0.00	0.00	0.06	0.00	0.00	0.01	0.01
Mercury (Hg)	mg/l	0.00	0.00	0.00	0.00	0.00	0.006	0.001

*WHO, 2011
**NSDWQ, 2007

The heavy metal concentration of the water samples collected from the boreholes and wells used for this study is shown in Table 3. Except for the well at Kofar Yamma (W3), where the concentration was 0.09 mg/l—above the regulation limit of 0.01 mg/l—lead was not found in any of the samples. The occurrence of lead in the well may have been because of its solubility at the higher acidity (5.64) of the well water, or it may have come from a local source of contamination, such as the disposal of lead-containing materials. It has no known nutritional, biochemical or physiological function and bioaccumulation in the tissues of the body are potential causes of nervous system disorders, anaemia and decreased haemoglobin synthesis, cardiovascular disease, blood enzyme changes, hyperactivity, and disorders in bone metabolism, renal function and reproduction (Sani and Amanabo, 2021). The well (W3) also contained elevated concentrations of Cr (0.08 mg/l) and As (0.06 mg/l). The water from the well in Sabon Gari (W1) contained elevated levels of chromium (0.16 mg/l) which was higher than the regulatory limit of 0.05 mg/l for drinking water. Chromium, arsenic and mercury have no know nutritional value; they are carcinogenic and bioaccumulate into toxic level to cause damage to essential human organs including the kidney and the central nervous systems (NSDWQ, 2007; Amadi *et al*., 2010).

Table 4: Bacteriological analysis of the water samples

Parameters	W1	W2	W3	B4	B5	W.H.O*	NSDWQ **
Coliform Count (cfu/ml/)	1.5 $x10^5$	0.35 $x10^5$	2.4 $x10^5$	0.92 $x10^5$	0.54 $x10^5$	0	10
E. coli (cfu/100ml)	1.2 $x10^5$	0.28 $x10^5$	1.5 $x10^5$	0.54 $x10^5$	0.57 $x10^5$	0	
TBC (cfu/100ml)	1.35 $x10^5$	0.26 $x10^5$	1.75 $x10^5$	0.76 $x10^5$	0.52 $x10^5$		

*WHO, 2011
**NSDWQ, 2007

According to drinking water quality guidelines, the bacteriological analysis of the five water samples (Table 4) revealed poor microbiological quality. The water sample from the well at Illela had the lowest coliform count, measuring 0.35 $x10^5$ cfu/ml, while the sample from the well at Kofar Yamma had the highest count at 2.4×10^5 cfu/ml. The total bacterial count ranged from 0.26×10^5 cfu/100ml to 1.75×10^5 cfu/100ml, with Illela showing the lowest bacterial load and Kofar Yamma the highest. This suggests that hygiene practices in the village may be inadequate, potentially due to the prevalence of open defecation or the proximity of boreholes to septic tanks. Additionally, surface runoff contamination or the use of contaminated tools for drawing water from the wells could have contributed to the high microbial loads. Although these values are lower than those reported by Adeoye et al. (2013) in Kwara State, the presence of microbial contamination indicates that the water is not safe for consumption. This contamination may explain the reported frequent occurrences of diarrhea and typhoid fever in the village. The detection of *E. coli* is particularly significant, as it indicates fecal contamination. Devane et al., (2020) similarly identified *E. coli* as a reliable indicator of fecal pollution in water. Furthermore, total coliforms should be absent immediately following water disinfection, and their presence in the samples suggests lack or inadequate treatment, as noted by Bai et al., (2022) and hence not suitable for drinking.

Conclusion

Access to water sources is not a challenge for people living in this community; however, the result of this study showed that the available water was not safe for drinking. It was observed that microbial contamination was more common than chemical contamination. Those at the greatest risk of waterborne disease are infants, young children, the elderly and people who are debilitated. For the WHO/UN SDG goals on safe drinking water to be achieved, contributory factors of sources of available of water, sanitation and hygiene practices of individuals and the community must be taken into consideration for many communities still lacking potable water supplies.

Recommendations

It was recommended that:

1. Community to practice better hygiene, chlorinate and boil the water from any of these sources before domestic use.
2. It was observed that microbial contamination was more common than chemical contamination. Those at the greatest risk of waterborne disease are infants, young children, the elderly and people who are debilitated

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