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Assessing Rural Water Quality: comparing improved and unimproved drinking water sources in Hawul LGA

Williams Kwari Joshua*
Faculty of Engineering and Technology, Federal University Wukari, P.M.B 1020 Wukari Taraba State, 660001 Nigeria
***Corresponding Author**: kwariwills@gmail.com

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Abstract

Rural water quality has been identified as an issue in most developing countries due to the large-scale agricultural activities and presence of industries. These in addition to poor or lack of water treatment facilities exposes rural water sources to contamination. This study analysed the suitability of water sources for drinking within rural settlements in Hawul LGA. Water sources from streams, open hand-dug wells, hand-pumped boreholes, and electrically operated boreholes were collected and analysed for physical, chemical, and bacteriological contaminants. Parameters were analysed using standard laboratory procedures. Water sources were grouped into improved (boreholes) and unimproved (stream and open wells) water sources and analysed using t-Test statistical method to infer if the mean of parameters were statistically greater than the NIS standard guidelines for drinking water. The results indicate that 39.50% of water from unimproved water sources failed to conform to the NIS standards and constitutes to the likelihood of health-related impacts especially water sources from the stream. Stream water sources with mean values 19TCU (colour), 24.70 NTU (turbidity), 92.60 mg L^{-1} (nitrate), 37.90 mg L^{-1} (magnesium), 0.30 mg L^{-1} (lead), 0.30 mg L^{-1} (manganese), 4.10 mg L^{-1} (potassium), 0.90 mg L^{-1} (phosphate), 186.70 mg L^{-1} (hardness), 4.70 cfu mL^{-1} (coliform count), and 1.70 cfu mL^{-1} (*E. coli*) are all significantly greater than the respective values stipulated by the NIS. However, only manganese and coliform count from hand-operated boreholes (Improved water sources) were found to exceed the stipulated standards. This indicates that only 5.30% of water from improved water sources failed to meet standards. More so, all water samples from electrically operated boreholes adhered to the NIS stipulated guidelines. The results shows that there is a low risk to health associated with water from improved water sources but there is a likelihood of health-related issues associated with water from unimproved sources due to the high values from chemical and bacteriological contaminants.

Keywords: rural water; improved sources; unimproved sources; water quality; drinking water

1. Introduction

Water, although often taken for granted is one of the most precious commodities. Water is considered fundamental to the survival of humans and the society [1, 2]. Without water, it is safe to say that there will be no life. In fact, every aspect of the ecosystem including agriculture and industrialisation depends solely on water resources to provide us with food and other commodity goods. Although 70% of the earth is covered by water, it has not always been available when and where it is needed, neither has it been of sufficient quality for human consumption [3]. Therefore, water is considered a fundamental human right and must be available and accessible in sufficient quality to everyone within a considerable distance of collection [4]. Rural dwellers especially in developing countries are often faced with either water availability, accessibility, or quality issues. In addition, because of their high intense agricultural practices, water resources in rural areas have been susceptible to pollution from pesticides, fertilizers, and other heavy metals [5, 6].

Water quality is one of the most important issues in water resource management alongside water accessibility and availability. Drinking water must therefore be free from contamination, impurities or components which may adversely affect human health [1]. Drinking water quality has been used as a powerful environmental health determinant [7] and therefore must be taken seriously at all levels in both rural and urban water sources and supplies. Water quality can be broadly classified into physical, chemical, and bacteriological quality, and each of these categories comprising of diverse parameters have of recent been influenced by both natural and anthropogenic activities [8, 9]. Water quality indicators have been developed to constantly assess and monitor water sources. water quality indicators or parameters are the physical, chemical, and bacteriological properties of water from diverse sources including surface and ground water sources. The process of assessing water quality indicators to monitor or determine the presence of contaminants will consist of the collection of water samples and assessing these parameters individually - often in the laboratory. However, recent measures such as in-situ and remote sensing techniques have been used to assess and monitor water quality effectively [10].

There have been sets of standards developed by several organisations against which, the quality of water from a given source, for a particular use is measured. Water does not often exist in a pure form but contains several constituents which may cause adverse impacts on human health. Therefore, regular monitoring of water quality is imperative to the protection of environmental health. In Nigeria for example, the Nigerian Industrial Standards (NIS), developed sets of permissible parameters that are acceptable in drinking water and other uses of water [11]. Any results that exceed the permissible standard is considered a health risk which can likely cause harm and hence require treatment before consumption. Water sources have been classified into improved and unimproved water sources [4]. Improved water sources are sources of water from controlled systems that can guarantee safety and free from impurities. These sources include piped water, protected well, boreholes and protected rainwater harvesting systems (Fig. 1). However, unprotected sources include river or stream water, open dug wells, tanker and water vendors, and uncontrolled/open rainwater storage (Fig. 1). Rural communities in developing countries often access water from unprotected sources as against urban cities that have access to protected sources [12, 13].

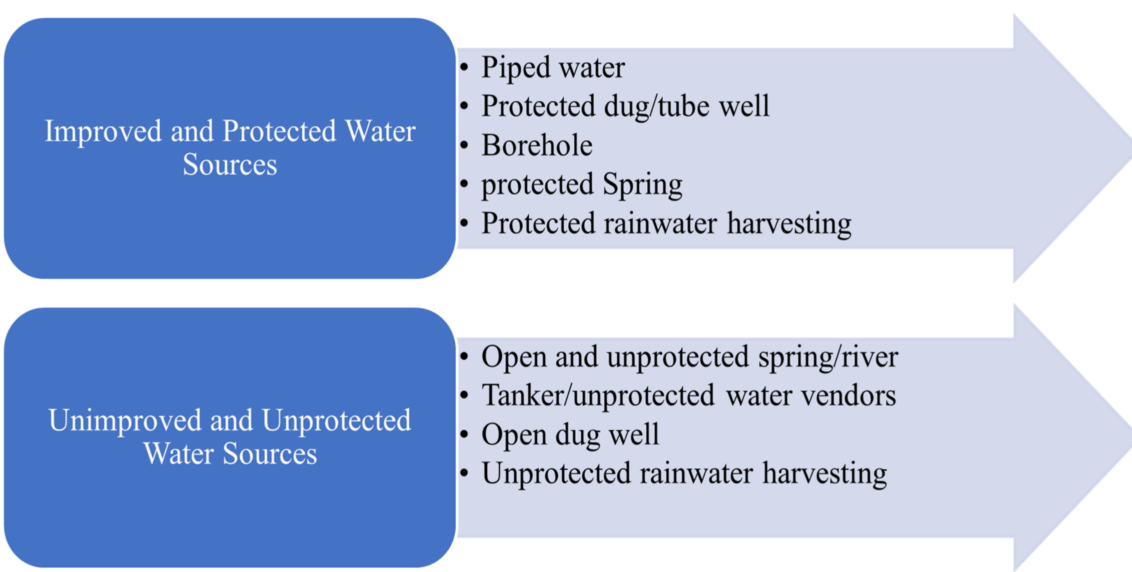

Fig. 1 Classification of improved and unimproved water sources

There has been limited information on the quality of water within Hawul LGA. In fact, from my findings on water quality within the study area, only one research focussed on groundwater quality within the rural areas. Study by Joshua [14] reveals that over 90% of well water samples collected had exceeded the WHO standards for drinking water. Parameters such as turbidity, potassium, nitrate, coliform count and E. coli, all had significant levels above the stipulated standards. Furthermore, rural environments in Hawul LGA and most developing countries have been saddled with deficiencies in water resource infrastructure or old and inefficient infrastructures. These coupled with lack of water quality testing, treatment and monitoring makes these areas prone to outbreaks of water-borne diseases [3, 6, 14]. In addition, ensuring safe, potable, and accessible rural drinking water sources in Nigeria has always been an issue especially with the ever-increasing population. Against this backdrop, this study evaluates the rural water quality within Hawul LGA by assessing improved (boreholes) and unimproved (open wells and streams) water sources. The results were analysed descriptively and compared to the Nigerian Industrial Standards (NIS) for drinking water in order to assess the suitability for domestic use.

2. Materials and Methods

Study Area

The study area covers rural settlements in Hawul Local Government Area (LGA) of Borno State, Nigeria. It is located along latitude 10°5'N and 11°40'N and longitude 12°00'E and 12°37'E. Hawul LGA shares boundaries with Biu LGA to the north, Askira LGA to the east, Gombi (Adamawa State) to the south and Shani and Kwaya kusar LGA to the west [15]. Hawul is dominated by basement complex rocks and falls within the tropical continental climate (Sudan climate). Hawul LGA settlements are mostly crop farmers with few animal farmers. Crops include maize, rice, beans, cocoyam, and tree crops. The mean annual rainfall ranges between 650 – 1,000 mm with an average mean temperature of 27 °C [16].

Sample collection

Water samples were collected from improved and unimproved water sources. A total of 33 sampling points were randomly identified as the most dominated water collection points within the settlement. These water collection points comprise of 6 electrically operated boreholes, 9 hand operated boreholes, 9 open wells and 9 points within the seasonal streams. Samples were collected in triplicates for a uniform distribution and statistical analysis. This gave a total of 99 samples collected across electric boreholes (18 samples), hand boreholes (27 samples), wells (27 samples) and streams (27 samples). Improved water sources include electrically operated boreholes and hand-pumped boreholes while unimproved sources include open hand-dug wells and seasonal streams within the study area. Samples were collected during wet season because seasonal streams often dry-up during the dry season. Water samples were collected in pre-treated 50 ml containers from water sources, pre-treatment was done by washing bottles with 0.05M HC1 and then rinsed with distilled water as specified by APHA, [17]. Before collection, sample bottles were rinsed 3 times with water samples before collection and stored under 4 °C in ice coolers before being transported to the laboratory for analysis. Parameters that could likely be affected by changes in temperature were analysed in-situ. These parameters include-temperature, pH, and electric conductivity (EC).

Field and Laboratory Analysis

Physical, chemical, and bacteriological parameters were analysed. Fast changing parameters like pH, temperature and EC were analysed in-situ. pH was measured using a pre-calibrated pH meter, temperature was measured using a mercury thermometer and EC was measured using a Horiba U90 meter with accuracy of 0.01 µs cm^{-1}. Turbidity was measured using a turbidimeter while colour was measured using the Hazen method. Other parameters like total dissolved solids (TDS), total hardness, sulphate, chloride, iron, lead, nitrate, fluoride, magnesium, Potassium, manganese, and phosphate were measured using standard laboratory procedures and flame absorption spectrophotometry as specified by APHA [1, 17].

Statistical Analysis

Results obtained were descriptively analysed and tabulated. A 1-sample t-Test using Mini-Tab version 18 was used to determine if the mean of each of the parameters is greater than the standard, allowable or permissible value (target) for drinking water as stipulated by the Nigerian Industrial Standards (NIS). The mean value that is considered statistically significant ($p>0.05$), suggests that the parameter is likely to constitute health risk.

3. Results and Discussion

Result Description

The results from the 1-sample t-Test for the samples reveals that some samples fall within the permissible limits stipulated by the Nigerian Industrial Standards (Table 2). However, parameters such as colour, turbidity, nitrate, magnesium, lead, manganese, potassium, phosphate, total hardness, coliform count, and *E. coli*, constituting 58% of the parameters that failed to conform to the NIS guidelines for drinking water (Table 2). In addition, unimproved water sources from open hand-dug wells shows that only turbidity, phosphate, coliform and *E. coli* constitutes 21% of the parameters that failed to conform to the stipulated standards. Improved water sources from hand-pumped boreholes shows that only 10.50% of the parameters failed to conform to NIS stipulated guidelines. Manganese and coliform count were the only parameters that did not conform to the standards. However, all the water samples from electrically operated boreholes conformed to the guidelines stipulated by the NIS for drinking water in Nigeria.

Table 1 Assessment of water samples based on conformity to NIS stipulated limits.

Sample Points	Stream water	Hand-dug well	Hand-pump borehole	Electric borehole
Colour	+	-	-	-
Turbidity	+	+	-	-
pH	-	-	-	-
EC	-	-	-	-
TDS	-	-	-	-
Chloride	-	-	-	-
Nitrate	+	-	-	-
Fluoride	-	-	-	-
Calcium	-	-	-	-
Sulphate	-	-	-	-
Magnesium	+	-	-	-
Lead	+	-	-	-
Iron	-	-	-	-
Manganese	+	-	+	-
Potassium	+	-	-	-
Phosphate	+	+	-	-
Total Hardness	+	-	-	-
Coliform count	+	+	+	-
E. coli	+	+	-	-

- *mean of parameters are NOT greater than NIS stipulated standard (in conformity to standard)*
+ *mean of parameters ARE greater than NIS stipulated standard (Fails to conform to standards)*

Public Health and Environmental Implication of contaminated water

The suitability of a water source often depends on its physical, chemical, and bacteriological quality. These indicators however can be influenced by natural and anthropogenic factors [2, 18]. Anthropogenic factors like waste management, agricultural activities, and industrialisation have severely impacted water quality [19] and led to water related diseases especially in rural settlements. The high rate of nitrate (92.60 mg L^{-1}), phosphorus (0.95 mg L^{-1}, 0.21 mg L^{-1}), and potassium (4.13 mg L^{-1}) from unimproved water sources indicates water contamination from agricultural activities within the region. Continuous consumption of water with high amount of nitrate exceeding 50 mg L^{-1} can cause cyanosis and asphyxia (blue baby syndrome) in infants under 3 months [11]. Phosphorus, potassium, and nitrate are considered as nutrient and can cause eutrophication of water bodies leading to competition over oxygen in water [14]. Lead in stream water samples (0.35 mg L^{-1}) was greater than the permissible limit of 0.01 mg L^{-1} and can likely interfere with vitamin D metabolism, impair mental development in infants, toxic to the central nervous systems and cause cancer [11].

Bacteriological impacts of water above the permissible limits can cause urinary tract infections, acute renal failure, haemolytic anaemia, diarrhea (main cause of morbidity and mortality in children), and typhoid [11, 20]. The results from unimproved water sources for *E. coli* (1.78 cfu mL^{-1}) indicates high risk to health-related issues. More so, rural areas are prone to open defecation and surface water contamination through animal faeces thereby increasing the likelihood to bacteriological contamination. This indicates the need to constantly test and monitor rural water sources especially unimproved sources within Hawul LGA communities. Open hand-dug wells need to be protected from contamination and river water sources must be protected from animals that can likely cause contamination. Open hand-dug wells must also be situated farther from latrines and animal ranches and dug at considerable depts to avoid groundwater contamination. In addition, water sources that conform to standards does not necessarily mean safe because contamination can still occur between collection and use [14]. The local water managers must ensure they create awareness amongst communities on measures to protect, collect and keep water safe.

Table 2 Mean and Standard Deviation values for physical, chemical, and bacteriological properties in comparison to NIS Standards

Parameters	Mean and Standard Deviation				
		Unimproved Water Sources		Improved Water Sources	
	NIS Standards	Stream Water	Hand-dug well	Hand borehole	Electric borehole
Colour (TCU)	15	19.00 ± 2.41	4.99 ± 0.96	3.77 ± 0.59	3.75 ± 0.30
pH	6.50 – 8.50	7.61 ± 0.13	7.60 ± 0.19	7.80 ± 0.34	7.70 ± 0.29
EC (µs cm^{-1})	1,000	9.37 ± 0.71	14.20 ± 5.06	10.96 ± 3.08	4.93 ± 0.09
Turbidity (NTU)	5	24.71 ± 5.94	10.35 ± 1.61	4.58 ± 0.81	3.07 ± 0.11
TDS (mg L^{-1})	500	330.10 ± 100.88	74.09 ± 24.39	32.87 ± 2.78	9.60 ± 2.13
Chloride (mg L^{-1})	250	19.34 ± 10.07	19.22 ± 10.75	16.84 ± 5.29	10.74 ± 1.29
Nitrate (mg L^{-1})	50	92.64 ± 6.05	51.96 ± 6.19	21.96 ± 7.18	9 ± 1.63
Fluoride (mg L^{-1})	1.5	1.34 ± 0.33	0.86 ± 0.11	0.62 ± 0.27	0.60 ± 0.09
Calcium (mg L^{-1})	75	73.66 ± 12.02	40.13 ± 8.60	39.74 ± 10.98	31.55 ± 3.43
Sulphate (mg L^{-1})	100	29.57 ± 2.65	23.15 ± 3.54	26.70 ± 5.29	21.62 ± 1.04
Magnesium (mg L^{-1})	30	37.95 ± 9.64	30.70 ± 1.55	22.55 ± 2.0	21.02 ± 1.66
Lead (mg L^{-1})	0.01	0.35 ± 0.42	0.01 ± 0.01	0.003 ± 0.01	0 ± 0
Iron (mg L^{-1})	0.30	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.03	0 ± 0
Manganese (mg L^{-1})	0.05	0.37 ± 0.31	0.18 ± 0.31	0.11 ± 0.07	0.07 ± 0.04
Potassium (mg L^{-1})	1	4.13 ± 2.15	1.02 ± 0.59	0.96 ± 0.12	0.27 ± 0.28
Phosphate (mg L^{-1})	0.05	0.96 ± 0.08	0.21 ± 0.22	0.01 ± 0.007	0 ± 0
Hardness (mg L^{-1})	150	186.70 ± 38.98	178.54 ± 67.42	100.68 ± 24.30	8.50 ± 15.45
Coliform (cfu mL^{-1})	0	4.78 ± 2.68	1.22 ± 0.83	0.44 ± 0.53	0 ± 0
E. coli (cfu mL^{-1})	0	1.78 ± 1.64	0.33 ± 0.50	0.11 ± 0.33	0 ± 0

4. Conclusion

Water quality has remained a major issue amongst rural communities in northern Nigeria and local water managers must ensure continuous monitoring of water sources to ensure adherence to guidelines and protect public health. Improved water sources are in limited supply within the study area despite the fact that these water sources are off better quality. Open hand-dug wells even though are unsafe, constitutes to the major source of drinking water within Hawul LGA, and hence needs to be disinfected, protected and monitored regularly. Other unimproved water sources such as rivers and streams should be protected, and communities should be made aware of simple measures to employ to keep water safe. Limitation to the study shows that additional water sampling points needs to be added which should include additional parameters including those of radiological origin. This will further provide detail information on the overall water quality of the study area. In addition, further research should focus on seasonal variation of water quality from both improved and unimproved water sources over considerable period of time. Apparently, there is limited information on both surface and groundwater quality within Hawul LGA and hence, the need to call for research to address the gap in knowledge across different water quality parameters.

5. Suggestion

The results from the study suggests that unimproved water sources in Hawul Local Government Area can likely result in public health concerns especially since there is no water treatment plant in the entire local government area. Therefore, the provision of improved and reliable water sources is key to protecting lives and promoting the sustainable development goal on access to improved, safe, and potable water and sanitation.

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