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Assessment of Bacteriological and Physicochemical Properties of Some Selected Sources of Drinking Water in Gashua, Nigeria

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Abstract

The study aimed at assessing the bacteriological and physicochemical properties of some selected sources of drinking water in Gashua, Nigeria. Water samples were collected from boreholes and hand pumps from three location using sterilized sample bottles. The bacteriological and physicochemical properties of the samples were analyzed using standard analytical methods described by APAH, EPA and Cheesbrough. The method used for enumeration of bacteria was multiple tube fermentation technique using MacConkey broth. After 24 hours, the tubes forming gas and acid were recorded and the corresponding MPN index was determined from the probability table. The positive tubes were streaked unto Nutrient agar plates, distinct colonies were picked and sub-cultured into Nutrient agar slant labeled appropriately. Pure isolates were Gram stained, isolates were further subjected to biochemical tests. Four bacteria species isolated from the boreholes and the hand pumps are *Escherichia coli*, *Staphylococcus aureus, Staphylococcus saprophyticu* and *Staphylococcus xylosus. Escherichia coli* and *Staphylococcus xylosus* were isolated from all the sources. *Escherichia coli* had the highest percentage of 17.07%, 14.65% and 7.32% in Sabon Gari borehole, Katuzu borehole and Low-Cost hand pump respectively while *Staphylococcus saprophyticus* was detected only in Katuzu hand pump with 2.44%. The physicochemical properties of the boreholes and hand pumps are within the recommended limits set by SON except the pH of both the boreholes and hand pumps found in Sabom Gari and Katuzu that was found below the recommended limits set by SON for drinking water.

Keywords

Bacteriological, Drinking Water Sources, Physicochemical Properties

1. Introduction

Potable drinking water is key for the survival and maintenance of all life processes. According to Priyanka *et al.* water is the principal need of all life on earth, and is an essential component for all forms of lives [1]. It is also require for maintenance of personal hygiene, food production and prevention of diseases [2]. Water of good drinking quality is of basic importance for human physiology and, man's continued existence depends very much on its availability. An average man of 35-63kg body weight requires about 3 liters of water in liquid and food daily to keep healthy [3]. Water is abundant in nature, yet most people lack adequate and safe drinking water due to increase in human population, coupled with human activities which lead to pollution of drinking water sources and failure from government to provide potable water to its citizens, more especially in developing countries [4]. The demand for safe drinking water in Nigeria cannot be overemphasized, considering the inability of government to provide adequate pipe borne water to its citizens. Moreover, treated pipe borne water may be contaminated due to poor maintenance of broken and leaking pipes, especially those close to gutter and drainages [5].

According to World Health Organization statistics, only 36% of Nigerians have access to potable water and 6% have access to improved sanitation [6]. An estimated 2.2 billion people all over the world lack access to potable water and close to 4.2 billion persons are not provided with adequate sanitation [7]. According to Solidarites International, 2.6 million people die every year due to water related diseases, 842000 people die every year from diarrhoea and 297000 children under the age of 5 die every year from diarrhea causing 50% cases of child undernutrition [7]. According to WHO, over 2 billion people live in countries experiencing high water stress and about 4 billion people experience severe water scarcity [8]. Stress levels will continue to increase as demand for water grows and the effects of climate change intensify. In Sub-Saharan Africa, three out of ten people do not have access to safe drinking water, almost half of people drinking water from unprotected sources [8]. According to the United Nations Medium Population Projection, over 2.8 billion people in 48 countries will be affected with water stress by 2025 [9].

Water is said to be potable when the physical, chemical and microbiological qualities conform to specified standard. Conformation with microbial standard set by World Health Organization and national agencies such as SON and NAFDAC will help in reducing the spread of water borne related diseases among the populace thereby increasing productivity and reducing maternal and child mortality. According to WHO, 80% of sicknesses and deaths among children in the world are caused by unsafe drinking water [10-11]. On the average, every 8s in the world, a child dies of contaminated water. The use of normal intestinal organisms as indicators of fecal pollution is universally accepted for monitoring and assessing the microbiological safety of water supplies [12]. Coliform bacteria are a group of intestinal bacteria used as indicators to determine if treated water is acceptable for human consumption. Coliforms will not likely cause illnesses. However, the presence of coliforms in drinking indicates the presence of disease-causing organisms [13]. The microbiological safety of drinking water remains a challenging problem in developing countries. The microbiological quality of drinking water is of serious concern to consumers and public health authorities. Certain microorganisms, including various bacteria, viruses, fungi and parasites, are well-known water contaminants, of which several may lead to waterborne disease and epidemics [14]. The bacteriological quality of drinking water is of paramount importance and monitoring must be given highest priority, this is so because studies have reveal several disease outbreak associated with untreated or poorly treated water containing bacteria pathogen that have been isolated from drinking water. The water contamination with fecal bacteria is a common and persistent problem that has a direct impact on the public health, and in economic and social aspects [15]. *Coliform* in water, though harmless to human health had been shown to portend the most probable presence of other pathogenic microorganisms like *Salmonella typhi*, *E. coli*, *Pseudomonas*, *Vibrio* species, *Shigella* species, *Aeromonas hydrophilia* among others [16].

The intake of unwholesome water could have devastating effects on our health as unsafe drinking water is a key determinant of many microbial diseases with serious complications in immune competent and immune compromised individuals. Water related diseases continue to be one of the major health problems globally [17]. Most chemicals arising in drinking water are of health concern. A few chemical contaminants have been shown to cause adverse health effects in humans as a consequence of prolonged exposure through drinking water. Some substances of health concern have effects on the acceptability of drinking-water that would normally lead to rejection of the water at concentrations significantly lower than those of health concern. Several research findings such as those of Egwari and Aboaba showed that water from several boreholes and wells in some urban centers in Nigeria were heavily contaminated with lead and toxic organic wastes [16].

This reliable supply of safe water is most often beyond the reach of people and they rely on these cheap boreholes and hand pumps as sources of drinking water. The boreholes and hand pumps in sub-Saharan Africa are seen associated with infiltration of dirty water from gutter and drainages while some are situated close to latrine and waste dumping sites. The majority of Nigeria depend on boreholes, wells and hand pumps for drinking water. According Lateef *et al*. and Getso *et al*. borehole water represents the major source of drinking water in Nigeria due to acute shortage of water supplies which resulted in rapid increase sinking of boreholes [18-19]. Moreover, Hati *et al*. reported that, the current available underground water sources especially in developing countries were becoming polluted due to; the increasing growth in human populations, industrialization, indiscriminate refuge dumpsites, and climatic changes [20]. Previous studies revealed that, the majority of water from the boreholes in Nigerian communities are unsafe for drinking due to high contamination level by microorganism placing communities at risk of water-borne diseases [20-22]. In view of the numerous problem associated with drinking water sources prompted the need to assess the bacteriological and physicochemical properties of some selected sources drinking water in Gashua, Nigeria.

2. Materials and Methods

2.1. Sample Collection

The water samples were collected from 3 locations. The samples were collected from boreholes and hand pumps. The samples were collected at random from each location for the period of two months. The samples were aseptically collected in sterilized 250ml sample bottles. Each sample collected were labeled accordingly before taking to the laboratory for analysis as described by [23-25].

2.2. Culture Media Preparation for Isolation of Bacteria

The recommended quantity of all culture media was weighed into conical flask and the appropriate quantity of distilled water was added to it according to manufacturer instruction. The suspension was boiled to completely dissolve the agar. Subsequently all the media were sterilized by autoclaving at 121°C at a pressure of 15 pound for 15 minutes. After sterilization, 15 ml of each medium were aseptically dispensed into sterile petri dishes and allowed to solidify. The petri dishes were labeled accordingly.

2.3. Method for Isolation of Bacteria

The method used for enumeration of bacteria was multiple tube fermentation technique as described by [24]. Presumptive test was done using MacConkey broth. Using 10ml sterile disposable syringe, 10ml of the sample was withdrawn and dispensed aseptically into five tubes containing 10ml of MacConkey broth double strength then 50 ml of the sample was dispensed into one tube containing 50ml of MacConkey broth double strength. Each bottle containing an inverted Durham tube accordingly. The test tubes were closed tightly and shaken to distribute the sample uniformly throughout the medium and to make sure the inverted Durham tube was full of broth and there was no air bubble trapped inside it. The test tubes were incubated at 37°C for 24 hours. After 24 hours the tubes from the presumptive fermentation test showing gas and acid formation were recorded and the corresponding Most Probably Number (MPN) index was determined from the Probability table. Those positive tubes were streaked unto Nutrient agar plates from which distinct colonies were picked and sub-cultured into Nutrient agar slant labeled appropriately and refrigerated for further assay.

2.4. Identification of Bacteria

Pure cultures of bacteria isolates were Gram stained to identify the bacteria type on the basis of cell shapes and Gram reaction. During Gram staining, a drop of distilled water was placed on clean microscopic slide, distinct colonies on the agar plates were picked using sterilized wire loop which was then smeared thinly on the slide. The smears were allowed to air dry and heat-fixed by passing the slide over Bunsen burner flame. The heat-fixed smear was then allowed to cool and was Gram stained. The smears were examined microscopically under microscope using oil immersion objective as described by [26]. The isolates were further subjected to various biochemical tests for identification described by [27].

2.5. Physicochemical Analytical Techniques

Physicochemical properties of the water samples were determined using analytical methods described by [23] and [25]. The temperature, pH, total dissolved solid and electrical conductivity of the water sample were determined using Hanna machine model HI 98129. A volume of 40 ml of each sample was poured into a beaker; the rod of the Hanna machine was inserted into the beaker containing the sample and the machine was turned on, the reading for each of the parameter was noted and recorded. The turbidity of the water samples was determined using D70 Jackson turbidity meter using 10 ml of deionised water, poured into a cuvette to standardized the machine and 10 ml of each sample was poured into cuvettes before inserted into the machine, reading was noted and recorded at 430nm. Dissolved oxygen of the water sample was measured using DO meter using 50ml of each water sample which was poured into 100cm^3 beaker before inserting the DO meter into the water sample, reading was taken after 3 to 5 minutes.

3. Results

The bacteriological parameters of the water samples collected from the boreholes and hand pumps were analyzed using standard analytical methods. The isolated bacteria species were subjected to biochemical test, the isolates utilized the substrates given different reaction (Table 1). Four bacteria species isolated from the boreholes and the hand pumps are *Escherichia coli*, *Staphylococcus aureus, Staphylococcus saprophyticu* and *Staphylococcus xylosus* (Table 2). *Escherichia coli* and *Staphylococcus xylosus* were isolated from all the water samples collected from the boreholes and the hand pumps in the three locations while *Staphylococcus aureus* was isolated from three sources while *Staphylococcus saprophyticus* was isolated from one water sources (Table 2). *Escherichia coli* had the highest percentage of 17.07%, 14.65% and 7.32% in Sabon Gari borehole, Katuzu borehole and Low-Cost hand pump respectively while *Staphylococcus saprophyticus* was detected only in Katuzu hand pump with 2.44% (Table 3).

Table 1. *Biochemical Characteristics of Bacteria Species Isolated.*

Biochemical Substrates	E coli	Bacteria species		
		S. aureus	S. saprohyticus	S. xylosus
Sucrose	-	+	+	+
Trehhalose	-	+	+	+
Mannitol	+	+	+	+
N-Acetyl Glucosamine	-	+	-	+
Mannose	-	+	+	+
Turanose	-	+	+	+
Glucosidase	-	+	+	+
Glucuronidase	-	+	+	+
Glucuronidase	-	+	-	+
Urease	-	+	+	+
Arginine	-	+	+	+
PYR Reagent	-	-	+	+
Catalase	+	+	+	+
Coagulase	+	+	-	+

+ =Positive,-=Negative, SGB=Sabon Gari Borehole, SGH=Sabon Gari Hand Pump, KTB=Katuzu Borehole, KTH=Katuzu Hand Pump, LCB=Low Cost Borehole, LCB=Low Cost Hand Pump.

Table 2. *Bacteria Species Isolated and their Distribution.*

Bacteria Species	Locations					
	SGB	**SGH**	**KTB**	**KTH**	**LCB**	**LCH**
Escherichia coli	√	√	√	√		√
Staphylococcus. aureus	√	√	√	-	-	-
Staphylococcus saprophyticus	-	-	-	√	-	-
Staphylococcus xylosus	√	√	√		√	√

√=Present,-=Absent, SGB=Sabon Gari Borehole, SGH=Sabon Gari Hand Pump, KTB=Katuzu Borehole, KTH=Katuzu Hand Pump, LCB=Low Cost Borehole, LCB=Low Cost Hand Pump.

Table 3. *Percentage of Bacteria Species Isolated from Boreholes and Hand Pumps Water.*

Bacteria Species	Locations					
	SGB	**SGH**	**KTB**	**KTH**	**LCB**	**LCH**
Escherichia coli	7 (17.07)	5 (12.19)	6 (14.63)	2 (4.88)	2 (4.88)	3 (7.32)
Staphylococcus. aureus	1 (2.44)	2 (4.88)	2 (4.88)	0 (0.00)	0 (0.00)	0 (0.00)
Staphylococcus saprophyticus	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.44)	0 (0.00)	0 (0.00)
Staphylococcus xylosus	3 (7.32)	1 (2.44)	1 (2.44)	2 (4.88)	1 (2.44)	2 (4.88)

SGB=Sabon Gari Borehole, SGH=Sabon Gari Hand Pump, KTB=Katuzu Borehole, KTH=Katuzu Hand Pump, LCB=Low Cost Borehole, LCB=Low Cost Hand Pump.

The physicochemical properties of the water samples were analyzed using standard analytical methods described by APHA and EPA. The physicochemical properties of boreholes and hand pumps are within the recommended limits set by SON except the pH of both the borehole and hand pump found in Sabom Gari and Katuzu that was found below the recommended limits set by SON for drinking (Tables 1 and 2). The temperature of Sabon Gari borehole ranged from 31.00-32.00°C with mean of 31.33°C while the hand pump ranged from 30.00-32.00°C with mean of 31.00°C. The turbidity of the borehole ranged from 0.53-1.00NTU with mean of 0.71 NTU while the hand pump ranged from 0.51-0.57 NTU with mean of 0.55 NTU. The electric conductivity of the borehole ranged from 539.00-670.00µs/cm with mean of 621µs/cm while the hand pump ranged from 533.00-677.00µs/cm with mean of 625.67µs/cm. The pH ranged from 6.16-6.50 with mean of 6.37 while the hand pump ranged from 6.10-6.55 with mean of 6.38. The dissolved oxygen of the borehole ranged from 2.00-2.20mg/l with mean of 2.10mg/l while the hand pump ranged from 2.00-2.20mg/l with the mean of 2.10mg/l. The total dissolved solid of the borehole ranged from 320.00-440.00 mg/l with mean of 366.67 mg/l while the hand pump ranged from 320.00-440.00 mg/l with the mean of 366.67 mg/l (Table 3).

Table 4. *Mean Values (±SE) of Physicochemical Parameters of Sources of Drinking Water in Sabon Gari.*

Parameters	Sabon Gari Sources of Drinking Water		SON Standard for Drinking Water (2007)
	Borehole	**Hand Pump**	
Temperature (°C)	31.33±0.47 (31.00-32.00)	31.00±0.81 (30.00-32,00)	Ambient
Turbidity	0.71±0.21 (0.53-1,00)	0.55±0.03 (0.51-0.57)	5 NTU
Electric Conductivity	621.00±58.35 (539.00-670.00)	625.67±65.65 (533.00-677.00)	1000 mg/L
pH	6.37±0.15 (6.16-6.50)	6.38±0.19 (6.10-6.55)	6.5-8.5
Dissolved Oxygen	2.10±0.08 (2.00-2.20)	2.10±0.08 (2.00-2.20)	4-5
Total Dissolved Solid	366.67±52.49 (320.00-440.00)	366.67±52.49 (320.00-440.00)	500 mg/L

* NA=Not Available, SON=Standard Organization of Nigeria Standard for Drinking Water, Range in parenthesis

The temperature of drinking water of Katuzu borehole ranged from 30.00-32.00°C with the mean of 31.00°C while the hand pump ranged from 30.00-31.00°C with the mean 30.33°C. The turbidity the borehole ranged from 0.56-0.57NTU with mean of 0.57 NTU while the hand pump ranged from 0.37-0.56 NTU with the mean of 0.49 NTU. The electric conductivity of the borehole ranged from 283.00-654.00µs/cm with mean of 414.30µs/cm while the hand pump ranged from 281.00-649.00µs/cm with the mean of 411.00µs/cm. The pH the borehole ranged from 5.91 6.58 with mean of 6.31 while the hand pump ranged from 5.87-6.58 with mean of 6.33. The dissolved oxygen of the borehole ranged from 2.00-2.80mg/l with mean of 2.27mg/l while the hand pump ranged from 2.10-2.20mg/l with the mean of 2.13mg/l. The total dissolved solid of the borehole ranged from 200.00-379.00mg/l with mean of 306.67 mg/l while the hand pump ranged from 345.00-450.00mg/l with the mean of 381.67 mg/l (Table 4).

Table 5. *Mean Values (±SE) of Physicochemical Parameters of Sources of Drinking Water in Katuzu.*

Parameters	Katuzu Sources of Drinking Water		SON Standard for Drinking Water (2007)
	Borehole	Hand Pump	
Temperature (°C)	31.00±0.82 (30.00-32.00)	30.33±0.47 (30.00-31.00)	Ambient
Turbidity	0.57±0.05 (0.56-0.57)	0.49±0.09 (0.37-0.56)	5 NTU
Electric Conductivity	414.30±169.73 (283.00-654.00)	411.00±168.53 (281.00-649.00)	1000 mg/L
pH	6.31±0.29 (5.91-6.58)	6.33±0.33 (5.87-6.58)	6.5-8.5
Dissolved Oxygen	2.27±0.38 (2.00-2.80)	2.13±0.05 (2.10-2.20)	4-5
Total Dissolved Solid	306.67±77.00 (200.00-379.00)	381.67±48.36 (345.00-450.00)	500 mg/L

* NA=Not Available, SON=Standard Organization of Nigeria Standard for Drinking Water, Range in parenthesis.

The temperature of drinking water for borehole in Low Cost ranged from 30.00-31.00°C with the mean 30.33°C while the hand pump ranged from 30.00-31.00°C with the mean of 30.33°C. The turbidity of the borehole ranged from 0.35-0.47NTU with mean of 0.42NTU while the hand pump ranged from 0.45-0.48NTU with mean of 0.46NTU. The electric conductivity of the borehole ranged from 207.00-651.00µs/cm with mean of 449.00µs/cm while the hand pump ranged from 206.00-700.00µs/cm with mean of 518.33µs/cm. The borehole pH ranged from 6.40-6.91 with mean of 6.67 while hand pump ranged from 6.57-6.58 with mean of 6.58. The dissolved oxygen of the borehole ranged from 2.00-3.00mg/l with mean of 2.37mg/l while the hand pump ranged from 2.00-2.80mg/l with the mean of 2.3mg/l. The total dissolved solid of the borehole ranged from 301.00-360.00mg/l with mean of 327mg/l while the hand pump ranged from 280.00-340.00mg/l with the mean of 320.00mg/l (Table 5).

Table 6. *Mean Values (±SE) of Physicochemical Parameters of Sources of Drinking Water in Low Cost.*

Parameters	Low Cost Sources of Drinking Water		SON Standard for Drinking Water (2007)
	Borehole	Hand Pump	
Temperature (°C)	30.33±0.47 (30.00-31.00)	30.33±0.47 (30.00-31.00)	Ambient
Turbidity	0.42±0.05 (0.35-0.47)	0.46±0.01 (0.45-0.48)	5 NTU
Electric Conductivity	449.00±183.46 (207.00-651.00)	518.33±221.83 (206.00-700.00)	1000 mg/L
pH	6.67±0.21 (6.40-6.91)	6.58±0.01 (6.57-6.58)	6.5-8.5
Dissolved Oxygen	2.37±0.45 (2.00-3.00)	2.30±0.36 (2.00-2.80)	4-5
Total Dissolved Solid	327.00±24.59 (301.00-360.00)	320.00±28.28 (280.00-340.00)	500 mg/L

* NA=Not Available, SON=Standard Organization of Nigeria Standard for Drinking Water, Range in parenthesis

4. Discussion

The study revealed high contamination of the boreholes and hand pumps with coliform bacteria. The presence of *Escherichia coli*, *Staphylococcus aureus, Staphylococcus saprophyticu* and *Staphylococcus xylosus* in the boreholes and hand pumps use as sources of drinking water varies. The variation in the percentage of bacteria among the boreholes and the hand pumps could be attributed to difference in location and level of hygiene around the boreholes and the hand pumps premises. This finding differed from the result obtained by Ajobiewe *et al*. who reported the presence of *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella species and Pseudomonas aeruginosa* isolated from boreholes, sachet water and well [28]. The variation could be adduced to differences in the sources of water and level of hygiene around the drinking water sources. The presence of these indicator organisms in drinking water sources may provide an indication of water-borne problems which have direct health implication that could be of threat to human health.

The high percentage of the bacteria observed in both the boreholes and hand pumps in all three location, the water sample obtained from Sabon Gari boreholes had the highest percentage of *Escherichia coli*. This finding is in agreement with the findings of Uzoigwe and Agwa [29]. The high percentage of this pathogenic bacteria in the water sources could be attributed to improper waste disposal around the premises of the drinking water sources, improper siting since some of the boreholes and hand pumps are found around gutter, latrine and waste dumping sites. The zero tolerance levels stipulated by regulatory agency for coliforms in drinking water, none of the drinking water sources meet the existing standards. The high prevalence *Escherichia coli* in the boreholes and hand pumps require public health attention. Based on the WHO standards, the boreholes and hand pumps water are unacceptable for human consumption due to high bacterial loads. According to WHO, all water intended for drinking whether treated or untreated must be free of *Escherichia coli* [30]. These microoganisms are known cause serious disease, such as urinary tract infections, bacteraemia, acute diarrhoea, abdominal cramps, nausea, vomiting and fever in infants, headache and meningitis [31].

The physicochemical properties of the boreholes and the hand pumps of all the three locations are within the recommended limits set by SON for drinking water except the pH of both the boreholes and hand pumps found in Sabon Gari and Katuzu were below the recommended limits set by SON for drinking. Similar observation was made by Ajobiewe *et al*. [28]. The temperature obtained is within the permissible limit by SON for drinking water. Though temperature does not have direct health impact, the temperature obtained in this study may favour the multiplication of microorganisms which could affect the affect the aesthetic quality, lead to the higher rate of chemical reactions in water, reduce solubility of gases and amplify the tastes and odour [32]. The turbidity is within the permissible limit set by SON. This finding is similar to the result obtained [33]. Turbidity is an indicator use to identifying contamination level and can provide space for the bacteria to adhered particle thereby provide them source of nutrient which aid their survival within the system. The electric conductivity, total dissolved solid and dissolve oxygen of both the boreholes and hand pumps are within the permissible limits set by SON [34]. Similar observation was made by [10]. The electric conductivity and total dissolved solid are of none health importance but could affect the aesthetical quality of the water and can serve as indicator of level of contaminate thereby having direct or indirectly influence on the acceptability water for drinking purpose [35]. The pH value obtained in this study could have health implication such as acidosis when consumed. This contradicts the result obtained by Sunday *et al*. [35]. The difference could be attributed to difference in sources and level of contamination by chemical substance which are hazardous in nature.

5. Conclusions

The study aimed at assessing the bacteriological and physicochemical properties of some selected drinking water sources in Gashua, Nigeria. The finding revealed that the water is contaminated by *Escherichia coli*, *Staphylococcus aureus, Staphylococcus saprophyticu* and *Staphylococcus xylosus* exceeding the World Health Organization standard of zero tolerance, the high percentage of bacteria in the selected drinking water sources have confirmed that the water is not fit for human consumption considering the fact that, they are capable of causing diverse disease to man. The physicochemical properties of the selected drinking water sources did not exceeded the limits recommended for drinking water quality by SON except the pH level that is slightly high which cause acidosis.

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