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Physicochemical and Bacteriological Assessment of Drinking Water Sources in Achusa Community Benue State, Nigeria

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Abstract:
This study was aimed at determining the physicochemical and bacteriological properties of hand dug wells and boreholes in Achusa community, Benue State, Nigeria. For this study a total of 16 water samples were collected from 4 Boreholes, 4 brands of sachet water commonly consumed within the locality, and 4 hand dug wells. The analyses for 13 physicochemical parameters were carried out in the laboratory using the PalinTest water test instructions manual on photometer method, 2014 while bacteriological assessment of the samples was carried out using the membrane filtration method and the results compared with World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ) guideline values. Results showed that Most of the physicochemical parameters were in compliance to the WHO/NSDWQ guideline values especially from the sachet water samples. However, some borehole samples were above the given standard value which included iron with mean values of 0.32mg/l, 0.35mg/l, and 0.41mg/l. Well samples with higher mean values included turbidity 6.0mg/l, 39.85mg/l, chloride 327.50mg/l and nitrite 2.07mg/l. Bacteriological properties of the sachet water samples were also in compliance with the compared standard values. Total viable counts above WHO/NSDWQ standard values were obtained from well samples with values of 128cfu/100ml and 131cfu/100ml. total coliform count in borehole samples included 12cfu/100ml and 15cfu/100ml while in well samples were both 20cfu/100ml. however it was interesting to note that a particular well sample had no TVC or TCC or E. coli count present. Bacteria isolates of pathogenic importance isolated in this study were E. coli, Faecal streptococcus, Salmonella species, Pseudomonas species, Bacillus species and Vibro cholerae. Based on these results the boreholes and sachet water sources were found to be better for drinking than the well water sources.

Keywords: borehole, guidelines, parameters, sachet water, standard wells.

INTRODUCTION

Studies have shown that over one billion people in the world lack access to safe drinking water and 2.5 billion people do not have access to adequate sanitation services (Tar *et al.*, 2009). Drinking water in developing countries especially in Nigeria in particular is susceptible to toxins as a result of effluents and pollutants (Dabi and Jidauna, 2010; Jidauna et al., 2013). Most communities in Nigeria are faced with the challenges of poor waste management system especially within the township. Indiscriminate waste disposal coupled with bad land practices are common scenes that can easily pollute water bodies and consequently degrading the water quality (Dabi and Jidauna, 2010).

Majority of the human population in semi-urban and urban areas in Nigeria are heavily reliant on well water as the main source of water supply for drinking and domestic use due to inadequate provision of potable pipe borne water. These ground water sources can easily be contaminated by faecal matter and thus increase the incidence and outbreaks of preventable water-borne diseases (Alonge et al., 2018). The Nyiman, communities in the South Region of Makurdi, Nigeria have a lot of wells and an increase of boreholes which provide drinking water to curb the acute water shortages experienced by the inhabitants, there are various improperly managed sanitation systems, including Ventilated Improved Pits (VIPs).

Water is an essential element for life but when polluted it may become undesirable and dangerous to human health (Aremu *et al.,* 2011). Poor water quality and Water pollution is a main global problem, a leading cause of diseases and deaths thus the need for evaluation and revision of water resources at all levels (Sibanda *et al*., 2014). The purity of water depends on its source, treatment received and storage facilities available (Ishaku *et al.,* 2010). Ground water serves as a source of water for many people; however, can be contaminated by biological and chemical pollutants arising from point and non-point sources (Venkateswara, 2010). Irrespective of sources, domestic water supply should be water of high quality, while water for other uses can be of moderate quality (Agrawal and Jageta, 2009).

Packaged water is any potable water that is manufactured or processed for sale which is sealed into food-grade bottles, sachet or other containers and intended for human consumption (Warburton, 2000). Sale of packaged water has exploded all over the world in recent years, largely as a result of public perception that it is safe, taste better and has a better quality compared to raw tap water (de França Doria et al., 2009; Fisher et al., 2015).

Packaged water has been implicated as a source of outbreak of cholera and typhoid fever as well as traveller's disease in countries such as Portugal and Spain (Bordalo and Machado, 2014). Several studies have shown that packaged water can be contaminated with bacteria at various stages of production (Semerjian 2011; Gangil et al., 2013). Under improper or prolonged storage of bottled water, bacteria can grow to levels that may be harmful to human health (Warburton, 2000). Accurate and timely information on the quality of water is necessary to shape a sound public policy and to implement the water quality improvement programme efficiently.

Previously no study has been done on the drinking water statue of Achusa community hence, it is interesting to carry out an analysis of the physicochemical and bacteriological quality of drinking water sources in Achusa community in Makurdi area of Benue State, this will reveal the quality and level of purification of their water sources and ascertain the extent of safety for drinking or if the water consumed poses threats to the health of consumers. This will serve as a forecast in tackling water borne diseases and creation of awareness to people living within the community.

MATERIALS AND METHODS

Description of the Study Area

According to Kogbe *et al*, (1998), Makurdi metropolis, the capital city of Benue State Nigeria is located within the Niger-Benue trough along the bank of the River Benue.

The town is located between latitude 7°30:7°431N and longitude 8°30:8°351E. The mean monthly temperature is between 22°C-38°C and the mean annual rainfall range is between 150mm-180mm. The town has a typical high tropical climate with two clearly marked out seasons: rainy season which is prolonged and starts from the month of April to early October and the dry season that begins in late October and ends in March. During the prolonged rainy season, most areas become swampy and wells become filled up due to the low water table of the town. The lack of pipe-borne water throughout 95% of the town, causes residents to resort to constructing hand dug wells or drilling boreholes. The people of Makurdi are predominantly civil servants and farmers. The most spoken languages are Tiv, Idoma, Igede and Etulo. (Eneji *et al* 2012).

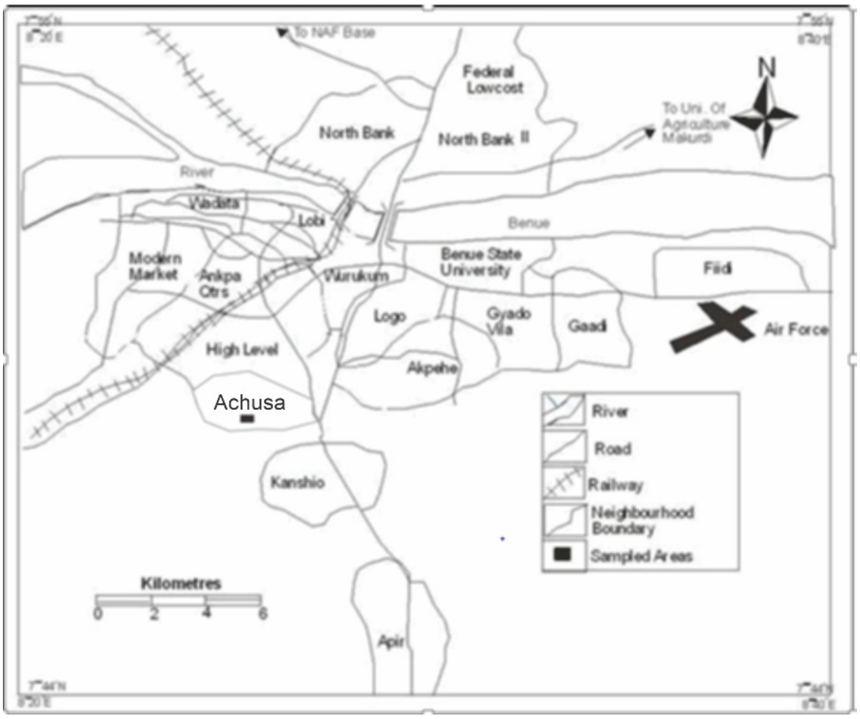

Figure 1: Map of Makurdi showing the sampled area.
Source: Ministry of Lands and Survey Makurdi, 2013

Water Sample Collection:
Sample collection was taken randomly from Nyiman. A total of 16 samples of water from 4 hand dug well and 4 boreholes. Samples were labelled B1, B2, B3, B4, S1, S2, S3, S4, W1, W2, W3, W4, (B for borehole and W for well water samples) for easy identification. Water samples were taken twice in a month from April to September 2019, three replicates were collected per source. Well water sample was collected directly from each well by means of a sterile plastic container fitted with a weight at the base; taking care to avoid contamination by surface scum. The outlet of each borehole was disinfected using cotton wool soaked in 70% (v/v) ethanol and was allowed to run for at least five minutes before taking the sample into a sterile plastic container. The water samples were transported to Benue State Rural Water and Sanitation Agency (BERWASA) laboratory in insulated containers with ice, samples were stored in a refrigerator at a temperature at $4^{o}C$, according to the method prescribed by American Public Health association (APHA, 2002) and analyzed within twenty-four hours of collection.

Methods
Physicochemical Analysis:
The water samples collected were analyzed for turbidity, electrical conductivity, pH, total dissolved solids (TDS), total hardness, chloride, nitrate, nitrite, sulphate, iron, copper, manganese and fluoride using the PalinTest water test instructions manual on photometer method, 2014. Turbidity levels of the water samples were determined using the Wagtech turbidity meter. The

pH of the water samples was determined using the Wagtech pH meter. Electrical Conductivity and Total Dissolved Solids were determined using the Wagtech Conductivity and TDS meter. While determination of Chloride, Nitrate, Nitrite, Total Hardness, Iron, Copper, Manganese and Fluoride concentrations were analyzed using the Wagtech photometer 7100 model.

Bacteriological Analysis:

The membrane filtration method of water analysis was employed. Membrane filters of 0.45µm pore size with diameter of 47mm were used in line with recommendations by APHA, 2002. 100mls each of water samples, from different locations, were filtered and the bacteria isolated and identified using the methods described by Cheesbrough (2006) and APHA (2002).

Isolation of Microorganisms:

Membrane filtration technique was used to isolate the microorganisms present in the water samples. The funnel of the membrane filtration unit has a capacity of 50ml and the funnel was mounted one receptacle fixed to the vacuum pump which allows the water to flow over the porous sterile membrane filter (0.45µm). Aseptically, the membrane filters were placed on each microbial growth medium using sterile forceps after passage of 100ml of water sample. The following media Membrane Lauryl Sulphate broth was used to isolate only total and thermotolerant coliforms, (Baired Parker broth, McConkey broth, Plate count broth, Potato dextrose broth and Pseudomonas broth base) were prepared and autoclaved at 121^{o}C for 15 minutes at 15Ib before being inoculated with membrane filters. (Buchanan and Gibbons, 1994)

The Method of Data Analysis:

GenStat 2014 was used to analyze the data. Data were represented as mean. Tables were used to present the results. Analysis of variance (ANOVA) was carried out using the statistical package for the social science (SPSS version 20.0) software.

RESULTS

Table 1: Mean concentration of values of physicochemical properties of borehole water samples

Parameters	B1	B2	B3	B4	WHO	NSDWQ
Turbidity (NTU)	0.15	0.18	0.15	0.13	5.00	5.00
Conductivity mg/l	219.50	230.00	191.00	218.00	500	500
TDS mg/l	117.00	123.00	127.00	136.00	500	1000
pH	7.77	6.68	7.30	7.40	8.5	8.5
Total hardness mg/l	42.50	47.50	45.00	64.00	150	150
Chloride mg/l	41.00	64.00	32.00	44.00	250	250
Iron mg/l	0.32	0,35	0.27	0.41	0.3	0.3
Nitrate mg/l	3.22	4.14	3.18	3.14	10	50
Nitrite mg/l	0.03	ND	0.05	0.03	0.2	0.2
Sulphate mg/l	1.00	22.00	7.00	20.00	500	100
Copper mg/l	0.16	0.11	0.02	0.12	1	1
Manganese mg/l	0.16	0.11	0.02	0.12	0.2	0.2
Fluoride mg/l	1.42	1.56	1.41	1.46	1.5	1.5

Table 2: Mean concentration of values of physicochemical properties of well water samples

Parameters	W1	W2	W3	W4	WHO	NSDWQ
Turbidity (NTU)	2.55	39.85	4.15	6.00	5	5
Conductivity mg/l	250.00	119.00	230.00	130.00	500	500
TDS mg/l	135.00	58.70	137.00	193.00	500	1000
pH	7.30	7.01	6.85	7.00	8.5	8.5
Total hardness mg/l	42.50	54.00	72.50	88.00	150	150
Chloride mg/l	327.50	200.00	155.00	261.00	250	250
Iron mg/l	0.08	0.05	0.06	0.04	0.3	0.3
Nitrate mg/l	2.57	2.80	4.02	3.10	10	50
Nitrite mg/l	0.03	2.07	0.05	0.08	0.2	0.2
Sulphate mg/l	18.50	15.50	11.00	31.00	500	500
Copper mg/l	0.16	0.14	0.14	0.18	1	1
Manganese mg/l	0.08	0.14	0.14	0.18	0.2	0.2

Table 3: Mean concentration of values of physicochemical properties of sachet water samples

Parameters	S1	S2	S3	S4	WHO	NSDWQ
Turbidity (NTU)	0.10	0.04	0.07	0.01	5	5
Conductivity mg/l	210.00	192.00	215.00	138.00	500	500
TDS mg/l	104.00	110.00	102.00	99.00	500	1000
pH	7.40	7.50	7.00	7.05	8.5	8.5
Total hardness mg/l	32.00	44.00	47.00	38.00	150	150
Chloride mg/l	48.50	102.00	57.00	62.00	250	250
Iron mg/l	0.05	0.13	0.12	0.19	0.3	0.3
Nitrate mg/l	3.01	3.26	3.41	3.06	10	50
Nitrite mg/l	0.04	ND	0.02	0.03	0.2	0.2
Sulphate mg/l	9.50	1.00	ND	2.00	500	100
Copper mg/l	0.02	0.13	0.05	0.04	1	1
Manganese mg/l	0.02	0.13	0.05	0.04	0.2	0.2
Fluoride mg/l	1.21	1.32	1.10	0.88	1.5	1.5

Table4: Bacteriological properties of borehole, sachet and well water samples

Sample Water	Total viable count cfu/100ml	Total coliform count cfu/100ml	Faecal coliform or *E. coli* count cfu/100ml
B1	8	6	3
B2	50	15	4
B3	55	12	6
B4	40	10	2
S1	8	4	2
S2	6	2	2
S3	9	0	0
S4	1	0	0
W1	0	0	0
W2	128	20	4
W3	131	12	8
W4	80	20	6
NSDWQ	100	10	0
WHO	100	10	0

Table 5: Bacterial isolates from drinking water sources (borehole, sachet and well)

Water samples	*E. coli*	*Faecal streptococcus*	*Salmonella spp*	*Pseudomonas spp*	*Bacillus spp*	*Vibro cholera*
B1	+	+	+	-	+	-
B2	+	+	-	+	+	-
B3	+	+	-	-	+	+
B4	-	+	-	+	-	-
S1	-	-	-	-	-	-
S2	-	-	-	-	-	-
S3	-	-	-	-	-	-
S4	-	-	-	-	-	-
W1	+	-	-	-	-	-
W2	+	+	+	-	+	-
W3	+	+	+	+	-	-
W4	+	-	-	-	-	+

+ Present, - Absent

DISCUSSION

The importance of good and safe drinking water cannot be overemphasized as regard to the health of the population. Turbidity defines the presence of suspended solids in water and causes the muddy or turbid appearance of water body (Tiwari *et al.*, 2015). In this study, Turbidity values of boreholes and sachet water samples had mean concentration values below 5 NTU. However, high turbidity values were recorded in well samples with values of 6.0NTU and 39.85 NTU which were far above the WHO/NSDWQ guideline limit on turbidity. High turbidity values is an indication of high presence of inorganic particulate matter and non-soluble metal oxides which are usually responsible for high turbidity values. High turbidity values in well water were also reported in similar findings in Makurdi, Benue state by Akaahan *et al.* (2016), Taraba state by Odoh *et al.* (2018) and Zangu, Kaduna state by Ali *et al.* (2012). The authors recorded turbidity values ranging as high as 5.70 NTU-49.0 NTU in well water samples. Due to the unlined structure of the wells, Soil particles may find their way into the water sources either through runoff or from the unstable side walls thereby increasing turbidity of the water sources.

The conductivity and Total Dissolved Solids (TDS) and total hardness values across the water sources studied were within the maximum permissible values of WHO/NSDWQ guidelines. These results are also similar when compared to the findings of Adenkunle *et al.* (2007), Apkoveta *et al*, 2011 and Malek *et al*, (2019) who observed low conductivity and TDS values in drinking water sources. pH is a term used universally to express the intensity of the acid or alkaline condition of a solution. The pH of samples of bore holes, sachet water and well samples had normal pH values however, this contradicts the works of Yusuf *et al.* (2015) in their studies on well water samples in Zaria, Kaduna State, documented a high alkalinity of the studied water samples. Adefemi *et al.* (2007) reported that high alkalinity in water is due to certain human activities near water sources. The concentrations of Iron and manganese were within the maximum permissible limit of WHO/NSDQW guideline value which implied that iron and manganese did not contribute to the pollution of the water sources. this result agrees with the findings of Adekola *et al*, (2015) and Odoh *et al*, (2018) who reported minimal concentrations of iron and manganese in well and borehole samples in Benue and Taraba states, Nigeria respectively.

Copper contaminated water is responsible for health hazards such as abdominal pains, nausea, vomiting, diarrhea, headache, and dizziness (Okeola *et al.*, 2010). Moreover, high copper concentration in water influences the rapid deterioration of aluminum utensils and galvanized steel fittings. The mean concentration values of copper recorded in this study were low and below 1.0 mg/l which is the maximum permissible limit Low concentration values of copper were also observed from the findings of Apkoveta *et al*, (2015) in Edo state and Odoh *et al*, (2018) in Benue State.

Mean values of nitrate obtained in all the water samples were within the acceptable values of WHO/NSDWQ guideline limit of 10 mg/l and 50 mg/l. this implies that there was no significant indication of the water being polluted by nitrate however, Nitrite's concentration in the well sample contributes significantly to the pollution status of the well water. Nitrite in drinking water is an important risk factor, for bottle-fed infants (under three months) given increases in asphyxia (blue baby syndrome) and possible cyanosis (Tiwari *et al.,* 2015). These results are similar to the findings of Malek *et al,* (2019) who reported absence of water pollution by nitrate compound in well water samples from Sedrata, Algeria. Odoh *et al,* (2018) also reported similar result in well water samples from Oturkpo, Nigeria.

Fluoride concentration in the sample location were within the permissible limit of WHO and NSDWQ. Similar reports were observed by Sadrina *et al.* (2013) in Legoon valley, Cameroan; Shigut *et al.* (2017) in Robe town, Ethiopia and Adekola *et al*. (2015) in Taraba state Nigeria. High concentration of fluoride contaminant in ground water tends to be found in association with crystalline rocks containing fluorine rich minerals especially granite and volcanic rocks. Fluoride has long been found to have beneficial effect on dental health as such it is an additive in toothpastes and food. However, when present in drinking water at concentration much above the guideline value of 1.5mg/l, long term use can result in development of dental fluorosis or at its worst, crippling skeletal fluorosis (Nishtha *et al.,* 2012). It is important for water managers to constantly monitor this parameter as other studies within the North central region have also revealed high incidence of water samples showing high fluoride concentrations.

It is interesting to note that a particular well sample had no record for total viable counts (TVC) or total coliform count (TCC} or presence of *E. coli.* This also implies that well water sources if properly handled can as well be safe for drinking and other domestic purposes. The TVC of microbes in the borehole and sachet samples were within the maximum permissible limit of NSDWQ guidelines whereas for well samples. Total coliform count (TCC) across the samples in this study had the presence of coliform count highest in well and borehole samples. Sachet samples had no coliform count. Presence of coliform in the well and borehole sample indicates the presence of contaminants in the water. Presence of *E. coli* were observed highest in the well and boreholes and a few sachet water samples, this indicates the extent of faecal contamination in the water sources. This result varies from the findings of Ali *et al.* (2012) who observed TCC and *E. coli* counts within the maximum permissible limit set by NSDWQ. Also, their findings indicated low level of faecal contamination in well water in Zangu Kaduna State.

The number of both total and faecal coliform bacterial were found to be similar to that found by Yusuf *et al.* (2015), Magami *et al.* (2013), Casanova *et al.* (2001) among other researchers. Adeboyega *et al.* (2015) documented those proper excreta disposal and improvement in general hygiene would enhance the quality of *E. coli* infested wells and borehole water sources and reduce possible infection by the indicator bacteria.

Virtually all the samples of sachet water analyzed in this study exhibited values of physicochemical and mean coliform and *E. coli* counts per 100 ml below the WHO/NSDWQ, maximum permissible levels except for sachet samples S1 and S2 in Achusa sample location. This may be attributed to the level of treatment of water sources before packaging for sale. It could be attributed to the total adherence to strict quality assurance procedures in the production premises of the companies concerned.

Contamination may however come from handling from person to person or where the sachet water was kept. The results of the physicochemical and bacteriological assessment of the collected sachet water samples agrees with earlier works done in Zaria (Yusuf *et al.* 2015), Abuja (Atiku *et al.*, 2017) and Ota (Chinedu *et al*., 2011). It is noteworthy, however, that some assessment of sachet water brands vended in Kebbi, Kalpana *et al.* (2011), Ogbomoso, Oladipo *et al.* (2009) have physicochemical values of concern and evidence of faecal coliforms. These varying reports highlights the need for ongoing implementation of the several legislations put in place by National Agency for Drug Administration and Control (NAFDAC) in Nigeria, and continuous monitoring to increase reduction in the sales of contaminated brands of sachet water and this may be the reflection of what we have observed in this study.

Bacteria isolates of pathogenic importance isolated in this study were *E. coli*, *Faecal streptococcus*, *Salmonella* species, *Pseudomonas* species, *Bacillus* species and *Vibro cholerae*. These microbes have been reported to be associated with various water borne diseases and their control depends on being able to assess the risks from any water source and to apply suitable treatment to eliminate the identified risks. Similarly, these microbial isolates were observed in studies in Cameroon (Tamungang *et al.*, 2016), Abeokuta (Shittu *et al.*, 2008), Algeria (Malek *et al.*, 2019), and Abuja (Atiku *et al.*, 2017) in their studies on bacteriological assessment on drinking water sources.

CONCLUSION

In this study, water samples from borehole, sachet and well of Achusa communities in Makurdi, Benue State, Nigeria were analyzed for physicochemical and bacteriological properties of the water sources to predict the drinking water quality status. Most of the results of the physicochemical parameters were within the maximum permissible limits of WHO/NSDWQ drinking water guidelines. However, physicochemical parameters that were above the maximum permissible limits of WHO/NSDWQ drinking water guidelines includes turbidity, chloride, nitrite, iron and fluoride which also implied that the parameters individually contributed to the pollution status of the water sources.

Bacteriological properties of the water sources also showed that Total Coliform Count (TCC) and *E. coli* counts were above maximum permissible limits of NSDWQ in boreholes and well samples indicating higher level of faecal contamination in the drinking water sources. Minimal contamination was observed in the sachet samples. Bacterial isolated from the water samples in order of their presence includes, *E. coli*, *Faecal streptococcus*, *Salmonella* species, *Pseudomonas* species, *Bacillus* species and *Vibrio cholerae* with the least presence Based on these results, it can be deduced that most sachet water and borehole water samples were more suitable for drinking than some well water sources.

Based on the findings in this study the following recommendations are suggested
(a) Drinking water quality routine should be done on a regular basis across communities. (b} Health education: this is to explain the importance of clean water and the relationship which exists between water, health, hygiene and sanitation. (c) Wells and bore holes should be properly located and constructed to avoid contamination of drinking water. {d) NAFDAC and other agencies should be monitoring the quality of water sold in packaged forms in order to ensure satisfactory quality. {e) Water sources for private use should be disinfected either by boiling to eliminate any trace of faecal contamination before drinking.

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