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Original Article

Comparative analysis of water quality from different sources in Masaka, Nasarawa State, Nigeria

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ABSTRACT

This study identified, assessed, and compared water quality from various sources in Masaka, Nasarawa state. Water samples were collected from five different sources (two streams, two sachet water [for both content and the body of the nylon], four boreholes, and four wells), making a total of 14 samples which were analyzed for physiochemical and biological properties. The samples were collected from the identified sources using thoroughly washed 75 cl plastic bottles and well labeled and taken to the laboratory for analysis on the same day. Standard equipment and procedures were adopted as prescribed by APHA (2005). Parameters such as pH, temperature, color, turbidity, conductivity, alkalinity, total hardness, iron, chloride, nitrate, calcium, magnesium, phosphate, and total coliform were analyzed. The result was presented in tables and charts. Some inferential statistics were performed to compare the differences in the concentration. The results for turbidity showed that turbidity was on the high side ranging from 13 NTU and 54 NTU, conductivity levels are also high in all water sources. Furthermore, the bacteriological property of the water samples appeared to be high and above the acceptable limit of the WHO. The hypotheses were tested using ANOVA and t-test, respectively. The results showed that there is a significant difference in the quality of water between concrete well water with cover and concrete well water without cover. Results also show that there is no significant variation between the four sources of water and the WHO standards. It is then recommended that public enlightenment should be carried out, NAFDAC to regularly monitor sachet water companies and that the best way to use wells is to cover them.

Keywords: Boreholes, comparative, river, sachet water, water quality, wells

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INTRODUCTION

Water is one of the most vital natural resources necessary for the existence of life. In most urban cities in most countries of the world, including Nigeria, it is the duty of the government to provide potable water. Most often, the responsibility is not adequately discharged, causing the inhabitants of those cities to look elsewhere to meet their water needs. These alternatives include sourcing for groundwater through borehole or well, and stream or river water.

Water is an essential element for the survival of all living organisms. In humans, it is shown to make up about 70% of the body mass.[1] Many infectious diseases in developing countries are associated with contaminated water.[2] Thus, good drinking water is a luxury but one of the most essential requirements of life.[3] Studies have shown that over 1 billion people in the world lack access to safe drinking water and 2.5 billion people do not have access to adequate sanitation services.[2] In many developing countries including Nigeria, clean pipe borne water availability is limited and inadequate for the teeming population. Thus, an increasing number of people in semi-urban areas in the country depend on hand-dug wells, boreholes, and water vendors for water supply.[4] Globally, 1.1 billion people rely on unsafe drinking water sources either or from lakes, rivers, and open wells among others. Majority of these people are in Asia and sub-Saharan Africa. Safe drinking water with pleasant taste and suitable for domestic purposes must not contain any chemical or biological impurity.[5] Groundwater has been described as the main source of potable water supply for domestic, industrial, and agricultural uses in Nigeria.[6,7] However, pollution of groundwater has gradually been on the increase, especially in our cities with lots of industrial activities, population growth,

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poor sanitation, land use for commercial agriculture, and other factors responsible for environmental degradation.[8] The concentration of contaminants in the groundwater depends on the level and type of elements introduced to it naturally or by human activities.

In developing countries, thousands of children under-5 years die every day due to drinking contaminated water.[9] The assessment of water quality has become an important part of water resource studies, planning, and management. It is gaining significant importance due to intense urbanization, industrialization, and agricultural activities that are increasing the risk of contamination of soil and water. Water quality monitoring is important for the protection of public health (drinking or domestic use), agriculture, industry, recreation, tourism, and protection of aquatic ecosystems.

Due to the unplanned nature of the study area Masaka, there is scarcity of water which has forced the inhabitants to rely on alternate sources of water to meet their daily needs. Masaka's water table is high, this is evident in the study area as most of the wells are shallow, streams and rivers are seen around the study area. These water sources are easily polluted and this pollution is common to low income, peri-urban settlements in developing countries, and Masaka in particular. As seen in the study area, most inhabitants of Masaka use water from rivers, streams, and wells for majority of their domestic needs, however, water gotten from community taps, boreholes and water factories are kept for cooking and drinking.

A study by Ujor and Al-Hassan,[10] on the assessment of groundwater quality for drinking from hand-dug wells in Masaka, revealed that geologically, the depth of strata was between 4 m and 8 m, which is dominated by sandstone, shale, and mica and is highly porous and permeable, their distances are very close to the surface and close to sources of pollution. The knowledge of the water quality status as well as the processes affecting water quality is vital. It is against this is background that this study attempts to compare the quality of water in Masaka from different sources and with international standards, with the view to identify the safest water source(s) for the study area.

METHODOLOGY

Masaka is located in Karu local government area of Nasarawa state. It lies on latitude 7°40'30"E and 7°42'0"E and longitude 9°0'0" N and 9°1'30"N [Figure 1]. It is bounded to the north by Jankawa and Luvu villages, to the south by Tudun Wada, to the east by Kuchikau and to the west by Nyanya Gwandara along the Keffi-Abuja Express Way.[10]

Karu is well endowed with enormous water resources, both surface and underground water and is drained by many rivers who take their sources from north central plateau. In the dry season, the volume of water is greatly reduced, whereas flash flood is experienced for most rivers in the rainy season. The rivers transport a lot of materials in suspension which affect color and turbidity of the water.[11]

The spatial pattern of rainfall in the study area is slightly influenced by the north central highlands with a mean annual rainfall between 1100 mm and about 2000 mm. The vegetation is typically of Guinea Savannah characterized by a transition between forest and grassland with typical transition woodland and tall grasses along the river channels or courses.[12,13]

Types and Sources of Data

The data requirements for the study were basically field based and comprised water samples from streams, wells, boreholes, and packaged (sachet) water available in the study area. Published works form journals and publications were also used. The World Health Organization (WHO) water quality standard was used to compare the results of the sampled parameters.

Sample Size and Sampling Techniques

The study identifies the following sources of water in the study area which includes nine boreholes, four streams, two packaged water factories, and a good number of wells. The wells were selected using different criteria which include open concrete wells, close concrete wells, open non-concrete wells, and close non-concrete wells [Appendix I]. Four bore holes were randomly selected, and two streams that are used by the people were also selected and the two sachet water companies were also used for this study. Figure 2 presents the sampling points.

Water Sample Collection

The water was sampled in 75 cl plastic bottles thoroughly rinsed with the water from each source before collecting the water. Two sets of sachet water brands each from the two production companies were purchased from the hawkers, neatly wrapped, and placed in different containers, making a total of 14 water samples for the study area. All the water samples were transported immediately within 4 h to the Regional Water Quality Control office Minna, Niger state for immediate physiochemical and microbial analyses. A calibrated conductivity meter was employed for the determination of the conductivity of the water samples. Other chemical analyses of the samples were done using methods specified in APHA.[14] Bacteriological examination of the samples was conducted by multiple tube fermentation tests described in APHA.[14,15]

Method of Data Analysis

The study applies descriptive statistical techniques for the analyses such as mean and standard deviation was performed. Some inferential analysis such as ANOVA and *t*-test were also computed to verify if there is significant difference in the water quality from different sources and the international set standards.

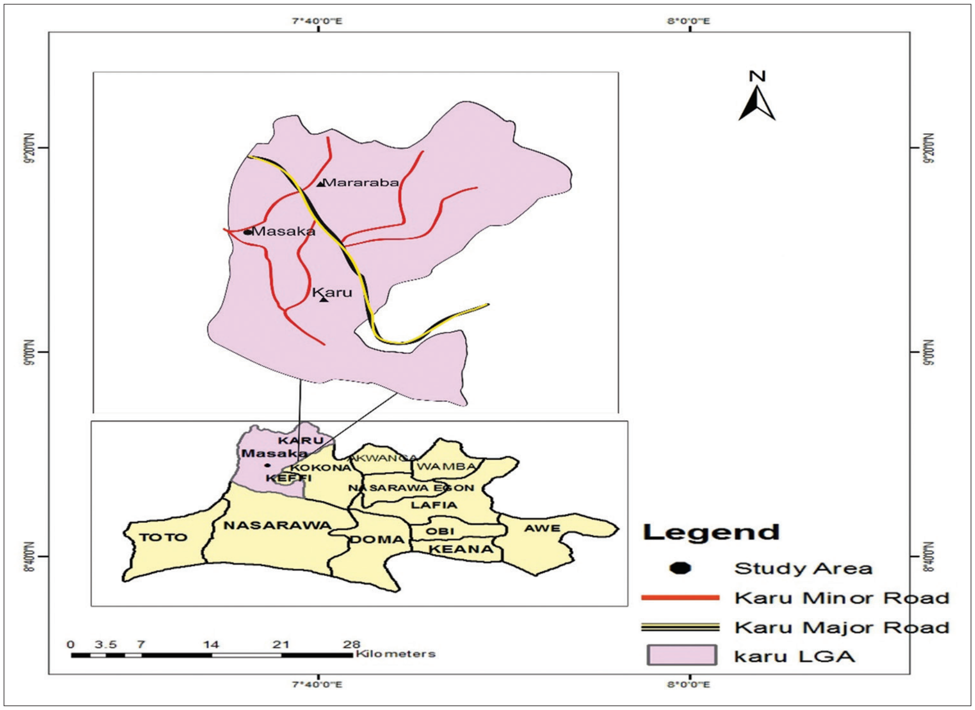

Figure 1: Map of Nasarawa showing the study area. Source: Adopted from NAGIS, 2019

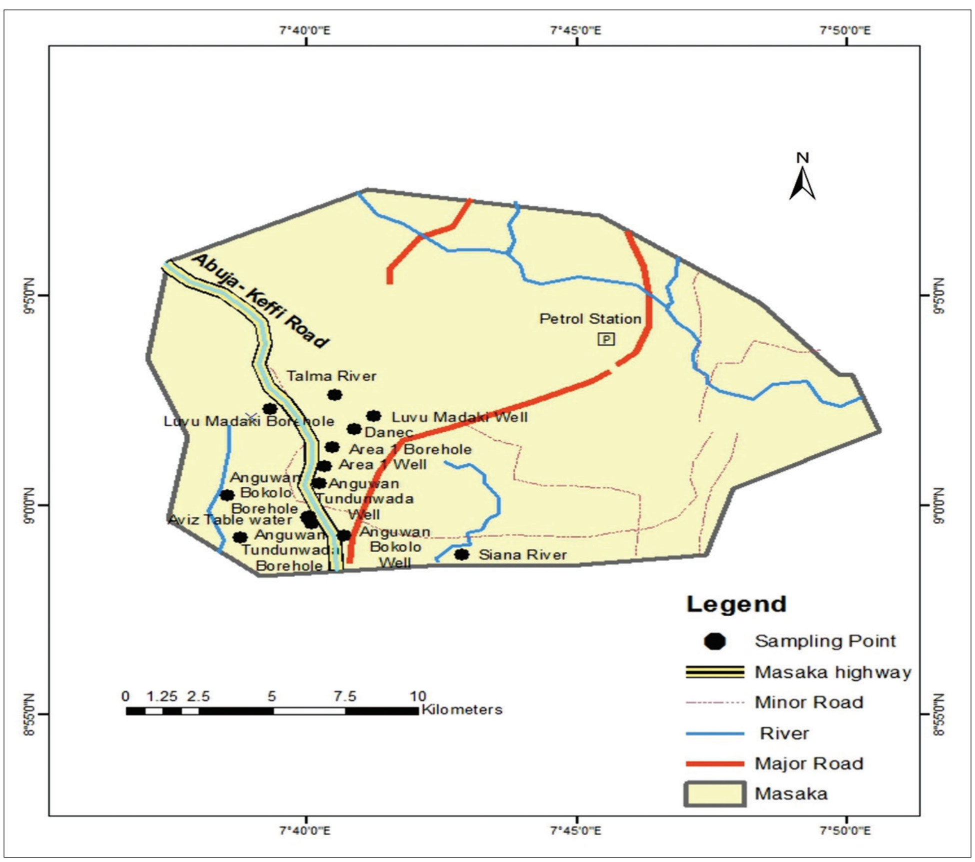

Figure 2: Map of Masaka showing the sampling points

RESULTS AND DISCUSSION

The physiochemical and biological properties of the water samples collected from the study area and the results of water samples from the study area Masaka are summarized and interpreted in Table 1.

Table 1 presents the descriptive analysis of physiochemical and biological properties of river water sample. Results show that pH, temperature, turbidity, alkalinity, and nitrate have low variation in their concentrations, and color total hardness, chlorite, calcium, magnesium, and phosphate have high variation while iron and coliform have moderate variation. This implies that there is no definite pattern in the concentration of the element in the water.

Table 2 presents the descriptive analysis of physiochemical and biological properties of river water sample. Results show that pH, temperature, and iron have low variation in their concentrations, while all other parameters showed high variation in their concentrations. This implies that there is a high variation in the concentration of the elements in the water.

Table 3 presents the descriptive analysis of physiochemical and biological properties of sachet water sample. Results show that there is low variation in the concentration of pH, temperature, alkalinity, total hardness, iron, chloride, and calcium nitrate and moderate variation in color, conductivity, and nitrate, while turbidity, magnesium phosphate, and coliform have high variation. This implies that there is variation in the concentration of the element in the sachet water.

The result of the analysis of the body of water shows that apart from color and phosphate that have moderate variation and conductivity that has high variation in the concentration all other analyzed parameters have low variation. This implies that there is generally low variation in the concentration of the element in the body of the sachet water.

Table 4 presents the descriptive analysis of physiochemical and biological properties of hand-dug wells water samples. This table tries to compare the different wells' water ranging from concreted wells open and close; non-concreted wells open and close. The analyzed parameters in the opened concreted well water are higher than those in the closed concreted well water. Similarly, the opened non-concreted well water has higher concentration than those in the closed non-concreted well water.

Comparison of between concreted well water and non-concreted water shows that the concreted well water has lower concentration of most of the analyzed parameters than the non-concreted well water. This is probably due to the fact that the water in the non-concreted wells has direct contact with the profile soils compared with the concreted that is protected (appendix). In general, the results show that apart from pH, and temperature, that have low concentration, all other analyzed parameters have high variation in the concentration of the element in the well water.

Table 5 presents the results of the mean samples of the parameters analyzed from different sources. The results show that the mean of the pH and temperatures is all within the WHO standard, even though that of the water body is more of alkaline compare to the others.

The water color and turbidity of the water are all above the WHO standard, though that of the body of the sachet water is

Table 1: Results of physiochemical and biological properties of sampled river water

Parameter (mg/L except mentioned)	Siana river	Talma river	Mean	Std. dev.	COV	Remarks
pH	7.9	7.6	7.7	0.16	2.1	Low
Temperature °C	26.2	26.6	26.4	0.28	11	Low
Color (TCU)	455	289	372	117.4	31.6	High
Turbidity (NTU)	54	54	54	0	0	Low
Conductivity (μS/cm)	73	65	69	5.66	8.2	Low
Alkalinity	38	46	42	5.66	13.5	Low
Total hardness	34	14	24	14.14	58.9	High
Iron	0.15	0.11	0.13	0.03	21.8	Moderate
Chloride	13.8	8.28	11.0	3.90	35.4	High
Nitrate	19.4	18.7	19.1	0.50	2.6	Low
Calcium	8.02	4.01	6.02	2.84	47.1	High
Magnesium	3.4	0.97	2.19	1.72	78.6	High
Phosphate	0.29	0.13	0.21	0.11	53.9	High
Total coliforms (cfu/100 ml)	800	1000	900	141	15.7	Moderate

Source: Field survey, 2020

Table 2: Results of physiochemical and biological properties of sampled borehole water

Parameter (mg/L except where mentioned)	BHW 1	BHW 2	BHW 3	BHW 4	Mean	Std. dev.	COV	Remarks
pH	6.44	6.86	6.35	6.17	6.4	0.3	4.5	Low
Temperature	26.8	26.4	26.6	26.7	26.6	0.2	0.6	Low
Color (TCU)	259	146	90	160	163.8	70.3	43	High
Turbidity (NTU)	14	13	16	37	20	11.0	57	High
Conductivity (µS/cm)	364	233	918	464	494.8	297.6	60.2	High
Alkalinity (mg/L)	114	74	336	76	150	125.4	83.6	High
Total hardness (mg/L)	84	60	328	138	152.5	121.5	79.6	High
Iron (mg/L)	0.11	0.1	0.09	0.1	0.1	0.01	8.2	Low
Chloride (mg/L)	33.1	27.6	113.2	44.2	54.5	39.7	72.8	High
Nitrate (mg/L)	18	16.7	11.9	55.6	25.6	20.2	79.1	High
Calcium (mg/L)	20	16	17.6	36.9	22.7	9.7	42.7	High
Magnesium (mg/)	7.8	4.9	69.3	11.2	23.3	30.8	132.1	High
Phosphate (mg/L)	0.7	0.62	0.05	1.13	0.6	0.4	71	High
Total coliforms (cfu/100 ml)	502	15	2	5	131	247.4	188	High

Source: Field survey, 2020

Table 3: Physiochemical and biological parameters of sampled sachet water content and body

Parameters	Sachet water (content)						Sachet water (body)					
Test performed	Sachet water 1	Sachet water 2	Mean	Std. dev.	COV	Remark	Sachet water 1	Sachet water 2	Mean	Std. dev.	COV	Remark
pH	7.13	6.64	6.9	0.35	5	Low	8.1	8.0	8.1	0.04	0.5	Low
Temperature	25	27.3	26.1	1.63	6.2	Low	27.7	27.7	27.7	0	0	Low
Color (TCU)	148	219	183.5	50.2	27.4	Moderate	106	150	128	31.1	24.3	Moderate
Turbidity (NTU)	41	18	29.5	16.3	55.1	High	15	18	16.5	2.1	12.9	Low
Conductivity µS/cm	151	210	180.5	41.7	23.1	Moderate	16	32	24	11.3	47.1	High
Alkalinity (mg/L)	48	46	47	1.41	3	Low	13	15	14	1.4	10.1	Low
Total hardness (mg/L)	60	52	56	5.66	10.1	Low	0	0	0	0	0	Low
Iron (mg/L)	0	0	0	0	0	Low	0	0	0	0	0	Low
Chloride (mg/L)	22.1	21.2	21.7	0.64	2.9	Low	7.37	9.2	8.3	1.3	15.8	Low
Nitrate (mg/L)	19.2	26.1	22.7	4.88	21.5	Moderate	4.4	3.8	4.1	0.4	10.3	Low
Calcium (mg/L)	12.8	15.2	14	1.70	12.1	Low	0	0	0	0	0	Low
Magnesium (mg/)	6.8	3.4	5.1	2.40	47.1	High	0	0	0	0	0	Low
Phosphate (mg/L)	0.6	0	0.3	0.42	141.4	High	0.04	0.06	0.05	0.01	28.3	Moderate
Total coliforms (cfu/100 ml)	0	86	43	60.81	141.4	High	0	0	0	0	0	Low

Source: Field survey, 2020

lower than the water from other sources. The concentration of conductivity, alkalinity, total hardness, iron chloride, calcium, magnesium, phosphate, and nitrate is all bellow WHO, except that the concentration of well water was slightly above the limit.

The biological analysis of the water samples shows that of all the samples analyzed, only the sachet water body has zero coliform. Judging from the WHO standard, they all occurred above the acceptable limit.

Table 6 presents the comparison between the water qualities of different source and with the WHO. The result of the analysis between concrete well water with cover and concrete well water without cover shows that the calculated t-cal. is 1.86 and t-critical is 1.771 at α=0.05 level of confidence. Here,

Table 4: Physical, chemical, and biological parameters or sampled wells

Parameter (mg/L except where mentioned)	Concrete well with cover well	Concrete well without cover	Non-concrete well with cover	Non-concrete well without cover	Mean	Std. dev.	COV	Remarks
pH	7.34	7.01	6.37	6.94	6.9	0.40	5.8	Low
Temperature	26.4	26	26.5	26.4	26.3	0.22	0.8	Low
Color (TCU)	255	201	118	256	208	65.0	31.3	High
Turbidity (NTU)	39	16	24	20	24.8	10.1	40.6	High
Conductivity (µS/cm)	87	1122	572	799	645	435.1	67.5	High
Alkalinity	42	198	82	84	102	67.2	66.2	High
Total hardness	28	258	128	188	133	94.7	71.2	High
Iron	0.1	0	0.07	0.18	0.09	0.08	85.2	High
Chloride	12.9	130.6	51.5	85.6	70.2	50.1	71.4	High
Nitrate	15.7	71.3	55.8	60.9	50.9	24.4	47.8	High
Calcium	11.2	35.3	26.5	44.1	29.3	14.0	47.9	High
Magnesium	0.49	41.5	15.1	11	17.0	17.4	102.5	High
Phosphate	0.2	1.3	0.14	0.31	0.49	0.55	112	High
Total coliforms (cfu/100 ml)	408	800	11	910	532	408.9	76.8	High

Source: Field survey, 2020

Table 5: Comparing the mean of all sampled water sources and WHO standard

Parameter (mg/L except where mentioned)	Well	Borehole	River	SW (content)	SW (body)	WHO standard
pH	6.92	6.46	7.8	6.9	8.1	6.5-8.5
Temperature	26.3	26.6	26.4	26.2	27.7	Null
Color (TCU)	207.5	163.8	372	183.5	128	15
Turbidity (NTU)	24.8	20	54	29.5	16.5	5
Conductivity (µS/cm)	645	494.8	69	180.5	24	1000
Alkalinity	101.5	150	42	47	14	250
Total hardness	133	152.5	24	56	0	150
Iron	0.09	0.1	0.13	0	0	0.3
Chloride	70.2	54.5	11.0	21.7	8.3	200
Nitrate	50.93	25.6	19.1	22.7	4.1	50
Calcium	29.28	22.7	6.02	14	0	200
Magnesium	17.02	23.3	2.19	5.1	0	50
Phosphate	0.49	0.63	0.21	0.3	0.05	0.5
Total coliforms (cfu/100 ml)	532.3	131	900	43	0	10

Source: Field survey, 2020

t-calculated is more than the t-critical, implying that there is significant difference between the physiochemical and biological properties of concrete well water with cover and concrete well water without cover. It can be concluded that the covering of wells helps in preserving the quality of well water.

The analysis between non-concrete well water with cover and non-concrete well water without cover shows that the calculated t-cal. is 1.532 and t-critical is 1.771 at α=0.05 level of confidence. The t-calculated is less than the t-critical, implying that there is no significant difference between the physiochemical and biological properties of non-concrete well water with cover and non-concrete well water without cover. We should understand that there is difference between them but that the difference is not significant.

The analysis between concrete well water and non-concrete well water shows that the calculated t-cal. is 0.646 and t-critical is 1.771 at α=0.05 level of confidence. The t-calculated is less than the t-critical, implying that there is no significant difference between

Table 6: Results of analysis comparing the experimental results and WHO standard (t-test)

Parameter	Freq.	Mean difference	Std. dev.	df	T	t-critical one –tail	Remark
Concrete well with cover versus concrete well without cover	14	141.05	298.5	13	1.86	1.771	Significant
Non-concrete well with cover versus non-concrete well without cover	14	98.25	149.2	13	1.532	1.771	Not significant
Concrete well versus non-concrete well	14	8.29	6.8	13	0.646	1.771	Not significant
Well versus WHO standard	14	9.335	380.8	13	0.177	1.771	Not significant
Borehole versus WHO standard	14	50.3	130.6	13	1.1982	1.771	Not significant
River versus WHO standard	14	31.6	15.3	13	0.3084	1.771	Not significant
Sachet versus WHO standard	14	95.7	201.8	13	1.551	1.771	Not significant

Source: Field survey, 2020

Table 7: Results of spatial analysis (ANOVA)

Source of variance	Sum of squares	df	Mean square	F	Sig.	Remark
Between groups	56,521.6	3	18,840.5	0.612	0.610	
Within groups	1,601,013.8	52	30,788.7			Significance
Total	1,657,535.5	55				

the physiochemical and biological properties of concrete well water and non-concrete well water. We should also note that there is difference between them but that the difference is not significant.

When the results of the water analysis from the four sources of water were compared with the WHO standard, it shows that there is no significant difference between them. We should note also that there is difference between them especially the total coliform count, only that the difference is not significant.

Table 7 presents the result of spatial analysis comparing the water quality of different source. The result shows that the calculated F-ratio is 1.592 and F-critical is 2.181. Here, F-calculated is less than the F-critical, implying that there is no significant variation between and within the physiochemical and biological properties of the sachet waster. This does not mean that there is no difference, but that the difference is not significant.

DISCUSSION OF RESULTS

The physiochemical and biological analysis of river water sample shows that the mean pH of the water is 7.8 which is within the WHO standard. This is an indication that anthropogenic activities around the river are still mild. However, the high turbidity and color could be attributed to the action of erosion through construction and agricultural activities.

The borehole water physiochemical and biological properties vary between the four sampled boreholes. The chances of borehole water getting external contamination are very slim; as such, these differences might be accounted for by the variation in the soil composition.

There is low variation in the concentration of the elements in sachet water, except turbidity, mg, P, and total coliform that varied considerably, though all within the set limit of the WHO. The variation might be due to the manufacturers of the sachet water. The point here is that we are only concerned with the maximum limits, neglecting the needed proportion for the body. Minerals such as iron, calcium, and magnesium concentration are very low. This is similar to the value obtained by Mustapha *et al*.[16] which reported that iron present in sachet water sold within Bauchi metropolis ranged from 0.01 to 0.07 mg/L.

Total coliform is another parameter examined, the results show that all the water sources contained coliform, though not specified whether *E. coli*, *Shigella*, or any other microbial can affect human health, with the exception of sachet water body which was free of the coliform. This is probably due to the level of sanitation and personal hygiene on the part of the manufacturers and the water vendors. This result is similar to the results of Ajayi *et al*.[17] Akpen *et al*.,[18] Magaji,[19] on sachet water microbial quality where they found that larger proportion of sachet water showed positive coliform counts compared to bottled water sold in Ibadan town. They attributed the contamination of packaged drinking water to be from the raw source of water, treatment employed, and handling during production. Magaji[18] also discovered that the body of the sachet nylon contains some coliforms which he also attributed as earlier stated.

The presence of high coliform count in the wells, rivers, and boreholes calls for concern. The rivers are been polluted in different dimensions, some people living close to the river bank, do not construct soakaways rather they channel all their toilets and bathrooms' sewage directly into the stream channels.

Other ways of the pollution could be leachates from waste dumps, feces from the river banks urban flood among others.

The presence of coliform in the well could commonly be due to improper sanitation and personal hygiene. Some wells are left opened were wind could blow dirt from elsewhere into it, or running water might also get into the well, above all, this could also be through the well-drawer itself. When the surrounding is dirty, the drawer also get contaminated and dirt might get into the well through it.

Further study would be needed in finding how the borehole gets contaminated, if not during drilling or the hole is left opened for long before covering. Another way might be proximity to soakaway or pit latrine, taking into consideration of the type of soils and depth of the borehole and the soakaway/latrine.

CONCLUSION AND RECOMMENDATIONS

Water is essential for life and at the same time a lot of diseases that affect man can be prevented by about 70% if portable water is provided. Water that does not meet the standard required for quality water is most likely to pose a health problem to the population. This study reveals apart from the presence of total coliform, high turbidity, and color the well, borehole, and sachet water parameters fall within the WHO standard. The river water is the most polluted and needs serious treatment before consumption. Base on the forego discussion, the following recommendations are made:

1. There is a need for public enlightenment on the need to sanitize the environment, especially their sources of water
2. NAFDAC needs to monitor all the registered and unregistered companies to ensure compliance
3. The best way to use wells is to cover the wells and ensure that the drawers are always hanged inside after used
4. A water vendor union should be formed to regulate their code of conduct so as to reduce the rate of water contamination.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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APPENDIX I

Sources of Water