Physicochemical and Microbiological Parameters of Water from Rivers in Keffi, Central Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author RCR designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors SDG and YA managed the analyses of the study. Author YA managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Four water samples were in respective cases collected from river Oadaji, Northern River (NR) designated NR1-NR4 and river Kantou the Southern River (SR) designated SR1-SR4 both of Nasarawa State University, Keffi, Main Campus land area, and were analysed for some physicochemical and microbiological parameters using standard methods. The results obtained were compared with Standard Organization of Nigeria (SON) and WHO standards for drinking and recreational water. The results showed Temperature range 23.50-27.00°C, pH (6.00-6.45), Conductivity (82.95-125.70 µS/cm), Total Dissolved Solids (20.0-58.0 mg/L), Turbidity (36.30-8.95NTU), Dissolved Oxygen (5.50-13.00 mg/L), Biological Oxygen Demand (5.78-8.68mg/L), Chemical Oxygen Demand (85-145 mg/L), Total Hardness (180-520 mg/L), Nitrate (4.40-25.00 mg/L), Chlorides (10.50-31.45 mg/L), Phosphate (0.10-0.51mg/L), Sulphate (3.50-18.61 mg/L). Results of Atomic Absorption Spectrophotometric (AAS) analysis for trace metals showed that the metal concentrations were minute in both the Northern and Southern rivers; Lead (0.02±0.011 and 0.03±0.017 mg/L) Copper (0.01±0.003 and 0.01±0.002 mg/L), Zinc (0.06±0.020 and 0.11±0.016

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mg/L), and Iron (0.16±0.026 and 0.12±0.022 mg/L). Nevertheless, the concentration of lead was above the acceptable limit. There was no statistically significant relationship (P>0.05) between these metals. The analysis of microbiological parameters revealed very high Total Viable Count for all the water samples, ranging between 25 ×10^4 to 42 ×10^{4}cfu/ml, and Most Probable Number index for coliforms to be ≥2400/100 ml, higher than the acceptable limits. Also, *E. coli, Salmonella* spp, *Proteus* spp, *Bacillus* spp, *Enterobacter* spp, *Klebsiella* spp and *Pseudomonas* spp were isolated from the samples examined. The usability of water from these rivers for domestic purposes is not recommended, hence proper treatment is needed before they are consumed or put to any reasonable domestic applications.

1. INTRODUCTION

Water is one of the most imperative and vital resources for human life [1]. An adequate supply of fresh and clean drinking water is a basic need for all human beings on the earth. The primary sources of fresh water are ground and surface water. Overexploitation, poor management and pollution continuously threaten these sources of freshwater resources. Pollution of freshwater bodies such as rivers, streams, lakes and ponds is mostly experienced as result of the industrial discharge, municipal waste disposal and surface run-off [2]. Also, increase, and changes in environmental pressure threaten water quality and complicate the assessment of its present and future spatial distribution [3]. The expansion of industry, new technologies absorbing and producing massive amount of chemicals, organic and inorganic compounds, and increasing urban developments have resulted in increasingly sewage polluted natural waters [4]. In Nigeria, access to safe water and sanitation is a significant challenge, 53% of the populace in rural and 28% in urban areas have no access to improved water sources [5]. Water Aids Nigeria reported that around 57 million Nigerians lack access to safe potable water while over 130 million people (two-thirds of the population) do not have access to adequate sanitation [6]. Furthermore, Nigeria's water resources have been under the spotlight due to the increasing threat of pollution in recent years brought about by rapid demographic changes, which have coincided with the establishment of human settlements lacking appropriate sanitary infrastructure [7].

In recent time, the environment has become hostile, posing a threat to health and welfare due to the release of pollutants from industries and urban sewage [8]. This continues to be a source of organic, heavy metals and miscellaneous chemical contaminants of an aquatic environment. Furthermore, microbial contamination also poses a potential public health risk when improperly managed [9,10]. At present, public water systems rely on bacterial indicators (i.e. coliforms) for monitoring water quality, and it has been shown that bacterial indicators are often poorly correlated with the presence of other microorganisms, such as protozoa and viruses, which can be found in various water sources including finished drinking water [11].

In urban areas, faecal microorganisms are mainly transported to the aquatic environments through the discharge of domestic wastewater and some industrial wastewater. In rural areas, faecal pollution in rivers is caused through non-point sources (surface runoff and soil leaching); its origin can be the wildlife animals and grazing livestock faeces and also cattle manure spread on cultivated fields [12]. The quality of water in rivers is not only vital to humans but animals and the maintenance of environmental integrity [13]. Kahara [14] reported that the rivers themselves are now considered an environmental health hazard due to the high concentrations of chemical and bacteriological pollution despite this, nearly half of the urban population are at one time or the other, dependent on them as a source of water for domestic use and in worst cases for drinking.

These polluting sources have had a significant effect on the quality of surface water bodies in Keffi, central Nigeria, where the lower reaches of these rivers catchments are being affected by urbanisation which poses a high risk to users due to microbial contamination. People living in these areas, as well as downstream users, often utilise the contaminated surface water for drinking, recreation and irrigation, which creates a situation that poses a severe health risk to the people. A larger population of Keffi is outside the grid of treated water and as such depends on

Rivers and the wells for drinking and other domestic activities. This study sought to determine the levels and concentration of some physicochemical and microbiological parameters of the two primary sources of natural water flowing across the campus mass of Nasarawa State University, Keffi, central Nigeria.

2. MATERIALS AND METHODS

2.1 Description of Study Area

Keffi town is located between longitude $07^0 49'03^0$-$07^0 55'04''$ and latitudes 08^0 46'' - 08^0 53' 50''. It is situated south of Abuja, the federal capital territory of Nigeria. Thus, the town serves as one of the satellite settlements to Abuja. The citing of the Nasarawa State University in the town has led to an increase in the demand for water in the town [15]. The Oadaji river, here referred to as the Northern River (NR) and the River Kantou, here referred to as the Southern River (SR) of the Nasarawa State University main campus (which constitute the study sites) passes through the university campus on the northern and southern parts, respectively. The NR is about three kilometers in length and has an average depth of between three and four meters. Both rivers flow from the east of the university and empty into River Antau at the far west of the university campus land mass running down to the southern part of the Keffi metropolis.

2.2 Sample Collection

The water samples were, in each case, collected at four different points of the two rivers; two each, from the sides and middle of the running water at distances of 500 meters intervals, spanning two kilometers for each river. Samples from North river were labeled NR1 to NR4 while those from South river were labelled SR1 to SR4in that order. Water samples for microbiological analysis were leached in 10ml universal containers while 1.75ml plastic containers were used for water collected for chemical analysis. Samples which could not be analysed immediately were stored at 4^0C to avoid destabilisation. The holding period for all samples which could not be analysed immediately never exceeded 7 days.

2.3 Analysis of Physicochemical Parameters

The physicochemical analysis carried out on the water samples included the pH, temperature, Conductivity, Total Dissolved Solids (TDS), Chlorides, Total Hardness, Turbidity, Chlorides, Nitrate, Sulphate, Phosphate, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) which were determined by standard methods [16-19] The pH, temperature and Dissolved Oxygen (DO) were determined and recorded immediately at the site. The determination of metal concentration viz. Copper (Cu), Zinc (Zn), Lead (Pb), and Iron (Fe) were subsequently conducted using an Atomic Absorption Spectrophotometer (AAS) as earlier described [18,20].

2.4 Microbiological Analysis

Both the presumptive and confirmatory tests were carried out in order to determine the presence of microbial contaminants particularly of faecal origin such. The microbiological analysis was carried out by the methods previously described [21]. The most probable number (MPN) – multiple-tube technique was used for coliform enumeration. Nutrient Agar and Eosin Methylene Blue Agar were used to determining the total viable count and for detection of coliforms respectively, as other selective media were also used for selective plating. After inoculation, all plates were incubated at 35°C for 24 hours. Presumptive colonies were confirmed by gram staining and biochemical test reactions [22,23].

2.5 Statistical Analysis

Results obtained from this study were statistically analysed. The analysis of variance (ANOVA) for water parameters of the two rivers were determined, and mean differences were be judged by Duncan's Multiple Range Test (DMRT).

3. RESULTS

The results of the physicochemical parameters of the water samples analysed from the Oandaji (North) and Kantou (South) Rivers are presented in Tables 1 and 2. The pH range obtained was between 6.0-6.6 for the two Rivers, with a mean ± standard deviation of 6.28±0.072 and 6.19±0.067. The temperature range of the two rivers was between 23.5 to 25.0°C and 24.8 to 27.0°C, given a mean ± standard deviation of 24.48±0.354°C and 25.56±0.497°C for the North and South Rivers respectively. There was no statistically significant relationship between the

pH and temperature of water samples from the two rivers (P=0.280) Fig. 1. The mean values of conductivity, Turbidity, hardness, nitrate, chlorides and phosphate were higher in North river than the south river while TDS, DO, BOD, COD, sulphate, Pb, Cu, Zn and Fe mean values were higher in the southern river than the north river. Figs. 2 and 3 present a clear comparison of TDS and turbidity (with P=0.598) and DO and BOD mean values (with P=0.062). Also, the mean values of nutrients and minerals are presented in in Figs. 4 and 5 respectively. Tables 3 and 4 show the microbiological parameters of water samples examined from the two rivers. The range of Total Viable Cell (TVC) obtained were between 25×10^4 cfu/ml to 42×10^4 cfu/ml and 29×10^4 cfu/ml to 35×10^4 cfu/ml for the north and south rivers respectively. More so, the MPN index of the all the water samples examined were found to be ≥2400/ 100 ml.

Table 1. Physicochemical properties of water samples from different sites of North River

Parameter	Water samples					
	NR1	NR2	NR3	NR4	Mean ± SD	SON Limit
pH	6.26	6.1	6.45	6 .30	6.28±0.072	6.5-8.5
Temperature (°C)	23.5	24.4	25	25	24.48±0.354	30
Conductivity (µS/cm)	96.31	118.02	101.5	125.7	110.383±6.891	1000
TDS (mg/L)	31	44.5	20	58	38.38±8.240	500
Turbidity (NTU)	36.3	8.95	12.84	25.45	20.89±6.229	5
DO (mg/L)	7	6.8	9.5	10	8.33±0.830	7.5
BOD (mg/L)	5.78	8.21	6.48	5.9	6.59±0.560	6
COD (mg/L)	109	87	132	95	105.75±9.860	200
Hardness (mg/L)	520	180	293	509	375.50±83.531	500
Nitrate (mg/L)	4.4	13.61	25	23.46	16.62±4.791	50
Chlorides (mg/L)	12.4	20	31.45	18.56	20.61±3.974	200
Phosphate (mg/L)	0.51	0.23	0.42	0.12	0.32±0.089	--
Sulphate (mg/L)	3.5	13	6.7	12.85	9.01±2.352	150
Pb (mg/L)	0.039	0.008	0.002	0.045	0.02±0.011	0.01
Cu (mg/L)	0.014	0.003	0.014	0.012	0.01±0.003	1
Zn (mg/L)	0.021	0.03	0.09	0.101	0.06±0.020	5
Fe (mg/L)	0.091	0.145	0.183	0.21	0.16±0.026	0.3

Table 2. Physicochemical properties of water samples from different sites of South River

Parameter	Water samples					
	SR1	SR2	SR3	SR4	Mean ± SD	SON Limit
pH	6.28	6.2	6.29	6	6.19±0.067	6.5-8.5
Temperature (°C)	25.5	24.8	25	27	25.56±0.497	30
Conductivity (µS/cm)	82.95	108.05	97.7	118.9	101.90±7.657	1000
TDS (mg/L)	24	32.5	28	33.5	29.50±2.189	500
Turbidity (NTU)	19.6	11.58	21.61	15.91	17.18±2.207	5
DO (mg/L)	5.5	9	8.8	13	9.08±1.535	7.5
BOD (mg/L)	7.05	6.51	8.68	5.85	8.33±0.830	6
COD (mg/L)	128	101	148	85	115.75±13.919	200
Hardness (mg/L)	195	180	200	198	193.25±4.535	500
Nitrate (mg/L)	6.9	8.51	13	20.46	12.22±3.036	50
Chlorides (mg/L)	10.5	20	15.63	19.85	16.50±2.240	200
Phosphate (mg/L)	0.1	0.19	0.35	0.11	0.19±0.058	--
Sulphate (mg/L)	18.61	12	15.75	12.3	14.67±1.566	150
Pb (mg/L)	0.002	0.05	0.008	0.073	0.03±0.017	0.01
Cu (mg/L)	0.01	0.015	0.011	0.019	0.01±0.002	1
Zn (mg/L)	0.075	0.15	0.092	0.11	0.11±0.016	5
Fe (mg/L)	0.171	0.096	0.129	0.47	0.12±0.022	0.3

Table 3. Microbiological parameters of Noth River

Sample	Total viable count (TVC)	MPN/100ml
NR1	39×10^4 cfu/ml	≥2400/ 100 ml
NR2	27×10^4 cfu/ml	≥2400/ 100 ml
NR3	25×10^4 cfu/ml	≥2400/ 100 ml
NR4	42×10^4 cfu/ml	≥2400/ 100 ml

Table 4. Microbiological parameters of South River

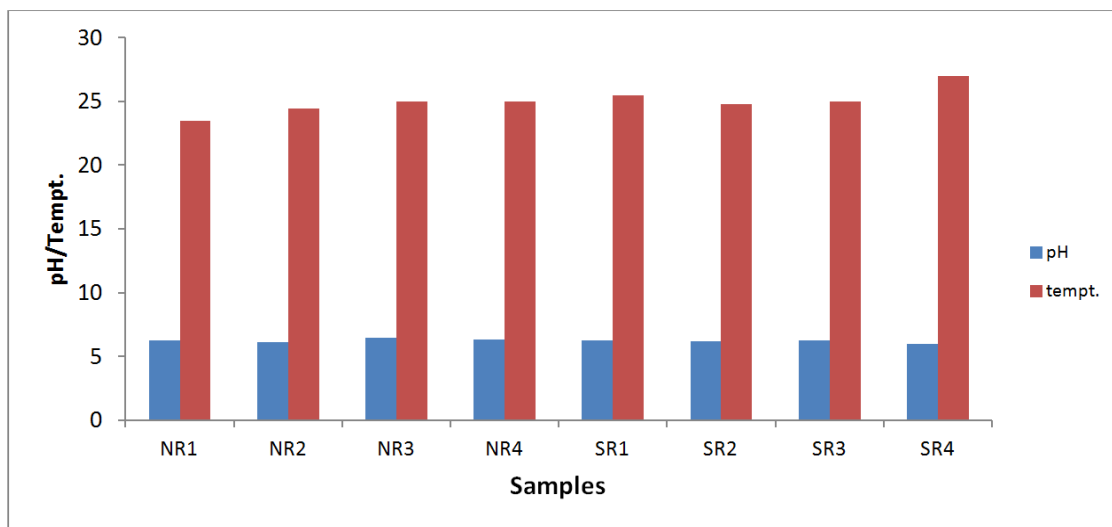| Sample	Total viable count (TVC)	MPN/100ml
SR1	35×10^4 cfu/ml	≥2400/ 100 ml
SR2	30×10^4 cfu/ml	≥2400/ 100 ml
SR3	31×10^4 cfu/ml	≥2400/ 100 ml
SR4	29×10^4 cfu/ml	≥2400/ 100 ml

Fig. 1. pH and Temperature values of water samples from North and South Rivers (p=0.280)
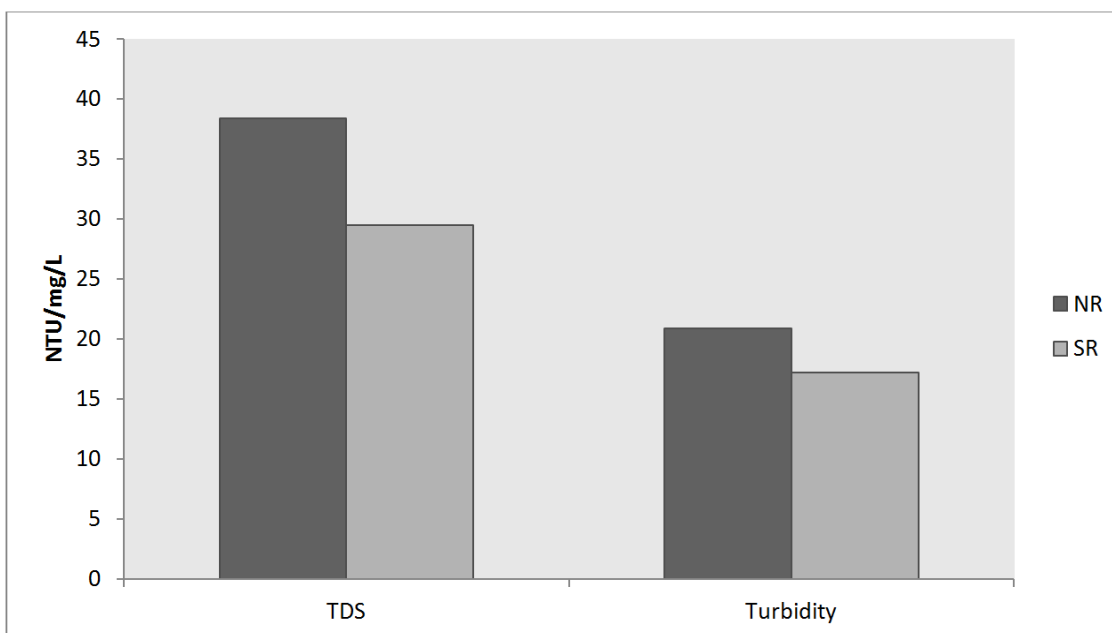

Fig. 2. Mean values of TDS and Turbidity of water samples from North and South Rivers (P=0.598)
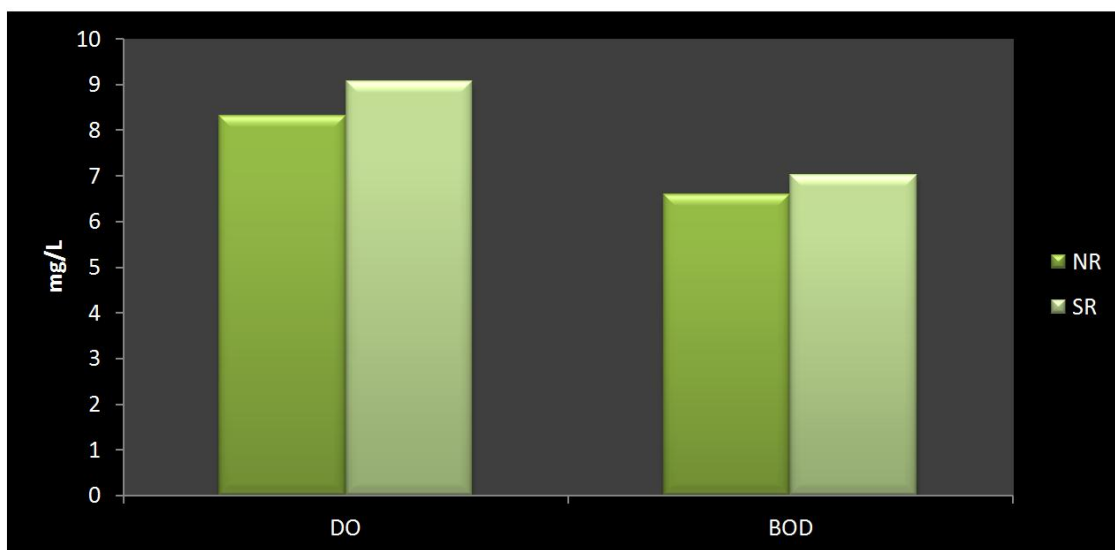
Fig. 3. Mean values of DO and BOD of water samples from North and South Rivers (P=0.062)
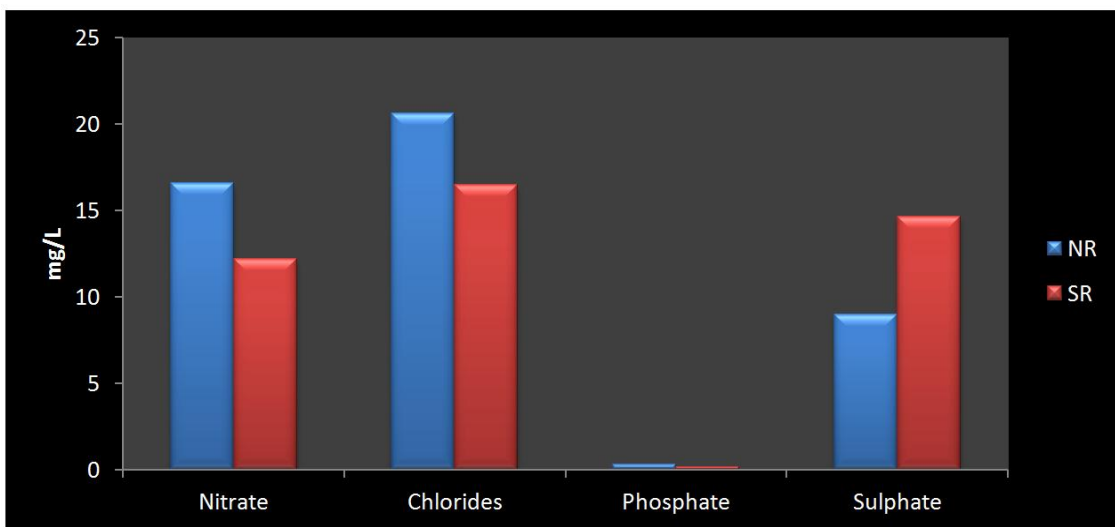

Fig. 4. Mean values of Nitrate, Chlorides, Phosphate and Sulphate of water samples from North and South Rivers (P=0.889)

4. DISCUSSION

The results obtained from this study shows clearly the various physicochemical parameters of water samples examined from the two rivers in Keffi, central Nigeria. The pH ranged obtained from this study was between 6.0-6.6 for the two rivers, which is slightly acidic. This falls little below the Standard Organization of Nigeria (SON) and by World Health Organization (WHO) limits [24, 25]. It should be noted that high pH increases the toxicity of ammonia in water while low pH enhances the toxicity of H_2S and cyanide [26]. Changes in pH are known to be a resultant of processes such as photosynthesis, respiration, temperature exposure to air, disposal of industrial wastes, geology and mineral content of a catchment area, acid mine drainage, agricultural runoff, carbon dioxide concentration in the atmosphere, and accumulation and decomposition of organic detritus in the water producing weak carbonic acids that impact on pH [27]. The pH of water is essential in that changes in pH values may affect the toxicity of microbial

poisons in the water [28]. Since the pH values of these rivers are near neutrality, the water may pose no serious health risk to consumers who use the water for agricultural, recreational and domestic uses. The temperature range of the two rivers was between 23.5 to 25.0^0C and 24.8 to 27.0^0C, given a mean ± standard deviation of 24.48 ± 0.354^0C and 25.56 ± 0.497^0C for the North and South Rivers respectively. These rightly fall within the safe and acceptable limits of both the SON and WHO [24, 25]. Nevertheless, Agbazue [29] and Aliyu [30] reported the temperature range of 28.52 ± 1.192 to 28.27 ± 1.292^0C from Oro-Obor and Ayo Rivers in Enugu South, Enugu State, Nigeria and 27.7 ± 0.76 to 27.95 ± 0.684^0C from 4 sampling stations of Udu River, Warri, Nigeria. Also, Raji [31] and Olorode [32] reported the temperature range of 25.3 to 29.2^0C from River Sokoto, Northwestern Nigeria and 25.0 to 28.0^0C from five different Rivers in Port Harcourt, Niger Delta Region of Nigeria. The temperature range observed in this work will discourage the rate of chemical and biochemical reactions, the solubility of gases in the water which could impact negativity on the taste and odour of the water at higher temperatures [33]. There was no statistically significant relationship (P=0.280) between pH and temperature of the water samples from the two Rivers studied.

The mean turbidity values obtained from the water samples from the two rivers were 20.89±6.229 and 17.18±2.207. This is exceedingly higher than the SON recommended guideline value of 5 NTU. Turbidity levels are dependent on the amount of suspended particles present in the water. Suspended particles act as a substrate for microorganisms in the water, thus promoting growth of the microbial populations [34]. Water turbidity is very important because high turbidity is often associated with higher level of disease-causing microorganisms such as bacteria and other parasites [35]. The increase in mean values of the turbidity of the rivers under study is an indication of pollution which enhances the increase in the number of pathogens. The mean values of TDS obtained from our study (29.50±2.189 and 38.38±8.240 mg/L) were within the SON and WHO acceptable limit of 500.00mg/L. TDS comprises inorganic salts and a small amount of organic matter that dissolved in water [25]. High TDS waters may interfere with the clarity, colour and taste of water, thereby indicating the presence of toxic minerals and microorganisms of health importance in the water [36,37]. Furthermore, TDS is primarily affected by depth, turbulence, allochthonous run-offs and sediment load generated by the flow dynamics of aquatic systems. Suspended solids in water apart from having an unsatisfactory aesthetic value also affects light transmittance and the heat capacity of the system. The amount of solid in suspension also affects the rate of oxygen dissolution and the feeding habit intensities of organisms [32]. Our findings showed no significant relationship (P>0.05) between turbidity and TDS.

The mean conductivity values were 110.383±6.891 µS/cm and 101.90±7.657 µS/cm. Although these values fell within the acceptable limits, they were nevertheless far less than the values obtained by Olorode [32] (303µs/cm to 8972µs/cm) and Oluyemi [38] (63 and 1039 µS/cm). The overall chemical richness of any water is a reflection of its conductivity values. The relatively low conductivity values may be attributed to low concentrations of chloride, sulphate and TDS which are indicators of lower salt content. The conductivity of water is a useful and accessible indicator of its salinity or total salt content [38].

The values of Dissolved Oxygen (DO) in this study were found to be 8.33±0.830 mg/L and 9.08±1.535 mg/L for water samples from both rivers. These values are higher than the acceptable limit (7.5 mg/L). DO is an essential measure of the extent of pollution, the lower its value, the higher the pollution concentration and vice versa [39]. Potable water should contain at least 5.0mg/L of DO [40]. Although it serves as an indicator of the biological health of a water body, nevertheless, it levels can fluctuate throughout the day and are affected by changes in water temperature, the concentration of organic materials (i.e., industrial or municipal wastes can increase the concentration of organic matter) [41].

Biological Oxygen Demand (BOD) measures the amount of oxygen used by microorganisms, in this case, bacterium, to oxidise organic matter present within the samples. The BOD values obtained from this study (6.59±0.560 and 8.33±0.830 mg/L) were higher than the standard acceptable limit (6.0). Water samples with the BOD less than 4.0 mg/l are considered clean [42]. This means that water from these rivers are not clean. From our study, there was no statistically significant relationship (P=0.062) between DO and COD.
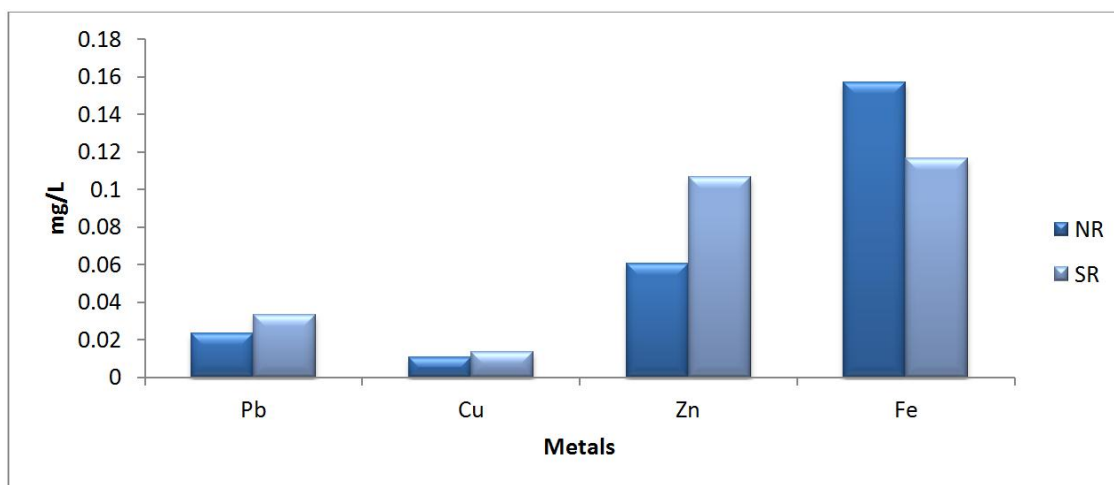
Fig. 5. Mean values of metals of water samples from North and South Rivers (P=0.523)

The mean Chemical Oxygen Demand (COD) values of 105.75±9.860 mg/L and 115.75±13.919 mg/L were obtained for the two rivers studied. They are observed to be within the SON and WHO acceptable limits. COD is a measure of the capacity of water to consume oxygen during the decomposition of inorganic chemicals such as nitrate and ammonia. The COD is related to BOD. However, BOD only measures the amount of oxygen consumed by microbial oxidation and is most relevant to water rich in organic matter. If the COD is higher, it will contain greater number of microorganisms [43].

The hardness of water samples from the rivers studied were 375.50±83.531 and 193.25±4.535 mg/L respectively. These values were within the stipulated SON and WHO acceptable limits (500 mg/L). The values obtained from this study were in consonance with the values previously reported [29,44,45]. Water hardness is occasioned by carbonate and bicarbonate of calcium and magnesium. Their relative low concentrations as recorded were indications of low contents of carbonate and bicarbonate.

The concentrations of nutrients such as nitrate, chloride, phosphate and sulphate in the water samples were 16.62±4.791 mg/L and 12.22±3.036 mg/L, 20.61±3.974 mg/L and 16.50±2.240 mg/L, 0.32±0.089 mg/L and 0.19±0.058 mg/L, 9.01±2.352 mg/L and 14.67±1.566 mg/L respectively. All these nutrients fall within the permissible SON and WHO standards, as such there presence may pose no health risk to consumers. Nevertheless, the relatively high levels of nitrate may be as a result of extensive farming taking place at the bank of these rivers with the possibility of the farmers making use of fertilisers which can easily be washed into the rivers. High nitrate content in the presence of microbial contamination can lead to cyanosis disease or blue baby syndrome in bottle-fed infants [25]. The level of chloride concentration obtained from this study is similar to the concentrations earlier reported [43,46]. The presence of chloride ions in these rivers is an indication that chloride ion is higher in this environment, at elevated levels; chloride can inhibit plant growth, slow reproduction and reduce the diversity of aquatic life. More so, excessive chloride concentration increases rates of corrosion of metals. Chloride is one of the major anions in water; it is generally associated with sodium. High level of chloride ions may result in an objectionably salty taste [25].

The mean concentration of lead (Pb) obtained from this study; 0.02±0.011 mg/L and 0.03±0.017 mg/L are higher than the SON and WHO acceptable limits (0.01 mg/L). Only samples NR2 (0.008 mg/L) and SR1 (0.002 mg/L) (from the side water), and NR3 (0.002 mg/L) and SR3 (0.008mg/L) from the middle running water had their Pb concentration within the expected limits. The high concentrations of Pb recorded in this study may be as a result of the direct disposal of domestic waste containing Pb from human activities at the riverbank and vehicular exhausts. Pb has been implicated in the ethiology of functional diseases such as microcytic anaemia, inhibitory effects on delta-aminolevulinic acid dehydratase [4,47] and in neurological damage in young children [48]. It is therefore very

important for rivers to be treated so that the Pb level meets these standards before it could be safe for drinking and use for domestic activities. The surface water may not also support recreational purposes until the Pb level is reduced to acceptable level.

Although the mean concentration values of Iron (Fe) (0.16±0.026 mg/L and 0.12±0.022 mg/L) falls within the SON and WHO acceptable limits (0.30 mg/L), sample SR4 from the middle running water of the south river had Fe value above the acceptable limit (0.470 mg/L). Iron, when present in high detectable amounts can affect the flavor of tea, coffee and alcoholic beverages. It can also promote the growth of iron bacteria in water and also makes the water distasteful [49]. Furthermore, the consumption of water containing Fe above the acceptable limit will certainly have negative health implications as iron overload is associated with polycythemia [50].

The minute values of Zinc (Zn) (0.06±0.020 mg/L) and 0.11±0.016 mg/L) and Cu (0.01±0.003 mg/L and 0.01±0.002 mg/L) obtained from this study falls within the acceptable SON and WHO limits Zinc is a micronutrient which at appropriate level helps in the regulation of vitamin A concentration in the blood. It is also a major component of insulin and is essential in the formation of protein. Likewise, copper is an important micronutrient associated with many metalloenzymes especially cytochrome-c oxidase. Cytochrome-c oxidase plays an essential role in oxidative metabolism [29]. On this basis, these rivers can support aquatic life if other conditions are favourable, hence may not pose any danger to the community. For the values of all the metals obtained from the two rivers studied, there was no statistically significant relationship (P=0.523) between them.

The results obtained from the three basic tests- the presumptive, confirmatory and completed test conducted to determine the quality of water samples indicated that the MPN index of the water sample was found to be ≥2400/100ml. Also, the Total Viable Count were between 25 ×10^{4}cfu/ml and 42 ×10^{4}cfu/ml for the North river and 29 ×10^{4}cfu/ml to 35 ×10^{4}cfu/ml for the south river respectively. Both values exceeded the SON and WHO of 0.00cfu/ml and 100cfu/ml respectively. This may be an indication of faecal contamination of the water. Both rivers transverse through residential areas and campus community, where residents and students often defecate since there are bushes and herbs by the rivers banks.

As a consequence, coliforms detected in higher concentrations are used as an index of the potential presence of entero-pathogens in water environments [51]. Coliforms are also routinely found in diversified natural environments, some of them are of telluric origin, but drinking water is not a natural environment for them [43]. As a result, their presence in drinking water has negative public health implications.

Further selective plating and biochemical tests conducted for some selected colonies revealed the presence of *E. coli, Salmonella* spp, *Proteus* spp, *Bacillus* spp, *Enterobacter* spp, *Klebsiella* spp and *Pseudomonas* spp. The high occurrence of members of Enterobacteriaceae family from the water samples examined further confirmed the high coliforms count observed. Similar pathogens were also reported by other scholars respectively [30,34,43,52]. Hence, the concentrations of these microbial indicators and pathogens in the water samples examined are indications of serious bacterial contamination; as such water from these rivers should be treated before consumption.

5. CONCLUSION

The study examined the physicochemical and microbiological parameters of rivers in Keffi, central Nigeria. Although some of the physicochemical parameters fall within the SON and WHO acceptable limits, few were however observed to be above the requirements. The presence of high microbial load and pathogens isolated renders the water unfit for human consumption, although they can be used for other purposes. The water of poor quality is a threat to the health and well-being of the populace. Potable and domestic water should not be of any public health threat for human consumption and other domestic uses. It is therefore recommended that severe effort in limiting the numbers of microorganisms released into the rivers in the study area should be implemented. Individuals residing along the riverine areas including students of Nasarawa State University, Keffi, should be educated on proper disposal of refuse, treatment of sewage and the need to purity water from these rivers before consumption. Open defecation, especially around the rivers, should be discouraged.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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