SEASONAL VARIATIONS IN IMABOLO STREAM WATER QUALITY IN ANKPA URBAN AREA OF KOGI STATE, NIGERIA

Abstract

Changes in season is one of the important drivers responsible for pollutants transported into surface waters. This study examined the seasonal variations in the quality of Imabolo stream water within Ankpa urban, Kogi State, Nigeria. To achieve the aim of the study, water samples were collected at the peak of the two seasons from seven points along the stream reach corresponding to the different land-use activities in the study area in March and June, 2018. In-situ and laboratory analysis of eighteen physico-chemical and two microbiological parameters were carried out according to standard procedures. Descriptive statistics and t-test were employed to analyze the data obtained for both dry and rainy seasons. The results were compared with WHO and NSDWQ standards for drinking water quality for characterization. The analysis revealed that water samples from six points had elevated values of parameters above the recommended limits for human consumption. The observed seasonal variation indicated that wet season values were higher for all the parameters except DO and Ca^{2+}*, while t-test showed significant difference (*$p<0.05$*) in the level of temperature, EC, TDS, turbidity, BOD, COD, nitrate, sulphate, iron, calcium, lead, cadmium, alkalinity, total hardness, total coliforms and E.coli between dry and rainy season. The study advances innovative recommendations to remediate and improve the quality of the stream water in order to meet the water needs of the users.*

Key words: *Water quality, Urban Population, Seasonal Variation, Pollutants, Water users*

Introduction

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is the measure of the condition of water relative to the requirements. Decline in the quality of water resource poses great risk to the users as such water can lead to health challenges. The quality of water in a stream is determined by the concentration levels of both the chemical and the physical properties. Stream water properties are largely governed by natural processes such as precipitation rate, weathering processes, soil erosion and anthropogenic effects such as urban, industrial and agricultural activities (Hassan *et al.,* 2015). However, the rates of these processes are strongly controlled by changes in seasons which in most cases lead to increasing trend in run-off, nutrient enrichment and growth of many aquatic organisms (Nouri *et al.*, 2011). These impurities in streams deteriorate the quality of the water, making it increasingly limited, difficult to exploit and often times expose the users to varieties of health issues (Guettaf, Maoui and Ihdene, 2014).

Nigeria has great network of streams and rivers that are largely influenced by seasonal variations (Eni and Efiong, 2011). The inability of the government to provide sustainable clean and safe drinking water have left the people with no option than to turn to the available streams and rivers for their water needs, which in most cases are safe for consumption (Ushurhe *et al.*, 2014). The poor waters quality in these streams are often due to the transportation of pollutant into the stream. The rate of the inflow of pollutants often times is associated with the seasons as experienced in both urban and rural areas in Nigeria (Ushurhe, 2013). Specifically, some pollutants in surface water are season's dependent and thus high in some seasons and minimal in other seasons. Unsafe water can lead to high prevalence of waterborne diseases such as cholera, diarrhoea, dysentery, hepatitis, etc. (Oguntoke *et al.*, 2009; Raji and Ibrahim, 2011). Hence, characterization of seasonal change in stream water quality is imperative in evaluating temporal variations of pollutant level from point and non-points sources. The knowledge is paramount to safeguard public health especially where many people depend on stream for their water needs.

In Ankpa Urban area, most residents depend principally on Imabolo stream for drinking, irrigation, industrial and recreational purposes (Figures 1 and 2). Water collected from the stream is not regulated by the federal or state governments and typically does not receive the same level of treatment as drinking water supplied from developed boreholes. This situation leaves users at risk levels which can only be determined by studies. Therefore, there is the need for in-depth knowledge and understanding of the water quality of the stream and its variations through the seasons. This is necessary to minimize the hazards associated with using the stream water, to have information on the quality status of the stream water and/or for effective management of the polluted stream water. There is also the need to guide the urban residents and other users on the probable deleterious effects of using the stream water on their health, productivity as well as on the industrial equipment used. As the population and demand for safe drinking water increases, it is important to examine the quality status of streams on which people depend, the seasonal variations in the quality of such stream and highlight the implications of using water of such status to the users. This will enable researchers to suggest appropriate policy intervention measures to reduce the level of risks to which users of such streams are exposed to.


Figure 1 & Figure 2: Ankpa Urban Residents abstracting water from Imabolo Stream

Materials and Methods

The Study Area

Ankpa urban area lies appropriately between Latitudes 7^0 $16'$ N and 7^0 $24'$ N and Longitudes 7^o $22'$ E and 7^0 $51'$ E. The area has warm Tropical Savannah Climate with clearly marked wet and dry seasons (Ali, 2010). Rainfall is well distributed and is of double maxima (Iloeje, 1972). The amount of rainfall ranges between 1,000mm to 1,750mm. Temperature is moderately high throughout the year, averaging 25^0C. The maximum temperature of the area lies between 29.7^0C – 35.6^0C while the minimum temperature ranges between 23.3^0C and 25.2^0C (Ali, 2010).

The geology of the area is the false bedded sandstone of the Ajali and Mamu Formations which falls within the Anambra Basin. These formations consist of thick, friable, poorly sorted sandstone, well drained soils, red or reddish brown in colour and sandy, surface horizons which occur on the crest of inter-fluves and on upper and middle slopes. The vegetation is that of the Guinea Savannah type and is characterized by scattered trees, most of which are deciduous (Areola, 1983).

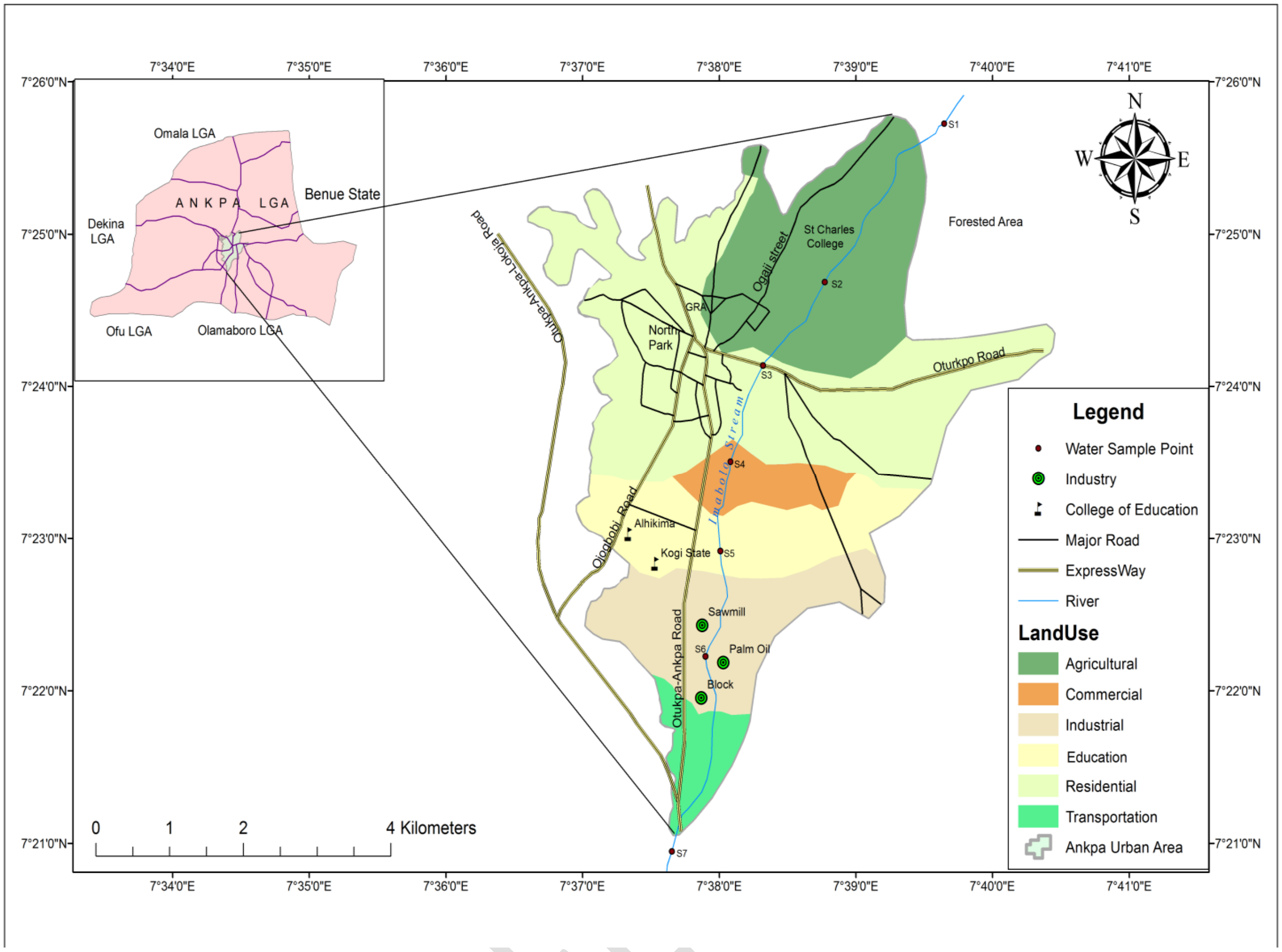

Figure 3: Ankpa Urban Area showing Imabolo Stream and Water Sample Points
(**Source:** GIS Unit, Department of Geography, University of Nigeria Nsukka)

Sample Locations

Table 1: Water Sample Locations and Coordinates

SITES	LOCATION	DATE	TIME	GPS COORDINATES	
				NORTHING	EASTING
S1	OGAJI	March, 2018 June, 2018	11:30am 11:30am	007°25'2.90"	007°39'5.80"
S2	OLUBOJO AND ST. CHARLES COLLEGE AREA	March, 2018 June, 2018	11:30am 11:30am	07° 24'18.7"	007° 38'27.8"
S3	CENTRAL RESIDENTIAL AREA	March, 2018 June, 2018	11:30am 11:30am	07° 24'.08.9"	007° 38'20.0"
S4	SABONGARI	March, 2018 June, 2018	11:30am 11:30am	07° 23'57.0"	007° 38'14.7"
S5	KOGI STATE COLLEGE OF EDUCATION AREA	March, 2018 June, 2018	11:30am 11:30am	007°23'2.01"	007°38'0.64"
S6	OJELANYI	March, 2018 June, 2018	11:30am 11:30am	07° 22' 20.6"	007° 37'59.0"
S7	OJOKODO	March, 2018 June, 2018	11:30am 11:30am	07° 24'18.7"	007° 38'27.8"

Water Sample Collection

Stream water samples were collected aseptically at each location into two litres sterilized polyethylene bottles and filled to the brim; one for physico-chemical analyses and the other for microbiological analyses according to recommended standard procedure for water quality analysis (APHA, 1995). Water samples were collected from seven different points along the length of the stream in March and July, 2018. This was to ensure that samples were collected at the peaks of the dry and rainy seasons respectively. This was also aimed to cover for variations between the wet and dry seasons for the physico-chemical and microbial water qualities for the locations. The direct sampling technique was employed at sites where water samples could be collected close to the stream bank and the dip sampling technique where direct access was limited (US EPA, 1994). Bottles were labelled before sampling and gloves were worn when handling the bottles. All samples were taken immediately to the laboratory for analysis. The water quality parameters analyzed are shown in Table 2.

Table 2: Selected Water Quality Parameters and their Standard Limits

Parameters	WHO (2011)	NSDWQ (2007)
Temp. (°C)	25	-
pH	6.5-8.5	6.5-8.5
EC (µS/m)	400	1000
TDS (mg/l)	500	500
Turbidity (NTU)	5.0	5.0
DO (mg/l)	6.0	6.0
BOD (mg/l)	10	-
COD (mg/l)	10 – 20	-
PO_4^{2-} (mg/l)	0.3	0.5
NH_3^-N(mg/l)	<1.5	1.0
NO_3^-N(mg/l)	10	50
SO_4(mg/l)	250	100
Fe^{2+} (mg/l)	0.3	0.3
Ca^{2+} (mg/l)	75-200	-
Pb^{2+} (mg/l)	0.01	0.01
Cd (mg/l)	0.003	0.003
Alkalinity (mg/l)	80-120	-
Total Hardness (mg/l)	500	150
Total Coliform Count (cfu/100ml)	10	10
E. Coli (cfu/100ml)	0	0

(Sources: WHO, 2011; NSDWQ, 2007)

Analysis of Stream Water Samples

The physical properties [pH, temperature, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Electrical Conductivity (EC) and Turbidity] of the water samples were measured *in situ* using digital electronic multi-parameter water quality monitoring instrument (HANNA Model HI 9812, HI 9813-0, HI 9813-5, HI 9813-6, LP 2000). Calibration of sensors was performed before every survey and the cuvette was rinsed three times with distilled water and the samples to be tested before every survey was conducted. The laboratory analysis of water samples for chemical parameters was carried out in the Department of Soil and Environment Management, Faculty of Agriculture, Kogi State University, Anyigba to determine their chemical properties according to Standard guideline of the Society for Analytical Chemistry (1973) and the APHA-AWWA-WPCF (1985) manual. Biochemical Oxygen Demand (Dilution Winkler Method), Chemical Oxygen Demand (Reflux Oxidation Titrimetric Method), Phosphate (Ascorbic acid colorimetric Method), Ammonia (Phenol-hypochlorite method), Nitrate (phenoldisulphonic acid colorimetric method) Sulphate (spectrophotometer method); Iron (flame atomic absorption spectrophotometer method); Calcium (EDTA Titration Method); Lead (atomic absorption spectrophotometric method); Alkalinity (titrating a known volume of water sample with 0.01M NaOH solution); Total Hardness (EDTA titrimetric method). All physico-chemical values obtained were compared to the WHO (2011) and NSDWQ which formed the recommended water quality guidelines in Nigeria (McDonald and Kay, 1988).

Microbiological Analysis of Stream Water Samples

Membrane filtration was used to isolate and enumerate all total coliform count and *E. coli* from the sampled water according to APHA (1998). All m-FC agar plates were incubated at 44.5°C for 24 hours while all MLG agar plates were incubated at 37°C for 24 hours. Colonies of interest on the surface of the filter membranes (blue and yellow colonies on m-FC agar as total coliforms and green colonies on MLG agar as *E. coli* were observed, counted and recorded as colony forming units (cfu) per 100ml.

Data analysis

Simple descriptive statistics such as minimum, maximum and mean were used to interpret the raw data on the physicochemical and microbiological parameters generated in the cause of this investigation with the aid of Statistical Package for Social Sciences (SPSS) Version 20 and Microsoft Excel 2010 software. The WHO (2011) and Nigerian Standard for Drinking Water Quality (NSDWQ) Guidelines on Drinking water were used as the benchmark for the interpretation of water quality in this study.

Results and Discussion

The results of the laboratory analysis of the water samples as well as the variations in the physico-chemical and microbiological characteristics of the water quality parameters are summarized in Table 3 and discussed below.

Table 3: Variations in the Physico-Chemical and Microbiological Characteristics of Water Samples in the Study Area

	Water Quality Parameters																			
	Temp. (°C)		pH		EC (mS/m)		TDS (mg/l)		Turbidity (NTU)		DO (mg/l)		BOD (mg/l)		COD (mg/l)		PO_4^{2-} (mg/l)		NH_3^-N(mg/l)	
	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS
Max	25.7	26.8	7.89	7.89	299	650	5.2	465.2	5.2	20.8	130	110	16.7	20.64	12.3	60.7	3.44	5.7	2.91	8.12
Min	22.1	23.2	7.22	7.19	10.3	51	1.06	168.9	1.06	5.2	23	79	2.39	4.12	5.6	6.7	0.2	1.5	0.1	0.12
Range	3.6	3.6	0.67	0.7	288.7	599	4.14	296.3	4.14	15.6	107	31	14.39	16.52	6.7	54.0	3.24	4.2	2.81	8.0
Mean	23.9	25	7.5	7.6	164.1	443.2	3.9	303.1	3.9	12	89.9	95.3	9.9	12.6	8.6	32.5	1.6	3.2	1.3	4.2
Variance	1.6	1.2	0.05	0.06	7172.3	43684.9	2.4	7793.5	2.4	37.5	1384.5	92.04	22.88	45.5	6.39	475.03	1.99	2.69	1.24	11.58
Std. Dev.	1.3	1.08	0.22	0.24	84.68	209	1.5	88.3	1.54	7.3	37.2	9.6	4.78	6.7	2.52	21.8	1.41	1.6	1.1	3.4
WHO	**25**		**6.5-8.5**		**400**		**500**		**5.0**		**6.0**		**10**		**10-20**		**0.3**		**<1.5**	
NSDWQ	**-**		**6.5-8.5**		**1000**		**500**		**5.0**		**6.0**		**-**		**-**		**0.5**		**1.0**	

	Water Quality Parameters																			
	NO_3^-N (mg/l)		SO_4 (mg/l)		Fe^{2+} (mg/l)		Ca^{2+} (mg/l)		Pb^{2+} (mg/l)		Cd (mg/l)		Alkalinity (mg/l)		Total Hardness (mg/l)		Total Coliform Count(cfu/100ml)		E. Coli (cfu/100ml)	
	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS
Max	1.6	2.5	201.6	286	0.3	1.3	17.3	11.4	0.012	0.05	0.003	0.03	3.16	5.44	74.6	120.6	15.3	28.5	1.8	3.1
Min	0.02	0.15	10.2	17.56	0.02	0.04	5.6	3.1	0	0	0	0	1.56	2.15	18.1	24.3	4	6	0	0
Range	1.58	2.35	191.4	268.44	0.28	1.26	11.7	8.3	0.0012	0.05	0.003	0.03	1.56	3.29	56.5	96.3	11.3	22.5	1.8	3.1
Mean	0.5	1.6	118.9	158.3	0.1	0.5	11.7	7.1	0.004	0.02	0.001	0.009	2.3	3.4	47.8	83.8	10.94	18	0.98	1.41
Variance	0.41	0.97	5825.9	10383.9	0.01	0.19	14.2	14.2	0.0001	0.0004	0.0000	0.0001	0.292	1.186	481.4	1037.1	14.5	72.2	0.49	1.26
Std. Dev.	0.6	1.0	76.32	102.0	0.11	0.42	3.77	2.6	0.00049	0.02	0.0009	0.01	0.54	1.1	21.9	32.2	3.8	8.5	0.7	1.1
WHO	**10**		**250**		**0.3**		**75-200**		**0.01**		**0.003**		**80-120**		**500**		**10**		**0**	
NSDWQ	**50**		**100**		**0.3**		**-**		**0.01**		**0.003**		**-**		**150**		**10**		**0**	

Std. Dev. = Standard Deviation; - = No guideline value
DS = Dry Season; RS = Rainy Season

Variation in Physico-Chemical Characteristics of Imabolo Stream Water

Temperature (°C): Temperature influences pH, alkalinity, acidity and dissolved oxygen in water. The rates of biological and chemical reactions depend to a large extent on temperature. Also growth of microorganisms, taste, odour, colour and corrosion problems may increase with increase water temperature (Ezemonye, 2009). The variations in temperature of the water samples are shown Table 3. The maximum, minimum and mean values of water temperature between the two seasons were 25.7°C, 22.1°C, 20.8°C (dry season) and 26.8°C, 23.2°C, 25°C (rainy season) respectively. The variance and standard deviations for the water samples were 1.6 and 1.3 (dry season) and 1.2 and 108 (rainy season). The mean temperature of water samples shows significant difference (p <0.05) between the two seasons.

pH: pH is the measure of hydrogen ions concentration in water. It is also the measure of the intensity of acidity or alkalinity. The pH of a stream water system can be a useful indicator of water quality because it determines the suitability of water for various purposes (Sunitha, *et al.*, 2012). Table 3shows variations in pH of the water samples. The maximum, minimum and mean values of pH in water samples between the two seasons were 7.89, 7.22, 7.5 (dry season) and 7.89, 7.19, 7.6 (rainy season), while the variance and standard deviations were 0.05 and 0.22 (dry seasons) and 0.06 and 0.24 (rainy season). Although the rainy period had slightly higher pH values, the difference between the two seasons was not significant (p >0.05).

Electrical Conductivity (EC): Electrical Conductivity (EC) is a measure of water capacity to convey electric current. It determines of levels of inorganic constituents in water (Awofolu and Rampedi, 2007) and signifies the amount of total dissolved salts (Morrison and Ekberg, 2001). Variations in the electrical conductivity of water samples in the study area are presented in Table 3. Electrical conductivity showed significant difference (p <0.05) between dry and rainy seasons. The maximum, minimum and mean values of EC in water samples between the two seasons were 299(µS/m), 10.3(µS/m), 164.1(µS/m) (dry season) and 650(µS/m), 51(µS/m), 443.2(µS/m) (rainy season). The cumulative variance and standard deviations of the EC in water samples were 7172.3 and 84.68 (dry season), and 43684.9 and 209 (rainy season). The higher values observed during the rainy season could be as result of the influence of the season

Total Dissolved Solid (TDS): Total Dissolved Solid (TDS) is a measure of total inorganic substances dissolved in water (ANZECC, 2000). It indicates the general nature of water quality or salinity. Variations of TDS in water samples between the two seasons are shown in Table 3. The maximum, minimum and mean values of TDS among water samples between the two seasons were 5.2 mg/l, 1.06 mg/l, 3.9 mg/l (dry season) and 465.2 mg/l, 168.9 mg/l, 303.1 mg/l (rainy season). The variance and standard deviation of TDS for the seasons were 2.4 and 1.5 (dry season) and 7793.5 and 88.3 (rainy season). From the analysis of water samples, total dissolved solid showed significant difference ($p < 0.05$) between dry and rainy seasons among the stations.

Variations in Turbidity: Turbidity is caused by suspended matter or impurities that interfere with the clarity of water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble coloured organic compounds, and plankton and other microscopic organisms. Table 3 shows the variations of turbidity in water samples among stations in both seasons. The maximum, minimum and mean value of turbidity in water samples in the study area were 5.2NTU, 1.06NTU, 3.9NTU (dry season) and 20.8NTU, 5.2NTU, 12NTU (rainy season). The variance and standard deviation of TDS for the seasons were 2.4 and 1.54 (dry season) and 37.5 and 7.3 (rainy season). The analysis showed significant difference ($p < 0.05$) between dry and rainy seasons among the stations.

Dissolved Oxygen (DO): Oxygen is probably the most important chemical constituent of stream water chemistry, because all aquatic organisms require it for survival. It reflects the physical and biological processes prevailing and the degree of pollution in water bodies. The variations of DO in water samples among stations in both seasons are presented in Table 3. The maximum, minimum and mean value of dissolved oxygen in water samples in the study area during the dry season were 130mg/l, 23mg/l, 89.9mg/l, while the rainy season returned 110mg/l, 79mg/l, 95.3mg/l. The variance and standard deviation of dissolved oxygen for the seasons were 1384.5, 37.2 (dry season) and 92.04, 9.6 (rainy season). The analysis showed no significant difference ($p > 0.05$) in the mean values of DO seasons among the stations between dry and rainy.

Biological Oxygen Demand (BOD): BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a water body to break down organic material present in a given water sample at certain temperature over a specific period. Table 3showed the variations of BOD concentrations in water samples among stations in both seasons. The maximum, minimum and mean value of biochemical oxygen demand in dry season were 16.7mg/l, 2.39mg/l, 9.9mg/l while the values for the rainy season were 20.64mg/l, 4.12mg/l, 12.6mg/l. The cumulative variance and standard deviations of BOD in water samples were 22.88 and 4.78 (dry season) and 45.5 and 6.7 (rainy season). The mean values of BOD among the water samples showed no significant difference ($p > 0.05$) between dry and rainy seasons.

Chemical Oxygen Demand (COD): Table 3 shows the variations of chemical oxygen demand in water samples from the study area. The maximum, minimum and mean value of chemical oxygen demand in dry season were 12.3mg/l, 5.6mg/l, 8.6mg/l and the values in rainy season were 60.7mg/l, 6.7mg/l, 32.5mg/l. The variance and standard deviation of chemical oxygen demand among water sample for the seasons were 6.39 and 2.52 (dry season) and 475.03 and 21.8 (rainy season). The values of COD among the water samples showed significant difference ($p < 0.05$) between dry and rainy seasons.

Phosphate (PO_4): Phosphate is an important parameter in assessing the potential biological productivity of stream water (Venkatesharaju, 2010). Variations of phosphate in water samples in the study area are shown in Table 3. The maximum, minimum and mean concentrations of phosphate in dry season were 3.44mg/l, 0.2mg/l, 1.6mg/l and that of the rainy season was 5.7mg/l, 1.5mg/l, 3.2mg/l. The variance and standard deviation of dissolved oxygen for the seasons were 1.99 and 1.41 (dry season) and 2.69 and 1.6 (rainy season). The values of phosphate among the water samples showed no significant difference ($p > 0.05$) between dry and rainy seasons.

Ammonia (NH_3-N): Ammonia is the by-product from protein metabolism excreted by fish and bacterial decomposition of organic matter such as wasted food, dead planktons, sewage etc. (Hala *et al.,* 2013). Variations of ammonia in water samples in the study area are shown in Table 3. The maximum, minimum and mean concentrations of ammonia in dry season were 2.91mg/l, 0.1mg/l, 1.3mg/l, while the values in rainy season were 8.12mg/l, 0.12mg/l, and 4.2mg/l. The variance and standard deviation of ammonia for the seasons were 1.24 and 1.1 (dry season) and 11.58 and 3.4 (rainy season). The values of phosphate among the water samples showed no significant difference ($p > 0.05$) between dry and rainy seasons.

Variations in Nitrate (NO_3-N): The presence of nitrate in water may result from excessive application of fertilizers or from leaching of wastewater or other organic waste into stream water (WHO, 1997). Table 3shows the variations of nitrate in water samples in the study area. The maximum, minimum and mean concentrations of nitrate in were 1.6mg/l, 0.02mg/l, and 0.5mg/l for the dry season and 2.5mg/l, 0.15mg/l and 1.6mg/l for the rainy season. The variance and standard deviation for the seasons were 0.41 and 0.6 (dry season) and 0.97 and 1.0 (rainy season). The analysis of nitrate among the water samples in the study area showed significant difference ($p < 0.05$) between dry and rainy seasons.

Sulphate (SO_4^{2-}): Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals (Shrinivasa and Venkateswaralu, 2000). Variations of sulphate concentrations in water samples are presented in Table 3. In dry season, the maximum, minimum and mean concentrations of sulphate in the water samples were 201.6mg/l, 10.2mg/l and

118.9mg/l, while in rainy season the values were 286mg/l, 17.56mg/l, and 158.3mg/l. The variance and standard deviation of sulphate for the seasons were 5825.9 and 76.32 (dry season) and rainy season were 10383.9 and 102.0. The variations of sulphate among sample stations in the study area revealed significant difference ($p < 0.05$) between dry and rainy seasons and along the sampling points.

Iron (Fe^{2+}): Iron in the stream water indicates possible contamination from inflows of waste rock dumpsites, geology of the stream channel and rock mineral types present (Taiwo, Olujimi, Bamgbose and Arowolo, 2012). Table 3 shows the variations of iron in water samples. The maximum, minimum and mean concentrations of iron in dry season were 0.3mg/l, 0.02mg/l and 0.1mg/l and 1.3mg/l, 0.04mg/l and 0.5mg/l in rainy season. The variance and standard deviation of iron for the seasons were 0.01, 0.11 (dry season) and 0.19, 0.42 (rainy season). The variations of iron among sample stations in the study area revealed significant difference ($p < 0.05$) between dry and rainy seasons and along the sampling points.

Calcium (Ca^{2+}): The variations of calcium concentrations in water samples for both seasons are presented in Table 3. The maximum, minimum and mean concentrations of calcium were 17.3mg/l, 5.6mg/l, 11.7mg/l (dry season) and 11.4mg/l, 3.1mg/l, 7.1mg/l (rainy season). The variance and standard deviation of calcium were 14.2 and 3.77 (dry season) and 14.2 and 2.6 (rainy season). The variations of iron among water samples stations in the study area revealed significant difference ($p < 0.05$) between dry and rainy seasons and along the sampling stations.

Alkalinity: Alkalinity is the measure of the ability of water to resist change in pH upon addition of acid, and it provides idea of natural salts present in water and it is primarily caused by carbonate, bicarbonate and hydroxide ions (Zahoor, *et al.,* 2015). The variations of total alkalinity among water samples in both seasons are shown in Table 3. The analysis of alkalinity showed significant difference ($p<0.05$) among samples and between dry and rain seasons. The maximum, minimum and mean concentrations of alkalinity in dry season were 3.16mg/l, 1.56mg/l and 2.3mg/l and rainy season were 5.44mg/l, 2.15mg/l and 3.4mg/l. The variance and standard deviation of alkalinity for the seasons were 0.292 and 0.54 (dry season) and 1.186 and 1.1 (rainy season).

Total Hardness: Water hardness is the property of water which prevents lather formation with soap and also increases the boiling point of water. It is an important criterion for ascertaining the suitability of water for drinking and domestic uses (Karanth, 1994). Variations of total hardness in water samples are shown in Table 3. The maximum, minimum and mean concentrations of total hardness in dry season were 74.6mg/l, 18.1mg/l and 47.8mg/l and in rainy season the values were 120.6mg/l, 24.3mg/l, and 83.8mg/l. The variance and standard deviation of total hardness for the seasons were 481.4, 21.9 (dry season) and 1037.1, 32.2 (rainy season). Total hardness in water samples showed significant difference ($p<0.05$) among samples and between dry and rainy seasons.

Variation in Heavy metals Characteristics of Imabolo Stream Water

Lead (Pb^{2+}): Lead is a toxic element that accumulates in skeletal structures. The toxic effects of lead decreases with increase water hardness and dissolved oxygen (Sanjoy and Rakesh, 2013). Lead variations in water samples for both seasons are presented in Table 3. The maximum, minimum and mean values of lead in dry season were 0.012mg/l, 0mg/l and 0.004mg/l, while the rainy season values were 0.05mg/l, 0mg/l, and 0.02mg/l. The variance and standard deviation of lead for the seasons were 0.0001 and 0.00049 (dry season) and 0.0004 and 0.02 (rainy season). The analysis revealed a significant difference ($p<0.05$) in the variations of lead concentrations among water samples stations in the study area between dry and rainy seasons and along the sampling stations.

Cadmium (Cd): Analysis of cadmium in drinking water is very important, because presence of cadmium in water can cause serious health problem in humans when such water is consumed (Adelekan and Alawode, 2011). Table 3shows the variations of cadmium in water samples from the study area for both seasons. The maximum, minimum and mean concentrations of cadmium in dry season were 0.003mg/l, 0mg/l, and 0.001mg/l while the rainy season values were 0.03mg/l, 0mg/l and 0.09mg/l. The variance and standard deviation of cadmium for the seasons were 0.0000 and 0.0009 (dry season) and 0.0001 and 0.01 (rainy season). The analysis showed significant difference ($p<0.05$) among samples in the study area between dry and rainy seasons and along the sampling stations.

Variation in Microbiological Characteristics of Imabolo Stream Water

Total Coliform Count: Total coliform count gives a clear indication of the general sanitary condition of water since this group includes bacteria of faecal origin and also may originate from growth in the aquatic environment. Variations of total coliform in water samples from the study area are shown in Table 3. The maximum, minimum and mean total coliform in dry season were 15.3(cfu/100ml), 28.5(cfu/100ml) and 10.4(cfu/100ml), while the values for the rainy season were 28.5(cfu/100ml), 6.0(cfu/100ml), 18.0(cfu/100ml). The variance and standard deviation of total coliform for the seasons were 14.5 and 3.8 (dry season) and 72.2 and 8.5 (rainy season). The analysis of total coliform in water samples showed significant difference ($p<0.05$) among samples and between dry and rainy seasons.

Escherichia Coli: The presence of the Escherichia coli is an indication of contamination of water supplies which can be attributed to the unhygienic conditions around water supply source which favours the growth of microorganisms. The variation in Escherichia coli in the water samples are presented in Table 3. The maximum, minimum and mean Escherichia coli in water samples during the dry season were 1.8(cfu/100ml), 0(cfu/100ml) and 0.98(cfu/100ml), while the values for the rainy season were 3.1(cfu/100ml), 0(cfu/100ml) and 1.41(cfu/100ml). The variance and standard deviation of Escherichia coli for the seasons were 0.49, 0.7 (dry season) and 1.26, 1.1 (rainy season). The differences in total coliform amongst stations were significant ($p<0.05$) between dry and rainy seasons.

Water Quality Index (WQI) Analysis of Imabolo Stream Water

Table 4: Water Quality Index of Imabolo Stream for both Rainy and Dry seasons

Sample Codes	LAND-USE TYPES	Rainy Season			Dry Season		
		WQI	**Class**	**Status (Brown et al., 1972)**	**WQI**	**Class**	**Status (Brown et al., 1972)**
S1	Forested	69.08	C	Medium	72.76	B	Good
S2	Agricultural	62.44	C	Medium	71.27	B	Good
S3	Residential	57.14	C	Medium	59.55	C	Medium
S4	Commercial	54.12	C	Medium	64.57	C	Medium
S5	Educational	49.30	E	Bad	69.43	C	Medium
S6	Industrial	51.14	C	Medium	64.77	C	Medium
S7	Transportation	49.63	E	Medium	64.77	C	Medium
Mean WQI		56.12	C	Medium	66.73	C	Medium

Water quality index analysis of the stream revealed significant variations from the upper course to the lower course during the rainy season. Water sample at forested land-use (Ogaji) returned value of 69.08, Agricultural land-use (Olubojo/St Charles College) was 62.44, Residential (Central Residential Area) was 57.14, Commercial land-use (Sabongari) was 54.12, Educational land-use (Kogi State College of Education Area) was 49.30, Industrial (Ojelanyi) was 51.14 and Transportation (Ojokodo) was 49.63 (Table 4). The WQI from the stations showed that the status water in the stream can be ranked as medium for all the stations except Kogi State College of Education Area and Transportation land-use zones that revealed bad status in terms of water quality categorization during this season. The water quality index among stations was in the pattern $S1>S2>S3>S4>S5<S6>S7$ which showed the decrease in the quality of water down the stream channel. The decrease in value along stations is a reflection of different types of pollutants entering the stream due to various activities such as discharge of domestic sewage, runoff water from agricultural lands near the banks of the stream (see Table 4)**.**

In dry season, the minimum and maximum water quality indexes were recorded at Central Residential Area and Ogaji. The calculated WQI values at Forested, Agricultural, Residential, Commercial, Educational, Industrial and Transportation land-uses were 7.2.76, 71.27, 59.55, 64.57, 69.43, 64.77 and 64.77 respectively. The water quality rating among the land-uses decreases from Forested land-use at Ogaji to the Transportation land-use at Ojokodo in this season. However, a sharp decrease was observed at Central Residential Area (59.55). The drop in water quality rating is probably due to contaminants from incessant activities such as solid wastes and excreta disposal directly into the stream, car wash effluents, washing of cloths, etc. that are constantly taking place at this section of the stream. In terms of water quality status, the values the water can be ranked as medium for all stations which is an indication of fair quality of water in the stream channel during this season (Table 4).

Implications of the Findings

The water quality of Imabolo stream is deteriorating, and parameters such as temperature, EC, turbidity, BOD, COD, PO_4^{2-}, NH_3-N, SO_4, Fe, Pb, Total coliforms, and E. coli returned values above World Health Organization (WHO) and NSDWQ recommended standards for human consumption. The results from the water quality analysis clearly revealed that seasonal variations exist in the physico-chemical and biological characteristics of the water quality of stream. The seasonal influence on the parameters indicated variations in the quality of water samples between the dry and the rainy season. Most of the studied variables showed higher values during the rainy season, an indication that the water from this stream should be not be used at this period. The possible sources of contaminants in this stream include agricultural and industrial activities within the stream environment as well as inorganic and organic wastes from household and runoff from the diverse land-uses.

Conclusion and Recommendation

The study of stream water chemistry is increasingly becoming an important focus of contemporary researches because of the problems arising from the diminishing quantity and quality of fresh water resources. Based on the findings of this study there is need to create public awareness with regards to the dangers associated with the intake of water from the contaminated stream. The continuous monitoring of the stream water quality is also essential for implementing appropriate remediation measures in order to safeguard the health of the users. Furthermore, certain activities such as dumping of wastes, washing of cloths, motorcycles, and cars, etc within the stream vicinity should be discouraged as that may have contributed to the pollution of the stream. Also, the practice of water treatment in the state should be strengthened, to protect the health of the users. Finally, there is the need to ensure that safe water sources in the area are protected, used, developed, conserved, managed and controlled in ways that meet the basic needs of the present and future generations. Therefore, government and communities should collaborate to organize sanitary and surveillance committees to protect the water sources in the rapidly urbanizing Ankpa urban area.

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