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Assessment of Surface Water Quality in Selected Locations in Abuja, Nigeria

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ABSTRACT

Surface water quality from different locations in Abuja, Nigeria was evaluated using Water Quality Index (WQI) approach to assess the suitability of the water for human consumption. The WQI was appraised through some important physicochemical and biological parameters such as pH, Total Dissolved Solids, Electrical Conductivity, Dissolved Oxygen, Turbidity, Total Hardness, Chemical Oxygen Demand, Sulphate, Nitrate, Chromium, Lead, Iron, Zinc, E. coli and Total Coliform using standard methods. Results obtained were compared with the World Health Organization (WHO) guidelines for drinking water. The profiles of the obtained results indicated that, the computed WQI values varied from 61.5053 to 105.4806 with an average value of 83.6655, indicating that the results oscillated between the "poor water quality" and "unsuitable for drinking purpose" categories, mostly with "very poor water quality" according to Weighted Arithmetic Water Quality Index (WAWQI) method. This showed that 66.67 % of the water samples fell within Grade D, 22.22 % fell within Grade C while 11.11 % fell within Grade E category, thus not suited as a source of drinking water. Residents within the city should be enlightened on the adverse effect of drinking polluted water and the need for treatment before consumption. With the current state of climatic change and population growth, these results can serve as a baseline study for management of the surface water within Abuja.

Keywords: Abuja, Assessment**,** Drinking purpose, Parameters, Water quality index

INTRODUCTION

Water is indispensable for every living thing on planet earth. Surface waters are large natural stream of water emptying into an ocean, lake, or other water bodies and usually fed along its course by converging tributaries (Ahaneku and Animashaun, 2013). Apart from being the domain of aquatic organisms, they also aid cultivation by supplying water for irrigation. Anthropogenic influences as well as natural processes are known to degrade surface waters and mar their use for drinking, industrial, agricultural, recreation or other purposes (Ashwani and Anish, 2009; Madilonga *et al.*, 2021).According to UNEP, water pollution has worsened since the 1990s in the majority of rivers in Africa (UNEP, 2016; Islam *et al.*, 2018).

The major source of clean and safe drinking water is mainly through the water supplied by government. Since this source is irregular, many of the inhabitants of most rural and urban communities in developing countries like Nigeria turn to fetching water from streams and rivers, which in most cases are not clean (Ochuko *et al.*, 2014). Research has shown that 80% of all the diseases which claim lives in the third world countries are directly related to poor drinking water quality (Ahaneku and Animashaun, 2013; Jeffre and Okuedo, 2015). Presently in Nigeria, high coliform values are typical characteristics of many surface waters. The high values of coliform reported for some river water samples confirm faecal pollution from domestic sewage, dumping sites and abattoir activities (Arimieari *et al.*, 2014; Jeffre and Okuedo, 2015; Andreea, 2017; Useh *et al.*, 2022). The increased application of commercial fertilizer and widespread use of new pesticides, insecticides, herbicides and weed killers in agricultural practices are resulting in a host of pollution problems from land drainage which has severe impact on water bodies, as most of the pollutants are resistant to natural degradation (Ejoh *et al.*, 2018).

Environmental monitoring of surface water in Nigeria showed that streams and rivers are presenting increasing trend of water pollution due to increased population, industrialization and urbanization (Arimieari *et al.*, 2014; Ejoh *et al.*, 2018; Olasoji *et al.*, 2019). The survival of life on earth will be threatened if the present rate of pollution continues unabatedly. The determination of water quality of most water bodies emerged out of the need to safeguard the quality of water available for mankind. Most of the studies related to the assessment of water resources use several water quality indices, among the most important are water quality index (WQI), water pollution index (WPI), and river habitat survey (RHS) (Andreea,2017; Islam *et al.,* 2018). The WQI which was first developed by Horton in the early 1970s is basically an attempt to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality (Ashwani and Anish, 2009; Ochuko *et al.,* 2014). After Horton a number of workers all over the world developed water quality indices based on rating of different water quality parameters. These include Weight Arithmetic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI) etc. which have been applied for evaluation of water quality in different areas (Shweta *et al.,* 2013; Ejoh *et al.,* 2018).

To evaluate the quality of river water for the purpose of domestic, irrigation and health use, there is need to ascertain the physicochemical and biological characteristics of the water samples and their acceptable levels of concentrations. Therefore, the aim of this study was to assess the surface water quality in selected locations in Abuja, Nigeria and to determine the extent to which various anthropogenic activities in the city impact on water quality using the Water Quality Index (WQI), which is a versatile tool for summarizing the water quality status of a water body.

MATERIALS AND METHODS

Study Area

Abuja city, capital of Nigeria is located in the central part of Nigeria, in the Federal Capital Territory (FCT; created 1976). It lies between latitude 9°4′N of the equator and longitude 7°29E of Greenwich Meridian The territory is located just north of the confluence of the Niger River and Benue River. It has borders with States such as, Niger to the West and North, Kaduna to the northeast, Nasarawa to the east and south and Kogi to the southwest. It has a landmass of approximately 7,315 km^2, with an estimated population of about 2.5 million and it is situated within the savannah region with moderate climatic conditions and also surrounded by abundant hills. The high altitudes and undulating terrain of the territory act as moderating influence on the weather of the territory. The annual total rainfall is in the range of 43.3 inches (1100 mm) to 63 inches (1600 mm).The major ethnic groups include the Afo, Fulani, Gwari, Hausa, Koro, Ganagana, Gwandara, and Bassa who are mainly farmers, civil servants, businessmen, artisans and entrepreneurs (Useh *et al.,* 2016).The city is highly populated due to urbanization with possible pollution sources impacting the surface waters including ablution facilities, domestic discharges, agricultural activities and dumping of refuse on open spaces and on the riverbank.

Sample Collection and Preservation

A total of twenty-seven (27)surface water samples were collected from nine (9) selected sites along three (3) communities [Kubwa (Phase 2 Site 1, Phase 4, PW); Gwagwa (Angwar Kirya, Chikin Garin, Angwar Basa); Gwagwalada (Ibuwa 1, Paiko, Dobi) and were coded KU1, KU2, KU3, GW1, GW2, GW3, GA1, GA2 and GA3 respectively]. Samples were collected once every month between the months of June and August, 2021. The samples were taken at a depth of 10–15 cm from the surface of the water, especially where the course of water was high, to acquire homogenized samples.The sample collection was done using 1-L plastic bottles, which were pre-rinsed with nitric acid and soaked overnight with distilled water. The samples were transported to the laboratory in a cooler of ice and was kept at a temperature of about 4°C prior to analyses.

Physicochemical and Biological Analysis

The standard methods adopted in investigating the physicochemical parameters of water samples were in consistence with the American Public Health Association series of Standard Methods of Examination of Water and Effluent (APHA, 2005) and all chemicals used were of AnalaR grade (BDH, England).

Water Quality Index (WQI)

The weighted Arithmetic index method (WAWQI) (Shweta *et al.,* 2013) was used for the calculation of WQI in this study due to suitability of the water for human consumption. In calculating the WQI,each parameter was assigned a unit weight (Wi) in the scale of 1–5, in which 1 represents the least health effect and 5 represents the adverse health effect the parameter causes when present in drinking water. The relative weight (Wr) was calculated according to Alobaidy *et al.,*(2010); Bouslah *et al.,*(2017); Wekesa and Otieno, (2022) using equation 1,

$$Wr = \frac{Wi}{\sum_{i=1}^{n} Wi} \qquad (1)$$

Where, Wr is the relative weight, Wi is the unit weight of ith parameter, n is the number of parameters. The calculated Wr values of each parameter are given in Table 1.

Table 1: Relative weight (Wr) of the water quality parameters

Parameters	WHO Standards	Unit Weight	Relative Weight
pH	6.5–8.5	4	0.06557
TDS (mg/l)	500	4	0.06557
Conductivity (µS/cm)	250	4	0.06557
DO(mg/l)	5	4	0.06557
Turbidity (NTU)	5	3	0.04918
Hardness (mg/l)	200	3	0.04918
COD (mg/l)	10	5	0.08197
SO_4^{2-} (mg/l)	250	3	0.04918
NO_3^- (mg/l)	50	5	0.08197
Cr (mg/l)	0.05	5	0.08197
Pb (mg/l)	0.01	5	0.08197
Fe (mg/l)	0.3	3	0.04918
Zn (mg/l)	3	3	0.04918
E.coli (CFU/100 ml)	0	5	0.08197
Coliform (MNP/100 ml)	0	5	0.08197
SUM		$\sum Wi = 61$	$\sum Wr = 1$

A quality rating scale (Qr) for each parameter was calculated according to Bouslah *et al.*,(2017); Wekesa and Otieno, (2022) and Olasoji *et al.*, (2019) using equation 2;

$$Qr = 100\left[\frac{Vc}{Vs} - \frac{Vi}{Vi}\right] \qquad (2)$$

Where, Qr is the quality rating, Vc is the observed value of ith parameter in the analysed water, Vs is the WHO recommended value of ith parameter, and Vi is the ideal value of this parameter in pure water which is 0 and is considered as 7.0 for pH and 14.6 mg/l for DO (Bouslah *et al.*, 2017; Wekesa and Otieno, 2022).The parameter subindex (SIi) was calculated as shown in equation 3;

$$SIi = Wr\ x\ Qr \qquad (3)$$

In computing the WQI, the sum of parameter subindices (equation 4) gives the water quality index, $WQI = \sum_{i=1}^{n} SIi$ --(4)

WQI was finally rated according to the water quality status as given in Table 2.

Table 2: Water quality status based on weight arithmetic water quality index method

WQI Value	Status of Water Quality	Grading	Possible Use
0-25	Excellent water quality	A	Drinking, irrigation and industrial use
26-50	Good water quality	B	Drinking, irrigation and industrial use
51-75	Poor water quality	C	Irrigation and industrial use
76-100	Very Poor water quality	D	Irrigation
Above 100	Unsuitable for drinking purpose	E	Requires proper treatment before use

Source: (Shweta *et al.*, 2013; Wekesa and Otieno, 2022)

Data Analysis

All determinations were conducted in triplicates and data generated were analyzed statistically by one-way analysis of variance (ANOVA) using (SPSS) version 25.0.

RESULTS AND DISCUSSION

Physicochemical and Biological Parameters

The results of physical, chemical, and biological parameters assessed in the study and their respective recommended standards are given in Table 3 while the descriptive statistics for all water quality parameters examined are shown in Table 4. The pH values of the surface water in the study area are between 6.73 and 6.94, with an average value of 6.83±0.07. According to WHO guidelines, the safe range of pH value for drinking water is 6.5-8.5. These pH values showed that the water environment in the study area is weakly acidic or almost neutral, and the pH values are within the allowable range in the entire area. pH is an important factor that determines the suitability of water for various purposes (Alobaidy *et al.*, 2010).Total Dissolved Solid (TDS) is a vital parameter which imparts an unusual taste to water and lessen its usage as potable water and the presence of TDS is an indication of saline water which can be as a result of discharge from industrial treatment plants (Tian *et al.,* 2021). Values obtained showed that TDS in all locations ranged between 75 mg/l and 143 mg/l with a mean value of 110.44±22.49 mg/l which indicated that TDS values were within the WHO permissible limit of 500 mg/l. The importance of Electrical Conductivity (EC) in the water sample is the ability to conduct electric current which is due to its measure of cations or dissolved salts present. This ability thatdepends on salinity, greatly affects the taste and thus has significant impact on the user acceptance of the water as potable (Adimalla and Venkatayogi, 2018; Olasoji *et al.,* 2019). The electrical conductivity value recorded ranged from 161 µS/cm to 485 µS/cm with a mean value of 297.78±117.11 µS/cm which was slightly higher than the WHO recommended value of 250 µS/cm. The results clearly indicated that water samples in the study area were considerably ionized and have high levels of ionic activities which could be from natural weathering of certain sedimentary rocks or may have an anthropogenic source, e.g. industrial and sewage effluent (Kumar *et al.,* 2017).

Dissolved oxygen (DO) values for all samples were below the WHO standard of 5 mg/l except in three sampling locations, KU3, GA1 and GA2, which had DO values slightly higher than WHO recommended standard. The levels of DO observed for the study range from 2.36 mg/l to 5.84 mg/l with an average value of 3.94±1.35 mg/l. DO is needed to support biological life in aquatic systems. It is one of the most vital factors in assessing the quality of a water body. Its deficiency directly affects the ecosystem of a river as it regulates the distribution of flora and fauna (Ahaneku and Animashaun, 2013). The low values of dissolved oxygen may be associated with the release of industrial waste and municipal discharge containing high concentration of organic matter, micro organisms and nutrient (Uddin *et al.,* 2014; Ahmed *et al.,* 2018).Turbidity is one of the most important parameters when considering water for the purpose of drinking (David *et al.*, 2020). The observed turbidity concentrations were between 6.04 NTU and 10.12 NTU with a mean value of 8.35±1.52 NTU. The values recorded for the studied samples were higher than the allowable level of 5 NTU recommended by the WHO for drinking water. Turbidity level of river or surface water such as the study area may be due to the effect of banks erosions, domestic wastewater discharge and the presence of suspended particles such as clay, silt, finely divided organic and inorganic matter, phytoplankton and other microorganisms (Emeka *et al.,* 2020).

Table 3: Results of analysed parameters of the surface water samples

Parameters	KU1	KU2	KU3	GW1	GW2	GW3	GA1	GA2	GA3	WHO Standards
pH	6.83	6.80	6.94	6.79	6.88	6.73	6.75	6.80	6.91	6.5–8.5
TDS (mg/l)	136	112	87	143	108	124	93	75	116	500
Conductivity (µS/cm)	427	254	176	485	392	325	187	161	273	250
DO(mg/l)	2.79	3.64	5.62	2.36	2.57	3.87	5.35	5.84	3.38	5
Turbidity (NTU)	6.63	8.27	10.06	7.51	9.18	7.56	6.04	9.76	10.12	5
Hardness (mg/l)	257	182	159	338	165	128	145	172	224	200
COD (mg/l)	16.05	11.68	14.73	13.95	17.36	13.81	15.47	18.64	15.02	10
SO_4^{2-} (mg/l)	7.52	9.17	4.79	3.86	1.95	6.52	4.84	2.89	6.47	250
NO_3^- (mg/l)	3.74	5.00	1.82	4.37	3.49	0.85	1.59	4.72	5.31	50
Cr (mg/l)	ND	ND	ND	0.01	0.01	0.03	0.01	0.04	0.02	0.05
Pb (mg/l)	0.03	0.04	0.02	0.03	0.05	0.04	0.02	0.03	0.02	0.01
Fe (mg/l)	0.72	0.39	0.37	0.58	0.81	0.64	0.82	0.49	0.64	0.3
Zn (mg/l)	0.05	0.02	0.06	3.72	3.10	1.63	0.03	0.01	0.08	3
E.coli (CFU/100 ml)	514	182	259	336	354	687	470	268	342	0
Total Coliform (MPN/100 ml)	7285	4936	2885	6074	4582	10271	2746	5003	3840	0

Total hardness of water is determined by the presence of soluble salts of calcium, magnesium and other heavy metals dissolved in it. Values obtained were within WHO permissive range of 200 mg/l except in some locations like KU1, GW1 and GA3 where the water appears to be very hard since the concentrations exceeded the recommended standards. The observed value ranged from 128 mg/l to 338 mg/l with a mean value of 196.67±66.14 mg/l. Hardwater with high concentration of minerals may have moderate health benefits. A number of ecological studies have shown a great significant inverse relationship between hardness of drinking water and cardiovascular diseases (Etim *et al.,* 2013; Useh *et al.,* 2022; Wekesa and Otieno, 2022). However, it can cause serious problems in washing and cleaning due to high mineral content present in hard water which prevents the foaming action of soap and detergents (Useh *et al.,* 2016).The COD in the water represents the degree of pollution of the water environment. The values observed were in the range of 11.68 mg/l and 18.64 mg/l with an average value of 15.19±2.04 mg/l which was higher than the WHO permissible limit of 10 mg/l COD is a measure of the total quantity of oxygen required to oxidize organic materials into carbon dioxide and water under strong oxidants (Adamu *et al.,* 2013). The degradation of organic matter in the water consumes the available DO, leading to the rapid depletion of available DO in water, resulting in high COD. The high COD values of the water samples indicated the presence of significant chemically oxidizable organic contaminants in the surface water, which infers that the surface water under study may not be safe for drinking (Useh *et al.,* 2022).

The concentrations of sulphate in all the samples analysed in this study ranged from 1.95 mg/l to 9.17 mg/l with a mean concentration of 5.33±2.30 mg/l which fell within the permissible limit of 250 mg/l recommended by WHO. Sulphate cannot readily be removed from drinking water, except by expensive process such as distillation, reverse osmosis or electrodialysis. It imparts a slightly milder taste to drinking water and no significant taste effects are detected below 300 mg/l (Etim *et al.,* 2013). Effluents from certain industries such as fermentation or sea food processing industry, photographic industry etc., may be a major source of sulphate on the receiving waters. Another significant source of sulphate to water systems is industrial pollutants containing oxides of sulphur, which convert to sulphuric acid in precipitation. Sulphate can also be produced by bacterial or oxidizing action as in the oxidation of organo-sulphur compounds (Uddin *et al.*, 2014).Nitrate concentration depends on the activity of nitrifying bacteria which in turn get influenced by presence of dissolved oxygen. In the present study the values of nitrate obtained were within the recommended standards for the entire water samples analysed. The data showed that the maximum value of NO_3^- at site GA3 was 5.31 mg/l and minimum value 0.85 mg/l at site GW3 with an average value of 3.43±1.63 mg/l. The possible sources of nitrate in the surface water could be from the atmosphere, surface runoff, sewage discharges, agricultural fertilizers and organic wastes (Ejoh *et al.*, 2018; Emeka *et al.,* 2020).

Table 4: Descriptive Statistics of the surface water parameters

Parameters	Min.	Max.	Mean	Std. Deviation	CV (%)
pH	6.73	6.94	6.8256	0.07126	1.04
TDS(mg/l)	75	143	110.4444	22.48950	20.36
EC(µS/cm)	161	485	297.7778	117.10548	39.33
DO(mg/l)	2.36	5.84	3.9356	1.34743	34.24
Turbidity(NTU)	6.04	10.12	8.3478	1.51511	18.15
TH(mg/l)	128	338	196.6667	66.13622	33.63
COD(mg/l)	11.68	18.64	15.1900	2.04426	13.46
Sulphate(mg/l)	1.95	9.17	5.3344	2.30021	43.12
Nitrate(mg/l)	0.85	5.31	3.4322	1.63098	47.52
Cr(mg/l)	0.01	0.04	0.0133	0.01414	106.32
Pb(mg/l)	0.02	0.05	0.0311	0.01054	33.89
Fe(mg/l)	0.37	0.82	0.6067	0.16553	27.28
Zn(mg/l)	0.01	3.72	0.9667	1.48783	153.91
Ecoli(CFU/100 ml)	182	687	379.1111	154.41134	40.73
TC(MPN/100 ml)	2746	10271	5291.3333	2357.76473	44.56

High levels of heavy metals in drinking water can cause poisoning, carcinogenesis and various diseases (Tian *et al.*, 2021). Chromium was not detected in all the three locations in Kubwa but present in trace amounts in other locations between the range of 0.01 mg/l and 0.04 mg/l with a mean concentration of 0.013±0.01 mg/l which was within the WHO recommended standard of 0.05 mg/l. The concentration of other heavy metals (lead, iron) ranged from 0.02 mg/l to 0.05 mg/l with a mean value of 0.03±0.01 mg/l and from 0.37 mg/l to 0.82 mg/l with a mean value of 0.61±0.17 mg/l respectively. According to WHO guidelines, the allowable concentration for Pb in water is 0.01 mg/l, and the limited concentration for Fe is 0.3 mg/l which indicated that the concentration of Pb and Fe exceeded the permissible level recommended by WHO for drinking water. Zinc was also present mostly in Gwagwa stations in the range of 0.01 mg/l and 3.72 mg/l with an average concentration of 0.97±1.49 mg/l. It exceeded the permissible level of 3.0 mg/l only in GW1 and GW2 with values of 3.72 mg/l and 3.10 mg/l respectively while its values in other stations were within the recommended standard. Fe in water imparts taste and promotes the growth of bacteria that accelerate the rusting process of ferrous metals that are exposed to water. Concentration above the permissible range may be as a result of weathering of minerals and rocks of Iron in the soil, and dissolution of iron natural deposit through leaching. Consumption of water containing high concentration of Fe can cause diabetes, mellitus, liver damage, arteriosclerosis, and other diseases (Emeka *et al.*, 2020). The negative effect of a high level of Pb present in the human body is damage to the kidney, central nervous system, brain, or even death (Adamu *et al.*, 2013). Among the heavy metals studied, lead is the most significant because it is very toxic and harmful even in small concentrations (Okoyomon *et al.*, 2021), it can harbour in the body tissue causing harm to humans as mentioned earlier. The high values recorded for the heavy metals in some of the locations of the river could be due to industrial discharge of effluent, indiscriminate disposal of domestic waste, runoffs, and atmospheric deposition (Ahaneku and Animashaun, 2013; Arimieari *et al.,* 2014; Hua *et al.,* 2016). The mean heavy metal concentration (mg/l) in the studied samples were in the following order Zn >> Fe >>Pb>> Cr.

The microbial population recorded showed *Escherichia coli*count ranged from 182 cfu/100ml to 687 cfu/100ml with a mean value of 379±154.41cfu/100ml and total coliform ranging from 2746 MPN/100ml to 10271 MPN/100ml with a mean value of 5291±2357.76 MPN/100ml. The coliform counts in all the water samples studied exceeded the WHO permissible limit of 0 coliform/100 ml bacteria in water. Escherichia coli is naturally present in the intestinal tracts of warm-blooded animals and it is widely used as an indicator of faecal contamination (David *et al.*, 2020; Madilonga *et al.*, 2021). David *et al.*, (2020) described faecal coliforms as the most relevant water quality parameter in the urban area of Petrópolis, mainly related to pollution caused by untreated domestic sewage. The potential sources of pollution have been linked to surface runoffs, discharge of sewage water, open defecation by free-ranging animals, dumping of diapers by the river bank, etc. (Jeffre and Okuedo, 2015; Madilonga *et al.*, 2021). The health hazards implication to those using the water is high as it is likely to sustain high growth of pathogenic organism. The consumption of faecal-contaminated water has been implicated in various disease outbreaks, such as diarrhoea and cholera (David *et al.*, 2020; Useh *et al.*, 2022). Arimieari *et al.*, (2014) reported that the consumption of raw vegetables irrigated with faecal-contaminated water in local areas could lead to stomach cramps, vomiting, and diarrhoea. The water samples under study in general fail to meet the standard of drinking water set by WHO, (2011).

Relationship of the Parameters of the Water Samples being investigated

Table 5 demonstrates the results of the correlation analysis of the parameters. The result showed that positive and negative correlations existed between the examined parameters. Statistically, a strong positive correlation (> +0.65) indicates that a change in one parameter will cause a similar change in the other parameter and a strong negative correlation (< -0.65) indicates that a change in one parameter will cause a change in the other parameter but in the opposite direction. From Table 5, a strong positive significant relationship was observed between TDS and EC (r = 0.900, p< 0.01).The sources of ions could be natural, i.e., geological condition such as weathering, lightening, waterfall, and from human activities such as domestic, agricultural and industrial wastes (Madilonga *et al.*, 2021).However, a strong negative correlation was observed between TDS and DO (r = -0.880, p< 0.01) as well as EC and DO (r = -0.926, p< 0.01) inferring that they could be from similar source.

Table 5: Pearson correlation coefficient matrix for the studied samples

	pH	TDS	EC	DO	Turbidity	TH	COD	Sulphate	Nitrate	Cr	Pb	Fe	Zn	Ecoli	TC
pH	1														
TDS	-0.195	1													
EC	-0.099	.900**	1												
DO	-0.025	-.880**	-.926**	1											
Turbidity	.728*	-0.455	-0.358	0.217	1										
TH	0.079	.679*	.695*	-0.615	-0.156	1									
COD	0.181	-0.449	-0.127	0.246	0.237	-0.123	1								
Sulphate	-0.153	0.369	-0.01	-0.148	-0.28	0.025	-.724*	1							
Nitrate	0.278	0.138	0.17	-0.348	0.368	0.555	0.061	0.094	1						
Cr	-0.343	-0.304	-0.26	0.314	0.263	-0.257	0.455	-0.357	0.017	1					
Pb	-0.226	0.24	0.435	-0.496	-0.03	-0.152	-0.012	-0.095	0.049	0.056	1				
Fe	-0.239	0.262	0.384	-0.359	-0.506	-0.009	0.387	-0.278	-0.233	0.048	0.153	1			
Zn	-0.128	0.505	.735*	-0.633	-0.095	0.402	-0.007	-0.505	-0.025	0.02	0.535	0.295	1		
Ecoli	-0.506	0.394	0.309	-0.168	-0.578	-0.17	0.034	0.106	-0.641	0.245	0.097	0.606	0.14	1	
TC	-0.538	0.585	0.516	-0.4	-0.343	0.085	-0.176	0.271	-0.216	0.315	0.483	0.101	0.306	.687*	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Further, a moderately positive significant relationship was observed between pH and turbidity (r = 0.728, p< 0.05), TDS and TH (r = 0.679, p< 0.05), EC and TH (r = 0.695, p< 0.05), EC and Zn (r = 735, p< 0.05) as well as E. coli and TC (r = 0.687, p< 0.05). Hence, the presence of E. coli can be used to infer the presence of coliforms. Then, a moderately negative significant correlation was seen between COD and sulphate (r = -0.724, p < 0.05) indicating that their sources are consistent and are closely related. Many other relationships between various quantitative variables were also seen with the least correlation values. These results of correlation can prove useful in understanding the relationships between the physicochemical and biological properties of the surface water samples (Useh *et al.*, 2022).

Table 6: Calculated water quality rating (Qr) of each parameter according to different locations

Parameters	KU1	KU2	KU3	GW1	GW2	GW3	GA1	GA2	GA3
pH	34	40	12	42	24	54	50	40	18
TDS (mg/l)	27.2	22.4	17.4	28.6	21.6	24.8	18.6	15	23.2
Conductivity (µS/cm)	170.8	101.6	70.4	194	156.8	130	74.8	64.4	109.2
DO(mg/l)	123.02	114.17	93.54	127.5	125.31	111.77	96.35	91.25	116.88
Turbidity (NTU)	132.6	165.4	201.2	150.2	183.6	151.2	120.8	195.2	202.4
Hardness (mg/l)	128.5	91	79.5	169	82.5	64	72.5	86	112
COD (mg/l)	160.5	116.8	147.3	139.5	173.6	138.1	154.7	186.4	150.2
SO_4^{2-} (mg/l)	3.01	3.67	1.92	1.54	0.78	2.61	1.94	1.16	2.59
NO_3^- (mg/l)	7.48	10	3.64	8.74	6.98	1.70	3.18	9.44	10.62
Cr (mg/l)	0	0	0	20	20	60	20	80	40
Pb (mg/l)	300	400	200	300	500	400	200	300	200
Fe (mg/l)	240	130	123.3	193.3	270	213.3	273.3	163.3	213.3
Zn (mg/l)	1.67	0.67	2	124	103.3	54.3	1	0.33	2.67
E.coli (CFU/100 ml)	-	-	-	-	-	-	-	-	-
Total Coliform (MPN/100 ml)	-	-	-	-	-	-	-	-	-

Table 7: Calculated subindex values (SIi) of each parameter according to different locations

Parameters	KU1	KU2	KU3	GW1	GW2	GW3	GA1	GA2	GA3
pH	2.2294	2.6228	0.7868	2.7539	1.5737	3.5408	3.2785	2.6228	1.1803
TDS (mg/l)	1.7835	1.4688	1.1409	1.8753	1.4163	1.6261	1.2196	0.9836	1.5212
Conductivity (µS/cm)	11.1994	6.6619	4.6161	12.7206	10.2814	8.5214	4.9046	4.2227	7.1602
DO(mg/l)	8.0664	7.4861	6.1334	8.3602	8.2166	7.3288	6.3177	5.9833	7.6638
Turbidity (NTU)	6.5213	8.1344	9.895	7.3868	9.0294	7.436	5.9409	9.5999	9.954
Hardness (mg/l)	6.3196	4.4754	3.9098	8.3114	4.0574	3.1475	3.5656	4.2295	5.5082
COD (mg/l)	13.1562	9.5741	12.0742	11.4348	14.2299	11.3201	12.6808	15.2792	12.3119
SO_4^{2-} (mg/l)	0.1480	0.1805	0.0944	0.0757	0.03836	0.1284	0.0954	0.0570	0.1274
NO_3^- (mg/l)	0.6131	0.8197	0.2984	0.7164	0.5722	0.1393	0.2607	0.7738	0.8705
Cr (mg/l)	0	0	0	1.6394	1.6394	4.9182	1.6394	6.5576	3.2788
Pb (mg/l)	24.591	32.788	16.394	24.591	40.985	32.788	16.394	24.591	16.394
Fe (mg/l)	11.8032	6.3934	6.0639	9.5065	13.2786	10.4901	13.4409	8.0311	10.4901
Zn (mg/l)	0.0821	0.0330	0.0984	6.0983	0.1623	2.6705	0.0492	0.0162	0.1313
E.coli (CFU/100 ml)	0	0	0	0	0	0	0	0	0
Total Coliform (MPN/100 ml)	0	0	0	0	0	0	0	0	0
WQI	86.5132	80.6381	61.5053	95.4703	105.48056	94.0552	69.7873	82.9477	76.5917

Table 8: Water quality index (WQI) and status of the studied samples

Water Source	WQI	Grade	Status
KU1	86.5132	D	Very Poor water quality
KU2	80.6381	D	Very Poor water quality
KU3	61.5053	C	Poor water quality
GW1	95.4703	D	Very Poor water quality
GW2	105.48056	E	Unsuitable for drinking purpose
GW3	94.0552	D	Very Poor water quality
GA1	69.7873	C	Poor water quality
GA2	82.9477	D	Very Poor water quality
GA3	76.5917	D	Very Poor water quality

Source: (Shweta *et al.*, 2013; Wekesa and Otieno, 2022)

Assessment of the Water Quality

Surface water within Abuja has declined in terms of water quality status which is possibly due to the increase in the population and human activities. The effect was quite evident from Tables 6 - 8. The quality of surface water under consideration in respect of drinking purpose has been established based on the WHO guidelines for drinking water (WHO, 2011). Table 8 summarized the computed WQI of the analysed water samples. WQI was employed in order to reveal the overall water quality status in a singular term which could be useful for the determination of suitable treatment and use.In this study, the profiles of the obtained results exposed that, the computed WQI values varied from61.5053 to 105.4806 with an average value of 83.6655, indicating that the results (Table 8) oscillated between the poor water quality and unsuitable for drinking purpose categories, mostly with very poor water quality. When relating the results of the computed water quality index with the classification according to Shweta *et al.*, (2013) and Wekesa and Otieno, (2022); it shows that 66.67 % of the water samples fall in Grade D and 22.22 % of the water samples fall in Grade C while 11.11 % of the water samples fall in Grade E category. Finally, it could be deduced that the domestic discharge and agricultural activities such as sewage water from rural localities, from animal farms and from industry are the main causes of pollution on surface water resources in this region and so the water should not be used without appropriate treatment.

CONCLUSION

Some physicochemical and biological properties of surface water within Abuja were assessed and the water quality status was evaluated using the WAWQI method. One of the limitations of WQI is that it does not account for microbial water quality parameters. The results of this study revealed that the surface water is not suitable for usage as drinking water. Also, the pattern of relative disparity of the coefficient of variation (C.V) showed that all the examined water parameters are heterogeneous; hence there is need for a routine monitoring of the water.

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