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Canadian Index Approach to Water Quality Assessment of Okulu River, Southern, Nigeria.

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Abstract: This study presents an evaluation of the effect of industrial wastewater discharged on Okulu river receiving water body. This was achieved by obtaining water samples from five sites. Water samples physicochemical characteristics analyzed include pH, Temperature, Electrical Conductivity, Turbidity, TSS, TDS, Chloride, Sulphate, Phosphate, DO, BOD, COD, Iron, Zinc, and Ammonia. The physicochemical characteristics of the surface water were within the allowable limits as prescribed by WHO and NSDWQ standards except for pH, Temperature, Turbidity, Dissolved Oxygen and Ammonia that were above the acceptable range. Although, there were significant difference at 95% confidence level within the sampling locations except for DO, Sulphate, and Ammonia. The results also revealed the status of the water quality using Canadian index approach, it shows that water quality index of different locations of the river ranged from 65 – 75, indicating the water quality category is Fair (64 -79), occasionally threatened or impaired and hence, unsuitable for human consumption and irrigational purposes. Therefore, prior to the utilization of the river water, it should be treated before human consumption.

Keywords— Canadian index approach, physicochemical, water pollution, water quality index.

1. INTRODUCTION

Water is one of the most essential needs of every living thing (human, animal, and plant) and most abundant natural resources on the surface of the earth [1], it is used for cooking, laundry services, cleaning, agricultural (irrigation purposes) and industrial activities [2], and also occupies about 70% of the earth's surface. It can be found both underground and on the surface of the earth [3]. Surface water is more contaminated as compared to groundwater [1, 4] because groundwater has self-cleansing ability and ease of treatment [5]. Water either surface or ground have been contaminated due to some factors such as increasing population, industrialization, urbanization, etc. Water travels through underground rocks and soils may pick up natural contaminants even with no human activity or pollution in the area [7, 8]. The increasing population and commercial activities have caused rapid increase in the volume of generated waste, from production to consumption activities, which may cause severe pollution [9]. Pollution is caused when a change in the chemical, physical or biological condition in the environment harmfully affects quality of human life, other animals and plants [10]. These are due to anthropogenic activities that have resulted in significant decrease of the quality of water and aquatic life [11]. Rivers play a major role in receiving and dispersal of municipal and industrial wastewater and runoff from agricultural land [12]. This is a serious issue because rivers are watershed's primary source of water for domestic, industrial, and agricultural uses. [13,14]. An increasing global concern is the anthropogenic cause of contamination of surface water bodies. [14,15]. Therefore, it is necessary to stop and manage river pollution and to have accurate information on the water quality for successful management. Therefore, this paper tends to provide quantitative assessment of Okulu river using a proven and globally accepted index approach of the quality of water.

2. MATERIALS AND METHODS

2.1 Sampling Collection

Sampling collection is known as an important step in wastewater analysis. There is need to find the origin of sample and how it is contained. Some of the parameters also change with time; therefore, time is regarded as very necessary when sample is collected, preserved during transportation for laboratory analysis. Before sampling, the containers were carefully washed and rinsed with distilled water. Five sampling stations (S1, S2, S3, S4, and S5) were established at intervals of 50 m along the stretch of Okulu River. samples were obtained in June from the designated sampling points. The samples were stored in an ice chest and transported immediately to the laboratory for analysis. They were properly labeled for easy identification according to APHA (2005)

2.2 Parameters for laboratory analysis

A detailed report is given on all the experimental methods according to APHA (2005). The water sample obtained from the various sample point were labeled for laboratory tests. Various samples were collected in a sample point and mixed together to form a general representative or average sample for that point. The test involves the determination of the major water control parameters. The physico-chemical parameters determined were pH, Temperature, Electrical Conductivity, Chloride, Total Suspended Solid, Sulphate, Turbidity, COD, BOD, Ammonia, Phosphate, Iron, Zinc.

2.3 In-situ measurement

Mercury in glass thermometer and multiple- parameter Horiba water checker was used to measure the Temperature, pH, TSS, TDS and conductivity. The probe was rinsed with distilled water before inserting into the water sample and the mode was put on for the parameter to be measured. The probe was stirred in the water sample and allowed to stand until a stable value is displayed. The mode was changed for the analysis of other parameters and the values recorded.

2.4 Chemical analysis

2.4.1 Determination of dissolved oxygen

Dissolved oxygen was determined according to APHA (2005). A well labelled clean 70 ml DO bottle initially rinsed with water sample from the station will be dipped below the water surface and allowed to fill to overflow in order to remove every bubble of trapped air. In the bottle filled with sample, 0.5ml manganous sulphate (Winkler -1) solution and 0.5ml alkali iodide azide reagent (Winkler-2) will be added, stopper placed in order to remove air bubbles from the sample and mixed properly with several inversions. The sample was set aside for a few minutes before being packed into a refrigerated box with ice blocks for transit to the laboratory for further investigation. To the water sample previously treated with Winklers 1 and 11 was in the laboratory added 0.5ml concentrated H_2SO_4, stopper placed and mixed for complete dissolution of precipitate. A 50 ml portion of the sample will be placed in Erlenmeyer flask, 5 drops of fleshly prepared starch will be added and titrated with 0.025N $Na_2S_2O_3$ (Sodium thiosulphate) solution. The titration was continued to the first disappearance of the blue colour using Horton (1970) methods to calculate DO mg/l.

$$DO = \frac{V \, x \, N \, x \, 800}{\text{ml of sample}}$$

2.4.2 Determination of ammonia (NH_3)

To a 5ml of sample or a portion diluted to 5ml, add 0.2ml of phenol, 0.2ml sodium nitroprusside solution, 0.5 oxidizing agent, mix thoroughly after each addition and allow to stand for 1 hour for colour development and measured absorbance at a wavelength of 630nm. This is in accordance to the procedure of American Public Health Association APHA, (1998).

2.4.3 Determination of phosphate

For determining the phosphate level in river water, the ascorbic acid method [19] was used. In a cuvette, 25ml of water will be introduced to an ascorbic acid-based reagent powdery pillow. The sample was left to stand for two minutes to allow for reaction. The absorbance and concentration in mg/l were measured using a HACH DR 2010 UV-Visible spectrophotometer at a wavelength of 890 nm. Ascorbic acid technique used was in agreement with (APHA, 1998).

2.4.4 Determination of Metals

The following heavy metal content (zinc, iron) was determined with the use of AAS as specified by (ASTM D 3557-95). Analysis for the metal of interest was by direct aspiration into the AAS. The concentration of each metal was determined by spraying the extracts into the flame, light rays from a hollow cathode lamp is shined through the flame which triggers the atoms of the element being determined to absorb radiation from the lamp. The absorption is proportional to the concentration of each element in each sample. Each element was detected with its own lamp. This is in accordance to the procedure of ASTM D 3557-95 in line with APHA, (1998)

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2.5 Water Quality Guidelines

The World Health Organization's [20] and the Nigeria Standard for Drinking Water Quality, [21] were adopted to calculate Canadian water quality index. using recognized physical and chemical properties of water that indicate that adverse effects may occur when the water quality criteria is exceeded, Similar procedure was described in Emeka *et al*. (2020),

2.6 Procedure of Canadian Water Quality Index

Water quality index is a useful tool that helps experts to translate vast amounts of water quality monitoring information into a simple overall rating [23]. The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) relates water quality data to the various beneficial uses of water by using relevant water quality guidelines as benchmarks. Every index is determined for a specific monitoring site and reference period. Each parameter measured values were compared to the relevant water quality standard. The percentage of parameters and tests that do not meet the standards, as well as the deviation from the guidelines for tests that do not meet the criteria, are represented in three factors that are employed in the index computation. These factors are scope (F1), frequency (F2), and amplitude (F3) were calculated using equations (1 to 3). The index yields a number between 0 and 100. A higher number indicates better water quality.

$$\text{CCME} = 100 - \left(\frac{\sqrt{\text{F1}^2+\text{F2}^2+\text{F3}^2}}{1.732}\right) \quad (1)$$

Scope (F_1): The scope factor represents the percentage of the total number of parameters that fails to meet the water quality guidelines at any time during the reference period.

$$\text{F1} = \left[\frac{number\ of\ failed\ parameters}{Total\ number\ of\ tests}\right] \times 100 \quad (2)$$

Frequency (F_2): The frequency factor denotes the proportion of individual tests that did not meet the water quality standards.

$$\text{F2} = \left[\frac{number\ of\ failed\ test}{Total\ number\ of\ tests}\right] \times 100 \quad (3)$$

When an individual parameter value within a sample exceeds the recommendation, the test fails. During the reference period, the total number of failed tests indicates the total number of failed parameter values in each sample. The total number of tests for a single site is determined by multiplying the average number of parameters per sample by the total number of samples collected during the reference period.

Amplitude (F3): The average deviation of failed test readings from their respective recommendations is represented by the amplitude factor. An excursion is the relative deviation of a failed test from the guideline, and is calculated as using equations (4) and (5):

When the value tested cannot exceed the limit

$$\text{Excursion}i = \left[\frac{failed\ test\ value}{guideline\ value}\right] - 1 \qquad (4)$$

When the value tested cannot fall below the guideline:

$$\text{Excursion}i = \left[\frac{guideline\ value}{failed\ test\ value}\right] - 1 \qquad (5)$$

The amounts by which specific tests are not in compliance is determined using equation (6):

$$\text{nse} = \frac{\sum excursion}{total\ number\ of\ tests} \qquad (6)$$

Where,the normalized sum of excursion from the guidelines is nse

The F3 factor is determined using equation (7) This scales the nse to provide a value between 0 and 100..

$$\text{F3} = \frac{nse}{(0.01nse+0.01)} \qquad (7)$$

Table 1. Water Rating for Canadian Water Quality Index Method

WQI Value	Rating of Water Quality
95-100	Excellent water quality
80-94	Good water quality
60-79	Fair water quality
45-59	Marginal water quality
0-44	Poor water quality

The results obtained were ranked into five categories as recommended by the Canadian Council of Ministers of Environment. These five categories for the assessment are as follows; Excellent: (CCME WQI Value 95-100) – Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. Good: (CCME WQI Value 80-94) – Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels. Fair: (CCME WQI Value 65-79) – Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels. Marginal: (CCME WQI Value 45-64) – Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels. Poor: (CCME WQI Value 0-44) – Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

2.7 Statistical Analysis

Single-factor analysis of variance (ANOVA) was used to compare the physicochemical properties of different sampling locations at 95% confidence level.

3. RESULTS AND DISCUSSION

Samples of surface water was collected from various location within Okulu river were analyzed on selected physicochemical characteristics of the water quality. Results obtained were compared with WHO and NSDWQ.

Results obtained from different locations showed that pH in the water sampling points of the river were 6, 5.8, 6. 5.9. 6.2 at SS1, SS2, SS3, SS4 and SS5 respectively. The results as shown in Table 4.3 were not within the allowable limit as directed by WHO and NSDWQ which indicates that the various locations of the river were highly acidic (Figure 1h). However, SS5 recorded the highest pH, followed by SS1 and SS2 while SS2 recorded the least. The acidity of the surface water may be attributed to discharge of untreated wastewater effluent into the water bodies, run-off from urban areas and leachates from improper functioning septic tank system and landfills. There was no significant difference among different location at 95% confidence level. Low pH can cause reproductive failure and local extinction of fish population due to low egg fertilization rates. Aquatic life disappears from acidifying streams. It also impedes many ecosystem processes that depends on proper biological enzymes function.

Table 2 shows that turbidity value ranged from 5.47 to 11.05 NTU in all locations, which were above the permissible limit for drinking water. High turbidity adversely affects the aquatic penetration of sunlight into water bodies [24]. The results obtained across all sampling points were significant at 95% confidential level.

Table 2: Physicochemical Properties of Water Sample from Five locations of Okulu River.

	Regulatory Guidelines

Parameters	SS1	SS2	SS3	SS4	SS5	WHO (2011).	NSDWQ (2015)
pH	6	5.8	6	5.9	6.2	6.5-8.5	6.5-8.5
Temp°C	29	32	28	29	29	25	-
EC (µS/cm)	36	29	27	33	30	1000	1000
DO (mg/l)	8.43	5.52	6	3.36	4.19	2	5
TDS (mg/l)	14.73	94.67	85.93	99.01	216	500	500
TSS (mg/l)	11.4	9.3	10	8.1	9.8	500	500
Chloride (mg/l)	10.48	12.19	7.53	15.52	9	250	-
Sulphate (mg/l)	7.32	5.11	8.2	2.93	2.7	200	-
Turbidity (NTU)	9.56	11.05	7.81	6.39	5.47	5	5
COD (mg/l)	32	31	38	25	28	100	200
BOD (mg/l)	21.17	33	19.6	27	15.92	40	30
Ammonia (mg/l)	3	1.89	2.73	0.91	9.2	1.5	1.5
Phosphate(mg/l)	0.06	0.13	0.41	0.36	0.49	5	5
Iron (mg/l)	0.1	0.19	0.04	0.1	0.03	0.3	0.3
Zinc (mg/l)	0.08	0.35	0.2	0.18	0.1	3	3

Dissolved oxygen is necessary for the life of fish and other aquatic organisms. Dissolved Oxygen (DO) value across all sampling points exceeded the threshold value as described by WHO (2011). High DO may be due to high volume and velocity of water flowing into the river because of frequent rainfall [25, 26]. The results obtained from different locations were analyzed using ANOVA, it showed that there was no significant difference at 95% confidence level.

Table 3: Failed Variables and Tests of Physicochemical Parameters of Surface Water Samples

Parameters	SS1	SS2	SS3	SS4	SS5	WHO (2011).
pH	6	5.8	6	5.9	6.2	6.5-8.5
Temp°C	29	32	28	29	29	25
DO (mg/l)	8.43	5.52	6	3.36	4.19	2
Turbidity (NTU)	9.56	11.05	7.81	6.39	5.47	5
Ammonia (mg/l)	3	1.89	2.73	-	9.2	1.5

The single factor ANOVA of EC results obtained in different sampling locations showed that there was significant difference at 95% confidence level. However, SS1 recorded the highest, followed by SS4 while SS3 recorded the least, the results were within the WHO and NSDWQ permissible limit.

High TDS may be attributed to the presence of sewage and industrial waste into the water body [27]. Results obtained showed that TDS values in all locations were within the permissible value as stipulated by WHO (2011). However, there was significant different at 5% significant level. TSS in all sampling locations (Figure 1n). The results obtained across all sampling points was significant at 5% confidential level. However, SS1 recorded the highest, next to SS5 while SS4 recorded the lowest. TSS values didn't exceed the permissible range as directed by WHO and NSDWQ.

Table 4: Calculated Excursion of Surface Water Samples at Five Sampling Locations

Parameter	SS1	SS2	SS3	SS4	SS5
pH	0.08	0.12	0.08	0.10	0.05
Temp°C	0.16	028	0.12	0.16	0.16
Dissolved Oxygen(mg/l)	3.22	1.76	2	0.68	1.10
Turbidity (NTU)	0.91	1.21	0.56	0.28	0.09
Ammonia(mg/l)	1	0.26	0.82	-	5.13

Phosphate concentrations in all samples were within the allowable limit. Phosphates are mostly derived through fertilizer, industrial cleaning, and insecticides, with natural sources including Phosphate-containing rock, as well as solid or liquid waste. Sulphate ions are present in natural water, and most of these irons are soluble in water. The concentration of sulphate in all samples is within the permissible range. At the 95% confidential level, the data observed across all sample locations were significant

Chloride is an important parameter surface water bodies often have low concentration of chloride as compared to groundwater. A high chloride concentration destroys metallic pipelines and buildings, as well as harming developing plants through irrigation. Chloride values were 10.48mg/l, 12.19mg/l, 7.53mg/l, 15.52mg/l, and 9mg/l which shows that Chloride concentration is within regulatory framework.

Figure 1d shows the results of BOD. The results revealed that BOD in all sampling locations were less than the allowable limit as prescribed by WHO (2011). Although, SS2 recorded the highest BOD of 33mg/l while SS5 recorded the lowest of 15.92mg/l. However, there was significant difference at 5% significant level.

The results shows that there was significant different ($P<0.05$) in Chemical Oxygen Demand ranging from 25 to 38 mg/l. However, COD was within the acceptable limit in all sampling locations as directed by WHO (2011) and NSDWQ (2015).

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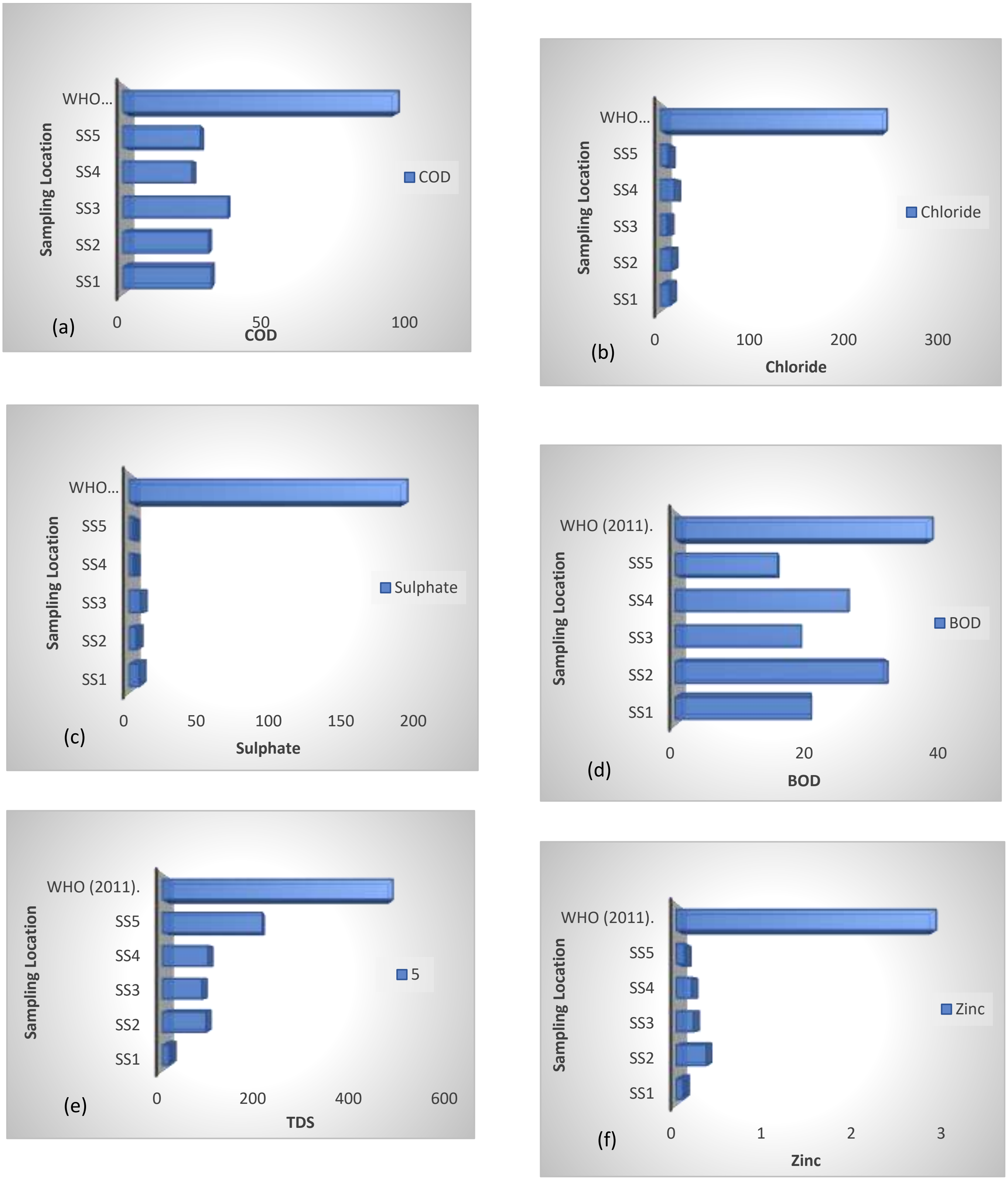

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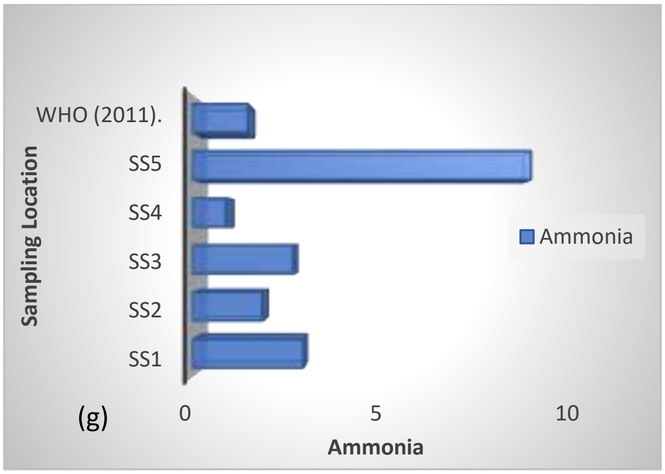

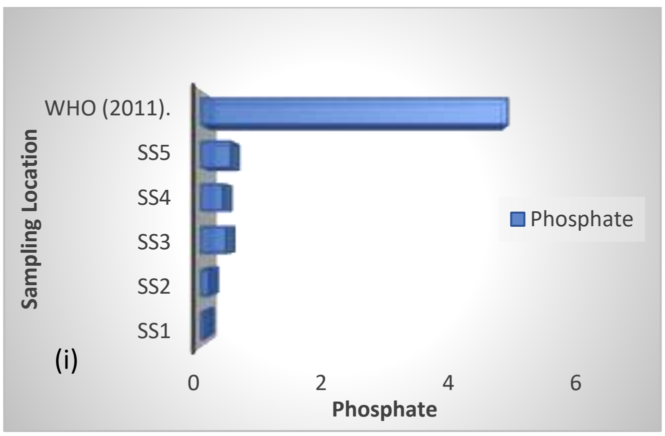

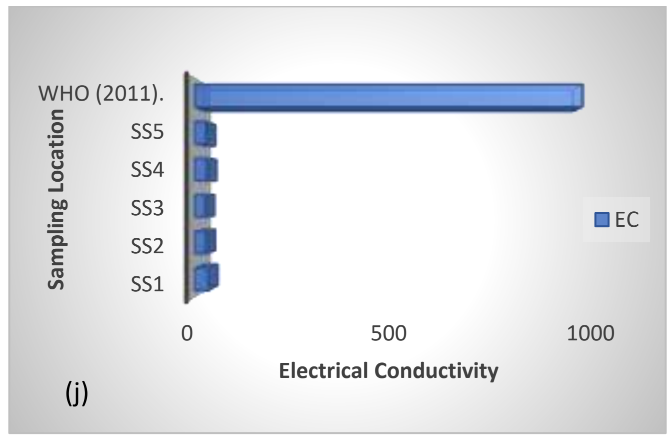

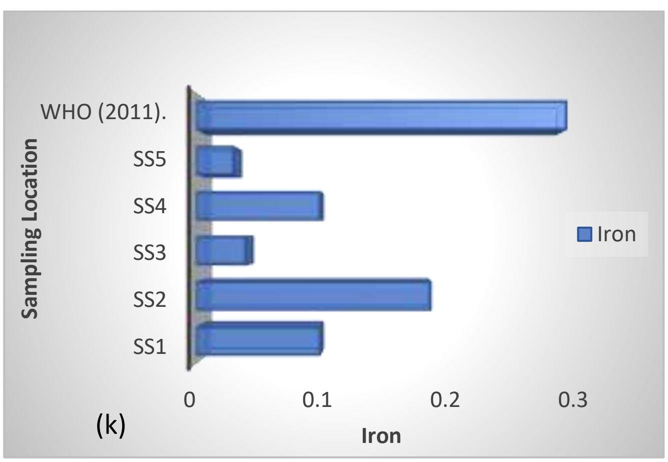

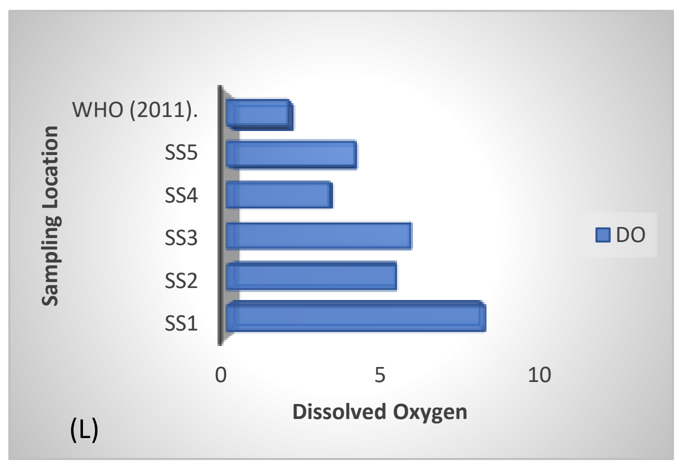

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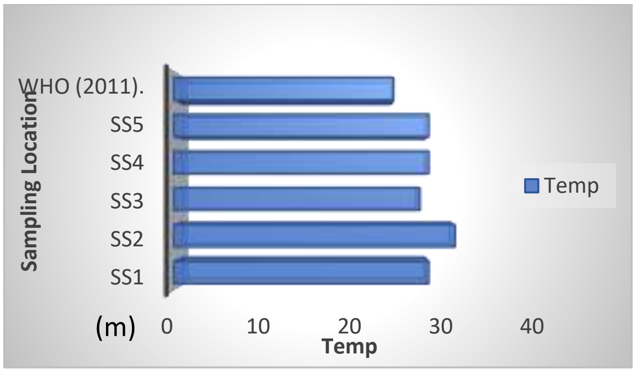
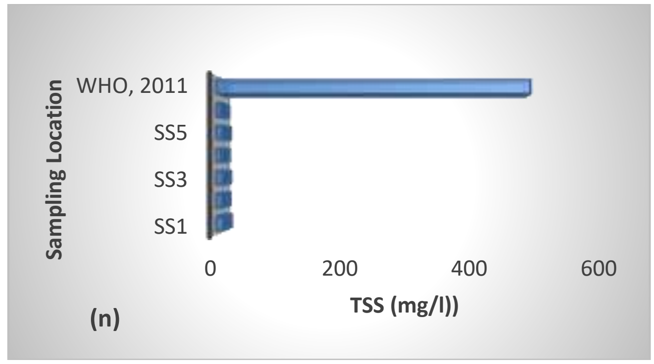


Figure 1: Physico-chemical Characteristics of Okulu River from Different Sampling Location: (a) COD (b) Chloride: (c) Sulphate: (d): BOD: (e) TDS: (f) Zinc: (g) Ammonia: (h) pH (i) Phosphate (j) Electrical Conductivity: (k) Iron: (l) Dissolved Oxygen: (m) Temperature: (n) TSS

Iron is known as dark-grey in coloration when in pure form and exists in groundwater as ferric Hydroxide [29]. The iron content in the findings obtained was less than 0.2 mg/l for all sites, which is under the WHO allowable limit of 0.3 mg/l.. Concentrations beyond the allowable range may be caused by weathering of iron minerals and rocks in the soil, as well as dissolving of iron natural deposits in groundwater bodies by leaching. Water with a high Fe content can induce diabetes, mellitus, liver damage, arteriosclerosis, and other disorders [29] and its toxic even when the concentration is low. However, there was significant difference at 5% significant level.

Ammonia is present in many surfaces and groundwater and, as such, comes from the microbiological activity of decomposition of organic nitrogen compounds; therefore, its presence in water is indicative of anew organic pollution [30]. Due to its high solubility in water. The toxicity of aqueous ammonia solutions is described in the unionized form.
The recommended value for NH_4^+ according to WHO standard is <1.5 mg/L. At SS1 the Ammonia parameter turned out to be in the range from 0.91 to 9.2mg/L, the minimum value to 0.91 mg/l and maximum value of 9.2mg/l. The values obtained for Ammonia in SS1, SS2, SS3 and SS5 locations exceeded WHO and NSDWQ permissive limit except for SS4 that was within the acceptable limit. However, the difference was not significant at 95% confidence level.

Zinc concentration were within acceptable limit in all samples. The results obtained across all sampling points was significant at 5% confidential level.SS2 recorded the highest concentration of zinc while SS1 recorded the least. However, there was significant difference at 5% significant level.



4.3 Water Quality Index

Water Quality Index (WQI) was determined using CCME which classify water quality according to the level of purity using the most commonly measured water quality variables [22] From the study, the water quality index calculated for Okulu River shows that the river had fair water quality as shown in Table 5 indicating that the water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels. Thus, rendering the river unsafe for drinking and irrigational purposes.

Table 5: Summary of Canadian WQI for different Sampling Locations of Okulu River

Location code	Location Name	WQI	interpretation
SS1	Sand mining, fishing, and farming	68.79	Fair, occasionally impaired (65-79)
SS2	Abattoir processing facility, car wash Auto mechanic garage	70.55	Fair, occasionally impaired (65-79)
SS3	Farming and dredging	70.58	Fair, occasionally impaired (65-79)
SS4	Fishing and NNPC Pipeline right of way	74.98	Fair, occasionally impaired (65-79)
SS5	Behind fertilizer processing plant	67.56	Fair, occasionally impaired (65-79)

4.1 CONCLUSION AND RECOMMENDATIONS

The study revealed the physicochemical characteristics of water collected from different locations of Okulu river in Southern, Nigeria. The following conclusion were drawn:

Selected physicochemical parameters were within the permissible limit whereas pH, Turbidity, Temperature, DO, and ammonia were higher than the permissible limits.

The analytical values on the determined WQI using the CCME revealed that the category of the water quality index was fair for all sampling locations indicating that the water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Thus, the water is unsafe for human consumption and irrigational purposes.

Therefore, this study furnishes the relevant authorities shouldered with the responsibility of managing surface water quality to address the water pollution problem by ensuring that companies operating within Okulu river to treat their effluents before discharging into the river bodies.

Hence, recommend for the treatment of Okulu river water before human consumption or for irrigational purposes.

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