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EVALUATION OF WATER QUALITY INDEX OF THE BRASS RIVER, BAYELSA STATE, SOUTH-SOUTH, NIGERIA

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Abstract

The purpose of this study is to evaluate some major physical, chemical variables and heavy metals in water of the Brass River, Bayelsa State, South-South, Nigeria and assess the potential ecological risk. The variables investigated were: pH, EC, turbidity, TDS, TSS, Cl^-, SO^{2-}_4, HCO^-_3, TH, TA, Ca^{2+}, K and Mg^{2+}, while the heavy metals were: Mn, Pb, Zn, Cu, Fe, Cd, Ni and Cr respectively. The results showed that pH, EC, TDS, Cl-, SO4, TA, TH, Na and K were appreciably high and the heavy metals: Fe, Pb, Zn, Cu and Cd, Ni was found at low concentration, Cr and Mn was below detection limits (BDL). Water quality index (WQI) was computed in order to assess suitability to beneficial purposes and assess the potential ecological risk of the Brass River. The results obtained on WQI from the four sampling stations (Mouth, Upstream, Downstream and Middlestream) fluctuate from 84.13 to 86.36. Hence, the Brass River water quality is considered good based on the water quality index (WQI). A comparative analysis of this study with FEPA, CCME standards for brackish water revealed that the results obtained in this study were within the permissible limits and concomitant with documented studies from similar environments.

Keywords: Water Quality Index; Heavy Metals; Brass River; Physico-Chemical; Ecological Risk; Evaluation.

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1. Introduction

In a coastal environment which play's host to multi-national oil company, subsidiary industries, LNG project, oil export terminal, constant ballasting of medium and small vessels, fishing, and other human activities, it is critical to think that the ecosystem may be at risk, and it needs to be protected from the animosity of contaminants.

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Coastal waters are defined as those marine systems that lie between the mean high-water mark of the coastal baseline and the shelf break, or approximately 20 nautical miles offshore when the continental shelf is extensive. This area will hereafter be referred to as coastal or near-coastal waters (USEPA, 2001).

Estuarine and coastal areas are complex and dynamic aquatic environment. When river water mixes with seawater, a large number of physical and chemical processes take place, which may influence of water quality (Morris et al., 1995; Prasanna and Ranjan 2010).

Egborge et al., 1986; Onwudinjo 1990; Emoyan et al., 2008 reported that the ecosystem is under threat from pollutants generated by a multiplicity of oil and gas related installations, including flow stations, oil well heads, loading terminals and tank farms.

Water quality is of influential and significant importance because of its role to human health, aquatic life, ecological integrity and sustainable economic growth (Vishnupriya Sowjanya et al., 2015).

Rivers play major roles to the community especially in the fishing industry and a source of water supply for people residing within the vicinity of the area. River contamination either directly or indirectly will affect humans as a final consumer. Although some of heavy metals are required as micronutrients, it can be toxic when present higher than the minimum requirements (Ahmad et al., 2009).

As water is one of the most important compounds of the ecosystem, but due to increased human population, industrialization, use of fertilizers in the agriculture and man-made activity. The natural aquatic resources are causing heavy and varied pollution in aquatic environment leading to pollute water quality and depletion of aquatic biota (Basavaraja et al., 2011)

The biogeochemical cycle of heavy metals and metalloids has been greatly accelerated by human activities. Accumulation of metal ions and metalloids in different compartments of the biosphere, and their possible mobilization under environmentally changing conditions induce a perturbation of both the structure and function of the ecosystem and might cause adverse health effects to biota (Fedotov and Mirò, 2008; Violante et al .,2010).

Some studies have been carried out on in different parts of the Brass River. This study was carried out to check the current status of physic-chemical parameters and heavy metals in water of the Brass River., it is expected that the results from this study would form a most recent baseline data for future pollution status of water in the area under study. The objectives of this study are: (1) to assess the concentrations of some major physico-chemical parameters and metals and to calculatethe Water Quality Index (WQI) in order to assess the suitability of water, (2) to compare the values with reference standards, and (3) to examine the river water quality using correlation coefficient (r)

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2. Materials and Methods

2.1. Study area

The Brass River is a natural river geographically located in Bayelsa state, Niger Delta region, Nigeria. Twon-Brass is a community on Brass Island in the Nun River estuary of Southern Bayelsa State, Nigeria, in the Brass Local Government Area. The river lies between the coordinates of latitude 04o 19' 1'' North and longitude 06o 14' 34'' East. Brass River is a distributary and it also flows into the Atlantic Ocean.

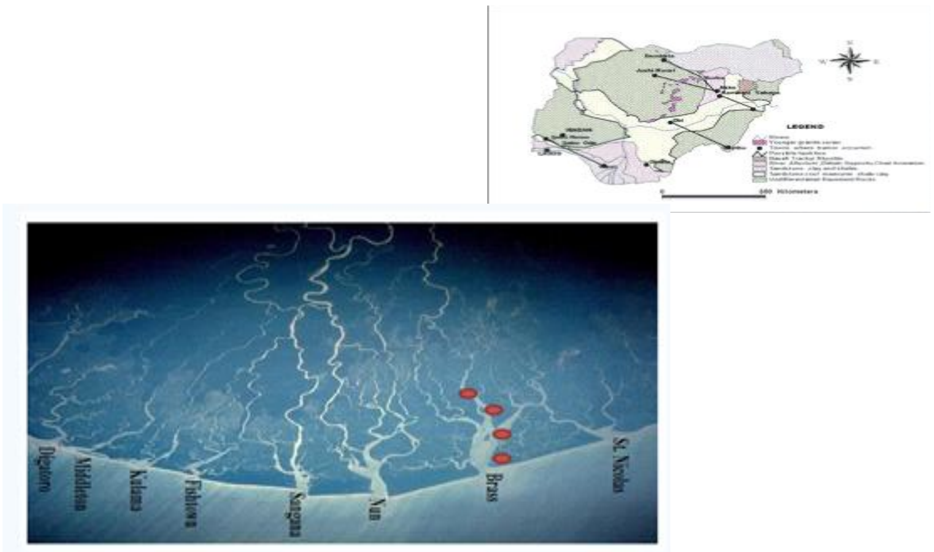

Figure 1: Map of Brass River showing sampling locations

2.2. Sampling and Analysis

Water samples were collected and analyzed for major physic-chemical parameters and heavy metals such as pH, Electrical conductivity (EC), Turbidity, Total Dissolved Solids(TDS), Total Suspended Solids(TSS), Chloride(Cl), Sulphate ($SO^{-2}{}_{4}$), Carbonate($HCO^{-}{}_{3}$), Acidity, Total alkalinity (TA), Total hardness(TH), Magnesium(Mg), Potassium(K), Sodium(Na), Manganese(Mn), Iron(Fe), Copper(Cu), Lead(Pb), Zinc(Zn), Cadmium(Cd), Nickel(Ni) and Chromium(Cr): according the standard methods (APHA 1995; Prasad et al., 2014).

2.3. Weighted Arithmetic Water Quality Index Method

The water quality index (WQI), first introduced by Horton (1965)] in United States, later by Brown et al., 1970 for determining water quality according to the suitability of water for various beneficial purposes, and has been used by various workers in their studies ((Tyagi et al, 2013; Goher et al, 2014; Kapoor et al., 2016; Ramakrishnaiah et al., 2009;) is mathematically expressed as:

$$\mathrm{WQI} = \frac{\sum_{i=1}^{n} \mathrm{QiWi}}{\sum_{i=1}^{n} \mathrm{Wi}}$$

Where: Qi=quality rating, Wi= relative weight

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The water quality index (WQI) scale consists of five grades (1-5) ranging from excellent to unsuitable (Table 1).

Table 1: Grads of Water Quality Index (WQI) and status of Water Quality Rating

CLASS	WQI VALUE	CATEGORY OF WATER QUALITY
1	<50	Excellent
2	50-100	Good
3	100-200	Poor
4	200-300	Very poor
5	>300	Unsuitable

3. Results and Discussion

Table 2-3 summaries the concentrations of physico-chemical parameters and heavy metals in (range, minimum, maximum, mean ± standard deviation) expressed as (mg/L), milligram / Liter, water of the Brass River. The variables and heavy metals are also represented graphically in Figs. 2-4

Table 2: Results of physicochemical parameters of water samples, Brass River

Parameters	SS1	SS4	SS3	SS2
pH	7.45	7.48	7.49	7.52
EC(µS/cm)	30219.00	24056.00	18023.00	23925.00
Tur.(mg/L)	2.00	3.00	4.00	2.00
TDS(mg/L)	19950.00	16880.00	11900.00	15790.00
TSS(mg/L)	< 0.50	< 0.50	< 0.50	< 0.50
Cl(mg/L)	13650.00	10343.00	7980.00	9400.00
SO^{-2}_4(mg/L)	2400.00	2050.00	1650.00	2100.00
HCO^-_3(mg/L)	51.00	47.00	39.00	54.00
Acidity(mg/L)	83.00	76.00	77.00	75.00
TA(mg/L)	85.00	80.00	65.00	90.00
TH(mg/L)	3760.00	2974.00	2160.00	3000.00
Mg(mg/L)	28.88	23.13	17.25	28.88
K(mg/L)	384.00	315.00	237.00	322.00
Na(mg/L)	12400.00	11035.00	9525.00	11175.00
Mn(mg/L)	BDL	BDL	BDL	BDL
Fe(mg/L)	0.15	0.12	BDL	0.01
Cu(mg/L)	0.02	0.01	BDL	0.01
Pb(mg/L)	0.15	0.07	0.03	0.05
Zn(mg/L)	0.04	0.03	0.02	0.04
Cd(mg/L)	0.03	0.02	0.01	0.02
Ni(mg/L)	0.16	0.13	0.01	0.11
Cr(mg/L)	BDL	BDL	BDL	BDL

SS1=MOUTH, SS2=DOWNSTREAM, SS3=MIDDLESTREAM, SS4=UPSTREAM

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Table 3: The Physico-chemical parameters of water sample sand WHO standards

Parameters	**Range**	**Mean±Std**	**CCME, 2008**	**FEPA, 1991**	**Lagos lagoon, Adebayo et al, 2007**	
pH	7.45-7.52	7.49±0.03	6.0-8.3	6-9	7.6	4.8
EC(μS/cm)	18023.00-30219.00	2.41E4 ±4979.85			761	1156.6
Tur.(mg/L)	2.00-4.00	2.75±0.96			11.6	573.6
TDS(mg/L)	11900.00-19950.00	1.61E4 ±3324.83	35000	2000		
TSS(mg/L)	0.50-0.50	0.50±0.01	2500	30	320	833.3
Cl(mg/L)	7980.00-13650.00	1.03E4 ±2408.96	19000			
SO^{-2}_4(mg/L)	1650.00-2400.00	2.05E3 ±308.22	2700			
HCO^-_3(mg/L)	39.00-54.00	47.75±6.50	140			
Acidity(mg/L)	75.00-83.00	77.75±3.60				
TA(mg/L)	65.00-90.00	80±10.80	115		766.6	445
TH(mg/L)	2160.00-3760.00	2.97E3 ±653.47	6250		1233.3	4083.3
Mg(mg/L)	17.25-28.88	23.03±4.74	NS			
K(mg/L)	237.00-384.00	3.14E2 ±60.26				
Na(mg/L)	9525.00-12400.00	1.10E4 ±1177.98				
Mn(mg/L)	BDL	BDL	NS			
Fe(mg/L)	0.01-0.15	0.12±0.02	NS			
Cu(mg/L)	0.01-0.02	0.01±0.01	NS	1.5		
Pb(mg/L)	0.03-0.15	0.07±0.05		0.05		
Zn(mg/L)	0.02-0.04	0.03±0.01	NS	1.0		
Cd(mg/L)	0.01-0.03	0.02±0.01		0.5		
Ni(mg/L)	0.01-0.16	0.13±0.02				
Cr(mg/L)	BDL	BDL		0.1		

The physical and chemical parameters are paramount, important and influenced by natural and manmade activities. They are also depends upon the depth of water body and ecological conditions of ecosystem (Mastan, 2014)

pH is a term used universally to express the intensity of the acid or alkaline condition of a solution. pH is considered as an important ecological factor and provides an important piece factor and piece of information on many types of geochemical equilibrium or solubility calculation (Shyamala et al., 2008; Prasad et al., 2014; Leizou et al., 2016).

The data for this study showed a narrow range of variation and near neutrality pH in all the studied locations, ranged from 7.45-7.52 with a mean value of 7.49±0.03 (Table 2-3). The water column above SS 4 recorded maximum pH of 7.52 when compared to the other locations closely followed by site SS3 and then SS2. Ahmad et al., 2009 documented a pH of 6.4±0.41 of the Sungai Kelantan, Kelantan, Malaysia. The pH values were slightly acidic, which is normal for tropical rivers. Similar results have also been reported by (Prassanna and Ranjan, 2010; Varadharajan and Soundarapandian, 2014). A comparative analysis of pH levels with CCME, 2008 (6.0-8.3) standards for brackish water and FEPA, 1991(6-9) standards revealed that the results obtained in this study were within the permissible limits and concomitant with documented studies from similar environments.

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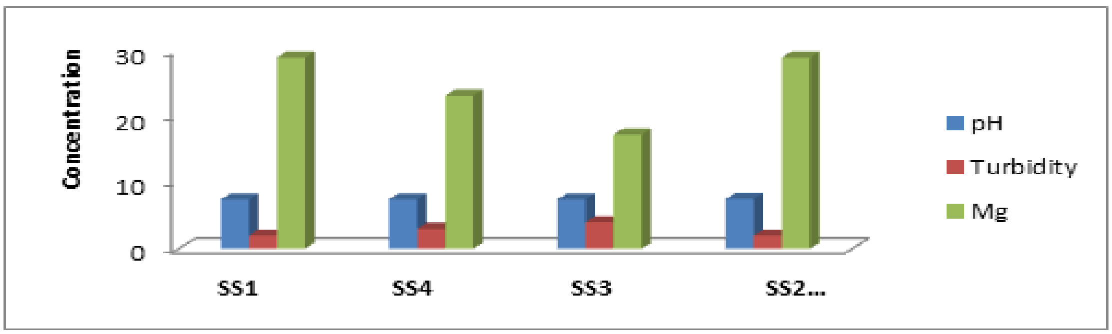
The Concentration (range, mean ± standard deviation) conductivity (μS/cm), turbidity(NTU) and TDS(mg/L) in the water ranged from 18023.00-30219.00, 2.00-4.00 and 11900.00-19950.00 with mean values of 2.41E4±4979.85, 2.75±0.96 and 1.61E4±3324.83 respectively (Table 1-2). Varadharajan and Soundarapandian, 2014 recorded turbidity minimum 27.0 and 28.0 during the summer season in the month of April and maximum was recorded 35.0 and 34.0 during monsoon season in the month of December.

The Concentration (range, mean ± standard deviation, mg/L) total suspended solutes (mg/L), chloride Cl^- (mg/L), sulphate,SO^{2-}_4(mg/L) and carbonate, HCO^-_3 (mg/L) of the water ranged from 0.50-0.50, 7980.00-13650.00, 1650.00-2400.00 and39.00-54.00 with mean values of 0.50±0.01, 1.03E4 ±2408.96, 2.05E3 ±308.22 and 47.75±6.50 (Table 2-3). The high concentration of Chloride is considered to be an indication of pollution due to high organic waste of animal origin (Rao et al, 2010; Kapoor et al, 2016). People accustomed to higher chloride in water are subjected to laxative effects (Dahiya and Kaur, 1999; Murhekar, 2011). Similar results have also been reported by (Prassanna and Ranjan, 2010; Varadharajan and Soundarapandian, 2014). A comparative analysis of TDS levels with CCME, 2008 (35000) standards for brackish water and FEPA, 1991(2000) standards revealed that the results obtained in this study were within the permissible and in concomitant with documented studies from similar environments.



SS1=MOUTH, SS2=DOWNSTREAM, SS3=MIDDLESTREAM, SS4=UPSTREAM.pH, Turbidity(NTU), Mg(mg/L)

Fig.2. Mg, Turbidity and pH in different stations from Brass River

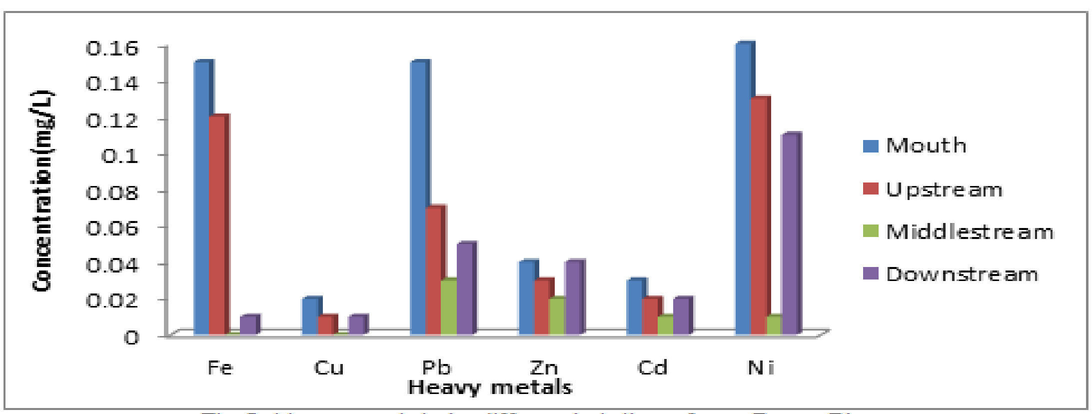


Fig.3. Heavy metals in different stations from Brass River

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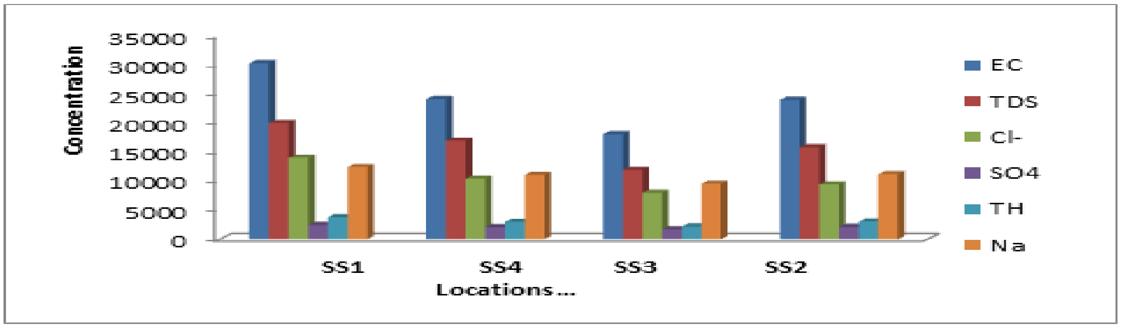

EC=Electrical conductivity (µS/cm), TDS=Total dissolved solids(mg/L), SO^{-4}_4 =Sulphate(mg/L), TH= Total hardness(mg/L), Na= sodium(mg/L)
SS1=MOUTH, SS2=DOWNSTREAM, SS3=MIDDLESTREAM, SS4=UPSTREAM, pH, Turbidity (NTU), Mg(mg/L)
Fig.4. Variables in different stations from Brass River

Total Alkalinity (TA) in mg/l: Alkalinity of water is its capacity to neutralize a strong acid and it is normally due to the presence of bicarbonate, carbonate and hydroxide compound of calcium, sodium and potassium (Murhekar 2011) and hardness is the capacity of water to neutralize soap and is defined as the sum of the Calcium and Magnesium concentration. Hardness increases the boiling point of water. (Trivedy and Goel, 1986).

The Concentration (range, mean ± standard deviation, mg/L) of total alkalinity, HCO^-_3(mg/L (mg/L) and total hardness (mg/L) in the water ranged from 65.00-90.00, 39.00-54.00 and 2160.00-3760.00 with mean values of 80.00±10.00, 47.75±6.50 and 2.97E3±653.47 respectively(Table 1-2). A comparative analysis of hardness levels with CCME, 2008(6250) standards for brackish water and FEPA, 1991 standards revealed that the results obtained in this study were within the permissible limits and in concomitant with documented studies from similar environments.

The Concentration (range, mean ± standard deviation, mg/L) Mg, K, Na in the water ranged from 17.25-28.88, 237.00-384.00 and 9525.00-12400.00 with mean values of 23.03±4.74, 3.14E2±60.26 and 1.10E4±1177.98 respectively (Table 2-3). Magnesium and calcium are directly related to hardness (Murhekar 2011). A comparative analysis of Mg, K and Na levels with CCME, 2008 standards for brackish water and FEPA, 1991 standards revealed that the results obtained in this study were within the permissible limits and in concomitant with documented studies from similar environments.

Table 4 Correlation of various variable of the Brass River

	pH	TDS	TURB.	Cl^-	SO_4^{2-}	EC	Mg	Cu	Zn	Pb	Cd	Ni
pH	1.00											
TDS	-0.592	1.00										
TURB.	0.060	-0.807	1.00									
Cl^-	-0.770	0.995	-0.683	1.00								
SO_4^{2-}	-0.468	0.980	-0.904	0.923	1.00							
EC	-0.581	0.989	-0.844	0.966	0.991	1.00						
Mg	-0.582	0.991	-0.841	0.966	0.991	1.000	1.00					
Cu	-0.566	0.988	-0.853	0.961	0.993	1.000	1.000	1.00				
Zn	-0.060	0.807	-1.000	0.683	0.904	0.844	0.841	0.853	1.00			
Pb	-0.812	0.918	-0.629	0.994	0.884	0.938	0.937	0.931	0.629	1.00		
Cd	-0.593	0.984	-0.838	0.970	0.988	0.999	0.999	0.999	0.838	0.946	1.00	
Ni	-0.989	0.658	-0.178	0.835	0.558	0.663	0.663	0.649	0.178	0.877	0.678	1.00

Correlation is significant at the 0.05 level (2-tailed)
Correlation is significant at the 0.01 level (2-tailed)

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The concentration (mg/L) of Mn, Fe, , Cu, Pb, Zn, Cd, Ni and Cr varies between 0.01-0.15, 0.01-0.02, 0.03-0.15, 0.02-0.04, 0.01-0.03 and 0.01-0.16 with mean values of 0.12±0.02, 0.01±0.01, 0.07±0.05, 0.03±0.01, 0.02±0.01 and 0.13±0.02 (Table 2-3) It was observed that manganese and chromium were below detection limit (BDL) and Fe Cu, Pb, Zn, Cd and Ni showed appreciable accumulation in the water samples. A comparative analysis of heavy metals level with CCME, 2008 standards for brackish water and FEPA, 1991 standards revealed that the results obtained in this study were within the permissible limits and in concomitant with documented studies from similar environments (Kalu et al, 2015;Olusola and Festus, 2015; etc). The correlation matrixes for the different water quality variables for the Brass River water are presented (Table 4). High positive correlation coefficient was observed between the parameters, and can also be attributed to same origin, while the metals with negative correlation is an indication of distinctive sources for the metals in the river (Amadi, 2012): Zn-Cu(r=0.853), Pb-Cu(r=0.931),Pb-Zn(0.639),Cd-Cu(r=0.999), Cd-Zn(r=0.838), Cd-Pb(0.946), Ni-Cu(0.649), Ni-Zn(0.178), Ni-Pb(0.877), Ni-Cd(r=0.678), chloride ion and TDS(r=0.995), SO^{2-}_4 and TDS (r=0.980), SO^{2-}_4 and chloride ion (r=0.923), conductivity and TDS (r=0.989), conductivity and chloride ion (r=0.966), Mg and TDS(r=0.991), Mg and chloride ion (r=0.966), chloride ion and Cu(r=0.961) Tale 3. Magnesium and chloride are highly interrelated among themselves. This interrelationship indicates that the hardness of the water is permanent in nature (Ramakrishnaiah et al, 2009)

The environmental state of the water was determined by the water quality index WQI according to (Horton 1965; Brown et al., 1970; Tyagi et al., 2013) the scale of the water quality is classified into five classes of water quality (Table 4). Investigations on water quality revealed appreciable differences between the CCME, 2008 standards, however the water quality is far from excellent. The high value of WQI at the stations had been found to be mainly due to the high values of pH, EC, TDS, Cl-, SO4, HCO3, TA and TH. Furthermore, it was found that there is a very strong correlation coefficient between them. The result shows that the water quality index (WQI) place Brass River in good category

WQI indicates the quality of water in terms of index number which represents overall quality of water for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters were taken into consideration for the calculation of water Quality index (WQI) .The indices are among the most effective ways to communicate the information on water quality trends to the general public or to the policy makers and in water quality management (Rao et al., 2010).

Table 5: Water Quality Index of Brass River

SAMPLE CODE	LOCATIONS	WQI VALUES	WATER QUALITY CATEGORY
SS1	Mouth	85.36	Good
SS4	Upstream	85.13	Good
SS3	Middlestream	84.13	Good
SS2	Downstream	86.36	Good

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4. Conclusion

The weighted arithmetic water quality index (WQI) is a powerful and versatile technique that categories the water quality according to the suitability of water for various beneficial purposes using the most commonly measured water quality parameters. Most environmentally important physico-chemical parameters and heavy metals being pH, EC, turbidity, TDS, TSS, Cl^-, SO^{2-}_4, HCO^-_3, TH, TA, Ca^{2+}, K, Mg^{2+} Mn, Pb, Zn, Cu, Fe, Cd, Ni and C were investigated. The result showed that there was no significant change in the pH, values ranged from 7.45 to 7.52 during the observation period. Hence, on the basis of water quality index (WQI) it can be concluded that the water quality at all sampling stations (Mouth, Upstream, Downstream and Middlestream) in Brass River was good and within the maximum allowed FEPA, CCME brackish water standards, however, the Brass River water quality status is far from excellent. Consequently, the study recommended protection of the biodiversity and aesthetic value of the Brass River, to achieve this, allochthonous inputs should be devoid of harmful chemicals.

Competing Interests

Authors have declared that no competing interests exist.

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