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Water quality assessment of Ntawogba Stream in Port Harcourt metropolis, Rivers State, Nigeria

Kalagbor Ihesinachi A.[1*], Echem Ogbonda G.[2] and Banwo Elechi[2]

[1]Research and Development Centre, Ken Saro-Wiwa Polytechnic, P. M. B. 20 Bori, Rivers State, Nigeria.
[2]Department of Science Laboratory Technology, School of Applied Sciences, Ken Saro-Wiwa Polytechnic, P. M. B. 20 Bori, Rivers State, Nigeria.

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Ntawogba stream is one of the natural water bodies that drain the marshy swamp forest water from Port Harcourt municipality into Amadi Creek which empties into the Bonny estuary. Water quality assessment was carried out for three consecutive months (July - September) across three sampling points (upstream, midstream, and downstream). The physical parameters pH, temperature, EC, and turbidity were measured *in-situ*. The concentration of the anions Cl^-, NO_3^- and PO_4^{2-} were determined using standard analytical methods according to APHA 1998. TSS and TDS were determined gravimetrically while the levels of Mg and Ca were determined titrimetrically. Spectroscopic analysis was carried out for nine heavy metals (Cd, Zn, Cr, Cu, Ni, Fe, Mn, Co, and Pb) using AAS. The microbial population was measured by the standard plate method using nutrient agar. Pearson correlation coefficients provided considerable insight into the water quality of this stream and the correlation between the various parameters. High correlation coefficients are observed between parameters. ANOVA results showed that there was no significant difference in the mean values of the parameters for the period of study. Ntawogba stream is highly polluted and there is an urgent need to address this problem to protect the water body, maintain good water quality and enhance its use.

Key words: Bonny estuary, heavy metals, microbial population, Ntawogba stream, pollution, Pearson correlation, water quality.

INTRODUCTION

The contamination of groundwater and the discharge of toxic substances are some of the processes that lead to eutrophication of surface waters. They are also for the degradation of water quality (Stoner and Albrey, 2017). Anthropogenic activities have been reported to show spatial variabilities in surface water quality parameters in India (Hamid et al. 2020) and Romania (Dunea et al., 2020) Various factors influence the water quality of streams (Sharma et al. 2016) and river basins in Africa (Klubi et al. 2019, Houssou et al. 2017, Karikari and Ansa-Asare, 2006). Nigeria has abundant water resources that are unevenly distributed. Inland water bodies have

*Corresponding author. E-mail: ksinachi@yahoo.com or kalagbor.ihesinachi@kenpoly.edu.ng.

been estimated to occupy 900 km^2 representing 0.1% of the total landmass while the coastal area stretches up to 853km (Ekiye and Luo, 2010). There are four principal surface water basins in the country, the Niger basin, Lake Chad Basin, the Southwestern littoral basin, and the Southeastern littoral basin. This last basin has its major watercourses as the Cross River and Imo River. The rivers and streams in Rivers State fall under this basin. There are three principal streams in Port Harcourt metropolis namely Ntawogba, Miniweja, and Miniokoro (also known as Rumuogba-Woji stream). These streams finally empty into the Bonny estuary and the Atlantic. Ntawogba and other streams play important roles in the lives of the people who are agrarian and indulged mostly in farming and fishing before the water bodies within the metropolis and beyond became too polluted. With the relatively small nature of the populations in the settlements in the early 20th century, the wastes generated and discharged into the environment had a little or insignificant impact on the environment (Onuoha et al. 1991). The advent of civilization and urbanization has attracted the human population, urban growth, industrial activities, infrastructural development, intensive farming, and other economic activities (Arimieari et al. 2014, Onderka et al. 2010, Amadi et al. 1997, Ubalua and Ezereonye, 2006). Ntawogba stream serves as a source of water to some communities downstream. It serves a variety of purposes such as irrigation for proximate farmlands, drinking, and other domestic uses without prior treatment. This water body was known to have played a crucial role in the growth, sustenance, and development of the communities within and around it. Paradoxically, it has undergone degradation in modern times due to various anthropogenic activities. The prime cause of critical unsanitary conditions of the water body is due to the lack of facilities for the collection and disposal of waste effectively in the city as in other fast-growing cities (Ideriah et al. 2012, Akoto et al. 2008). Waste generated by industries and household has continued to increase and are impacting on surface water quality generally. Industrial and domestic effluents have been known to have a continued impact on surface water quality (Kuforiji and Ayandiran, 2012, Aremu et al. 2000, Muhibbu-din et al. 2011, Okoh, 2007). Pollution of the aquatic ecosystem by heavy metals constitutes some of the most dangerous toxicants that can bio-accumulate in living tissues (Omoregie, 2002).The health hazards implication to ignorant users is high as the water is likely to sustain the high growth of pathogenic organisms. Assessment of Ntawogba stream is not only for its suitability for human consumption but also with its agricultural, industrial, recreational, and commercial uses as well as its ability to sustain aquatic life. This study aims at providing additional information to existing data on water quality assessment of this water body (Ntawogba stream) so that it can be protected and its water quality improved upon to enhance its use.

MATERIALS AND METHODS

Study area

Port Harcourt is one of the big cities in the Niger Delta region of Nigeria and is located in the South-Eastern part of Rivers State as shown in Figure 1. Ntawogba is a single-channel low gradient freshwater body (Amangbara and Gobo, 2007) which lies on the extreme west of Port Harcourt metropolis between the approximate longitude 6°58' to 7°06' E and latitude 4°40' to 4°55' N (Gobo and Abam,2006). Its upstream is Rumueme and Rumuepirikom in Obio/Akpor local government area then flows through the Government Reservation Area (GRA) Phase III, a less densely populated area to a more densely populated and high economic activity areas which are the Diobu axis of Port Harcourt local government area and empties into the Amadi Creek. The map of the study area is presented in Figure 2. Pictures taken from the sampling points are presented as Pictures 1, 2, and 3.

Sampling

Water samples were collected for three months (July, August, and September). These months are the periods of the rainy season. The samplings were done at different points, upstream (SP 1), midstream (SP 2), and downstream (SP 3) by dipping the sample container against the flow direction. These sampling points were GRA (276848.885E, 533582.882N), Olu Obasanjo Diobu (277750.291E, 531138.159N), and Aba Road (278578.896E, 530401.009N), respectively. The samples were then transported in a cooler box and taken to the research laboratory for the various analyses.

Analytical methods

Physicochemical analysis

The pH of the water samples was determined *in-situ* using a pH meter (Model 112). The temperature of the water was also measured at the site of sample collection using a calibrated mercury-in-glass thermometer that was NIST certified with a calibration range of ±0.5°C. Electrical conductivity readings were obtained using a Hanna conductivity meter (Model EC 215) and turbidity values were determined using a standardized Xin Rui Waz-IB turbidimeter. Total suspended solids (TSS) and total dissolved solids (TDS) were determined by gravimetric methods. The dissolved oxygen (DO) was measured using a portable oxygen analyzer (Model JPB-607). Samples for Biochemical Oxygen Demand (BOD) were incubated in the Shivaki incubator (PID-906 Model) for 5 days. Measurements taken were reported as BOD_5. Chemical Oxygen Demand (COD) was determined using the open reflux method with the samples being preserved using concentrated H_2SO_4. The anions, Cl^-, NO_3^- and PO_4^{3-} were determined using the argentometric method, cadmium reduction method, and the ascorbic acid method, respectively. Alkalinity, Mg, and Ca present in the samples were determined titrimetrically according to APHA 1998. The chemicals used were of analytical grade Table 1.

Heavy metals analysis

The digestion was carried out with 5 ml concentrated HNO_3 in 100

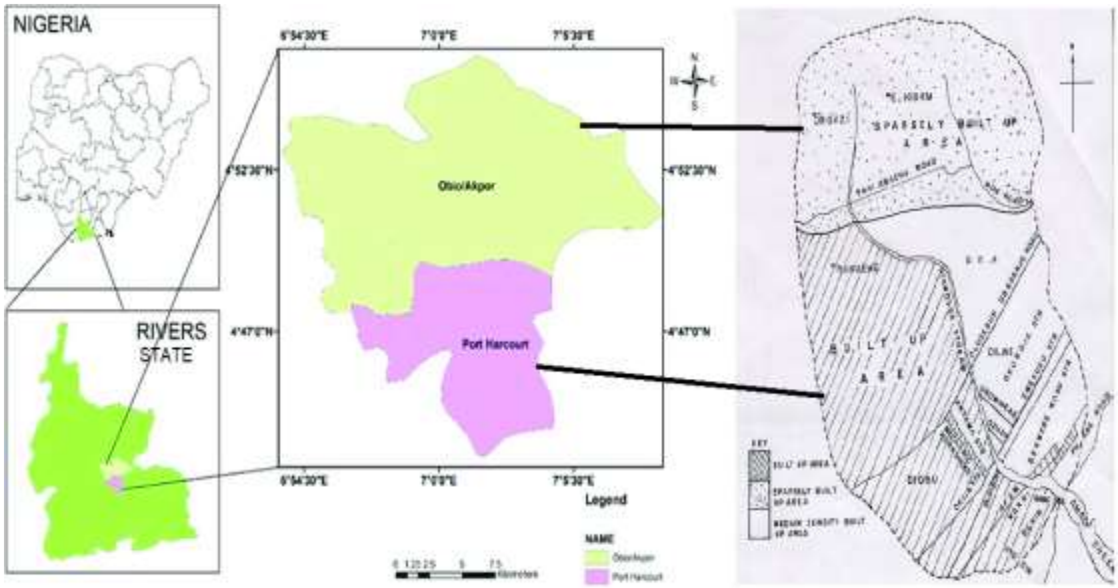

Figure 1. The study area.

ml of water samples at a temperature of 70°C for 2 h to reduce organic matter interference and convert the metals to soluble nitrates forms that can be analyzed by AAS. The concentrations of Fe, Pb, Ni, Zn, Mn, Co, Cu, Cd, and Cr in the samples were determined using the atomic absorption spectrophotometer, Raliegh WFF 320 model.

Microbial analysis

The microbial analysis of the stream water samples was studied within 24 h of collection. The numbers of bacterial colonies were measured by standard plate using standard nutrient agar and counted by a digital colony counter. Bacterial populations were expressed as colony-forming units per milliliter (cfu/mL).

Statistical analysis

The results were subjected to Pearson correlation, ANOVA, and test of mean (homogeneity of variance). Pearson correlation is used here to assess the relationship between one parameter and the others. When the value of $P<0.05$, there is no significant difference between the parameters. If the correlation coefficient, r is greater than 0.5, it shows high significant correlations.

In ANOVA, p-value<0.05 implies a statistical significant difference in the means of the groups. This statistical tool was used to check for significant differences between the parameters studied. Homogeneity of variance tests the equality of variance. A p-value>0.05 shows that the variance across groups is equal according to the null hypothesis (Ho).

RESULTS AND DISCUSSION

Ph

The pH values were consistent (11.0) across the three sampling points for July. The months of August and September had a range of 8.3 to 9.0 and 10.2 to 10.8, respectively. The mean values were 11±0, 8.6±0.36, and 10.5±1.48 for July, August, and September, respectively. These pH values showed that the stream was mostly alkaline throughout the study. The high pH value is probably due to the direct disposal of refuse into the water body. Water with a pH outside the normal range which can adversely affect the growth and development of aquatic life (Bolawa and Gbenle, 2012, Morrison et al, 2001).

Temperature

The water temperature during the period of study varied from 24 to 29°C with an overall mean value of 28±0.58°C in July and September. In August, the overall mean value was 25±1°C. This study confirmed that water temperatures were generally high for three months. However, these variations were not significantly different across the points. The values were within the acceptable levels for the survival of aquatic organisms and are within the permissible limit of (NIS 2015) and (WHO 2011). The observed high temperature showed in the three consecutive months might be due to effluent from the industries, homes, and from hospitals too. These values are in agreement with the report of Chindah et al. 2011.

Electrical conductivity

The electrical conductivity value obtained in July was 130

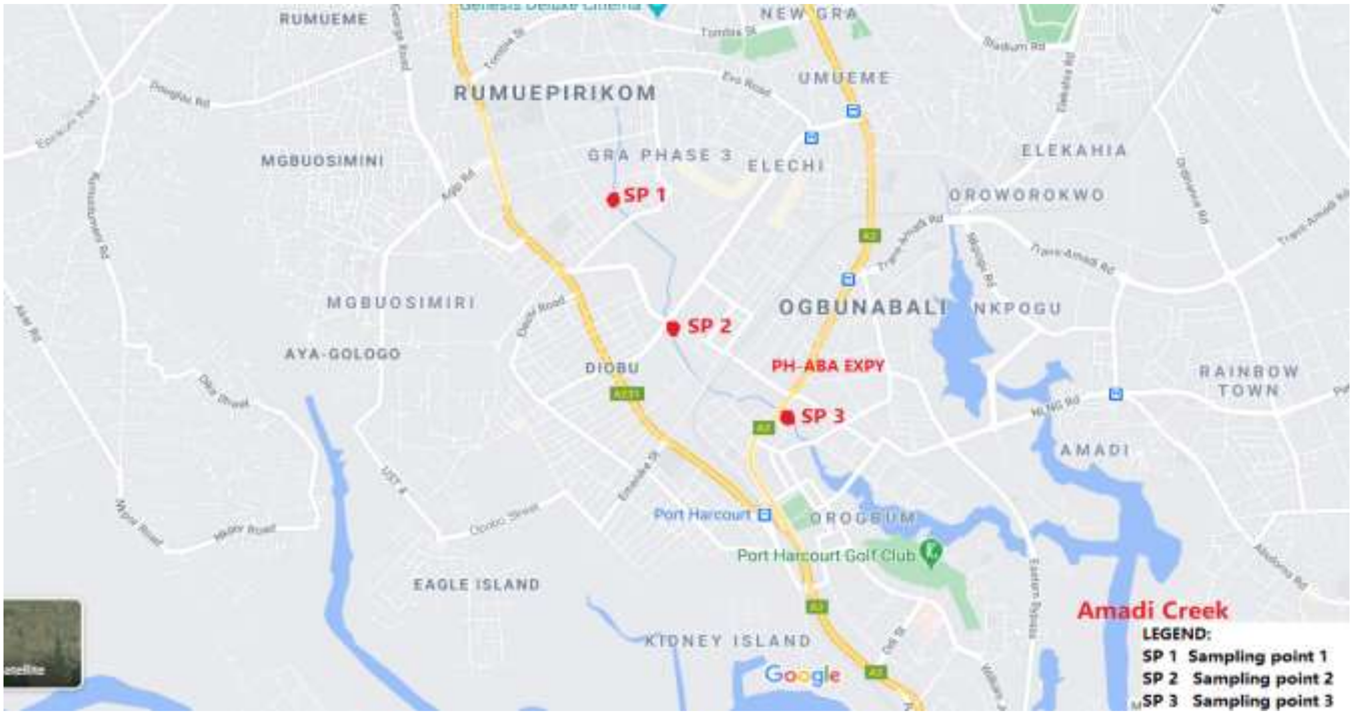

Figure 2. Map showing the sampling points.

to 140 µS/cm, in August, it was 580 to 590 µS/cm and 490 to 710 µS/cm in September with average values of 136.7±5.77, 583.3±5.77 and 650.0±113.7 µS/cm, respectively. High conductivities were observed across all the three sampling points, for the three consecutive months with September samples recording the highest. Electrical conductivity is a useful indicator of mineralization and salinity in water. The WHO acceptable limit for conductivity in the domestic water supply is 250 µS/cm. This limit was exceeded in the receiving water body (Ntawogba stream) but within the maximum permissible limits of NIS of 1000 µS/cm.

Turbidity

Turbidity has no direct health impact; however, it can cause the water to harbor microorganisms and can entrap heavy metals and biocides (NID). The average turbidity values obtained were 20.52, 18.57, and 20.33 NTU for July, August, and September, respectively. The turbidity values obtained from the sampling points were higher than the NIS and WHO standards of 5 NTU. The high turbidity values could be due to the indiscriminate disposal of waste into the water bodies. High turbidity in water can influence dissolved oxygen in water bodies by absorbing sunlight and increasing the temperature of the water (Ukabiala et al. 2010).

Total suspended solids

The presence of solid materials is responsible for the suspended and dissolved solids in surface water. The values of total suspended solids (TSS) were from 1000 to 4000 mg/l for all the months of study. The range in July was 2000 to 4000 mg/l, in August and September the values were lower, 1000 to 3000 mg/l with average values of 2666, 2333, and 2333 for July, August, and September, respectively. Suspended solids generally cause damage to fish gills affecting their oxygen consumption ultimately causing death.

Total dissolved solids

Average values for total dissolved solids (TDS) in this stream for July, August, and September were 2667, 2667, and 2333, respectively. In July the values were 3000 to 4000 mg/l, in August TDS values were 1000 to 2000 mg/l. In September, there was an increase in the values obtained. The average values obtained for TSS and TDS were found to be four times higher than the acceptable (500 mg/l) limit. Each of these parameters with such high levels is capable of having negative impacts on the aquatic ecosystem. This study revealed high significant levels of TSS and TDS above the recommended limit by NIS and WHO.

Picture 1. Study area showing its vegetation at point 1.

Picture 2. Study area showing the vegetation point 2.

Dissolved oxygen

The DO value was from 1.1 to 1.7 mg/L and agrees with the report of (Chinda et al. 2011). This study revealed that the DO across the three points was very low. According to (WHO 2011), DO standard for drinking water is 6 mg/L whereas for sustaining fish and aquatic life is 4 to 5 mg/L (Rao, 2005). Dissolved oxygen depletion leads to the death of fishes and other oxygen-requiring organisms in surface water (Pandey, 2003). Surface water quality recommended value for DO by WHO for domestic use is 10 mg/L. The DO values from this study fell short of this recommended standard. The DO depletion could be attributed to the presence of degradable organic matter which resulted in a tendency to demand more oxygen demand. The stream is associated with municipal drains, numerous open drains, pit latrines, and domestic waste disposal into the creek

Picture 3. Study area showing the vegetation at point 3.

Table 1. Mean values of the physicochemical parameters of Ntawogba stream.

Parameter	July	August	Sept	Mean	WHO	NIS
pH	11.2	8.6	10.5	10.03±1.84	8.5	8.5
Temp. (◦C)	28.4	25.6	28.8	27.60±1.74	28	
EC (µS/cm)	136.7	583.3	650.0	456.67±279.10	250	1000
Turbidity (NTU)	20.5	18.3	20.3	19.70±1.22	5	5
TSS (mg/L)	2666.0	2333.0	2333.0	2444.00±192.26	500	500
TDS (mg/L)	2667.0	2667.0	2333.0	2222.33±509.10	500	500
DO (mg/L)	1.31	1.53	1.37	1.40±0.11	6	-
BOD_5 (mg/L)	12.1	11.9	17.7	13.90±3.29	10	-
COD (mg/L)	24.8	27.7	28.2	26.90±1.84	150	-
Alkal. (mg/L)	10.1	15.2	15.4	13.57±3.00	200	-
Cl^- (mg/L)	718	693	747	719.33±27.02	250	250
NO^-_3 (mg/L)	58.7	59.7	56.1	58.13±1.91	50	50
PO^{3-}_4 (mg/L)	0.71	0.68	0.69	0.69±0.01	5	-
Mg (mg/L)	273.1	312.2	293.0	292.67±19.50	150	200
Ca (mg/L)	270.2	265.1	325.1	286.67±33.29	150	150
Fe (mg/L)	0.03	0.02	0.01	0.02±0.01	0.5	0.3
Co (mg/L)	0.03	0.06	0.02	0.04±0.02	0.02	-
Pb (mg/L)	0.03	0.07	0.12	0.07±0.05	0.01	0.01
Microb. (cfu/ml)	44.3	41.3	59.6	48.4±8.01	10	10

which impacts both the flow and water quality of the stream.

Biochemical oxygen demand

This parameter is used to determine the relative oxygen requirements of wastewaters and polluted waters. The test measures the oxygen utilized during a specific incubation period (APHA, 1998). The BOD value was from 11.5 to 20.4 mg/L with an overall mean of 17.7±2.46 mg/L. These values were in agreement with the report of Chindah et al. 2011.Oxygen is required for respiration by micro-organisms involved in the decomposition of organic materials (Nartey et al. 2012). A high concentration of BOD indicates the presence of organic effluents and hence oxygen requiring micro-organisms. Indiscriminate defecation and refuse disposal were observed at all the sampling points. From the BOD values from this study, it is evident that the BOD is significantly high and has exceeded the acceptable limits recommended by NIS and WHO for domestic use. The high BOD values may be attributed to the discharged of organic waste into water bodies resulting in the uptake of DO in the oxidative breakdown of these waste (Akuffo 1998, Shalom et al. 2011).It can also be attributed to untreated sewage, solid, and industrial waste discharge (Kalagbor and Tubonemi, 2018).

Chemical oxygen demand

The COD test is a measure of the relative oxygen depletion effect of a waste contaminant. It has been widely adopted as a measure of pollutants in wastewater and natural water. The values obtained in this study are from 19.2 to 32.8 mg/L with a mean of 24.8±7.11 mg/L for July, 27.73±3.23 mg/L for August, and 28.2±1.95 mg/L for September. Throughout the study period, high levels of COD were observed. An increase in COD could be attributed to an increase in the addition of both organic and inorganic substances in the environment, as well as organic contaminants entering the water system from municipal sewage and garbage. This trend was also observed by Ogunfowakan et al. (2005) in their study.

Alkalinity

Alkalinity being a measure of the acid-neutralizing capacity of water, it is an important parameter in assessing water quality. The values obtained for alkalinity during the study were 10 to 24 mg/L. The average value in July was 10±0 mg/L, while in August, the average value was15±5.0 mg/L, and 18.62±4.62 mg/L in September. These results are within the values obtained by (Arimeari et al. 2014) for the wet season. (Lawson 2011) obtained values of 20.5 to 90.0 mg/L in his studies which are higher than those obtained in this study. In both reports, the level of alkalinity during the wet season (which are the months of our study), are in agreement though these values are below the recommended limit of 200 mg/L by (WHO, 2011).

Chloride

The chloride concentrations in July were 624 to 810 mg/L and in August, 630 to 750 mg/L while in September, it was 700 to 800 mg/L. These values obtained for chloride in the water samples across the points exceeded the acceptable limit of 250 mg/L for NIS and WHO.

Nitrate

The nitrate values were relatively constant from July to September (50 - 69 mg/L). In July, the level of NO^-_3 was 50 to 69 mg/L, in August, 56 to 65 mg/L and in September it was 53 to 60 mg/L. The most highly oxidized form of nitrogen compounds is commonly present in surface and groundwater because it is the end product of aerobic decomposition of organic nitrogenous matter. Unpolluted natural waters usually contain minute quantities of nitrate (Ukabiala et al. 2010). The high nitrate level in the stream could be a source of eutrophication for receiving water as the obtained values exceeded the acceptable limit of 50 mg/L WHO and NIS standards. The high nutrient levels in the stream may be a result of effluents discharged into this stream.

Phosphate:

The phosphate concentrations were low (0.65 - 0.75 mg/L) across the points with mean concentrations of 0.70±0.05 mg/L in July, 0.68±0.05 mg/L in August and 0.69 ±0.04 mg/L in September. These values compare with that obtained by (Klubi et al. 2019). High levels of phosphate can be attributed to seepage from the dumpsites and agricultural runoffs into water bodies. A high phosphate concentration is an indication of pollution. It encourages eutrophication of a water body as phosphate is a limiting nutrient for algae growth. This study showed phosphate values that were below the permissible limit by WHO and NIS standards.

Magnesium

The concentration of magnesium was 250 to 300 mg/L in July, while in August, it was 255 to 400 mg/L and in September, 258 to 350 mg/L with average values of 273.1±25.24, 312.2±77.31, and 293.0±49.79 mg/L. Higher concentrations of magnesium can cause the hardness of the water. These values recorded for all the sampling points exceeded the acceptable limit of 200 and 150 mg/L by NIS and WHO, respectively.

Calcium

The value for calcium was from 250 to 400 mg/L for the three months. The average values were 270.2±25.17, 265.3±5.0, and 325.1 mg/L for July, August, and September. Water containing high calcium concentration is not suitable for washing and bathing. A high concentration in the body may cause intestinal diseases and kidney stone formation. These values have exceeded the acceptable limit of 150 mg/L by both water quality standards.

Heavy metals analysis

Out of the nine metals studied, Cd, Zn, Cr, Cu, Ni, and

Mn were not detected across the three points for the three consecutive months of this study. The average concentration value of iron (Fe) was 0.0153 mg/L in July, while in August and September the values were 0.02±0.01 and 0.01±0 mg/L. Fe is an important metal in both plants and animals, especially in the cellular processes. The concentrations Fe in this water body were within the permissible limit of 0.3 and 0.5 mg/L by NIS and WHO, respectively. Cobalt (Co) was detected in low concentrations in July and September compared to August. The range was from 0.015 to 0.065 mg/L with an overall mean of 0.04±0.02 mg/L. Co values from the water samples were not within the permissible limits of 0.02 mg/L by WHO [27]. The average concentration of lead Pb was 0.011±0.04, 0.07 ±0.01, and 0.088±0.03 mg/L in July, August, and September, respectively. The results obtained from the research showed that Pb was present in the stream and the values obtained exceeded the permissible limit of 0.01 mg/L by NIS and WHO. Pb has been reported to be associated with crude oil exploration, pipeline transportation, corrosion inhibition as well as many industrial processes (Pandey, 2003). Its presence is of concern as it can bioaccumulate and indicate potential toxicity (Nartey et al. 2005). It should be noted that the presence of metals such as Fe, Co, and Pb in the study area could be attributed to high organic and inorganic matter impacted to the water bodies from economic activities, refuse and garbage disposal.

Microbial analysis

Microbial population value was from 30 to 59 cfu/mL in July, while in August, it was from 27 to 55 cfu/mL, and in September, it was from 150 to 210 cfu/mL. The value for the microbial colony counter for the Ntawogba stream was very high. This indicates the seriousness of the impact of municipal wastewater on this receiving surface water. The water samples in general fail to meet the standard of drinking water set by NIS and WHO.

Pearson correlation

The results presented in Table 2 show that pH had a positive correlation coefficient with EC, TDS, Fe, and Co but a negative correlation with the other parameters. This is similar to the results obtained by Shyamala et al. 2008. Unlike pH, the temperature had negative correlation coefficients with the four parameters. Electrical conductivity (EC) had a positive correlation with only Co and Pb. High significant correlations were observed between TB (turbidity) and Temp. (r = 0.981), pH and Co (r = 0.972), EC and Pb (r = 0.893), TS/TDS and Fe (r = 0.866 for both cases), TS and Co (r = 0.693) and between pH and TDS (r = 0.505). DO has negative correlations with Cl, PO_4, and Ca. However, with COD, Alk (alkalinity), and Mg it has a high positive correlation. The results from Table 4 show that BOD, COD, and Alk have a negative correlation with the anions (NO_3 and PO_4) and a high correlation coefficient with the metals, Mg, and Ca. It is however observed that these metals have a negative correlation with each other. High correlation coefficients are observed between BOD and Ca (r = 0.999), COD and Alk (r = 0.995), DO and Mg (r = 0.963), Ca and Cl (r = 0.919), Alk and Mg (r = 0.857), COD and Mg (r = 0.799), DO and Alk (r = 0.687), COD and DO (r = 0.608) and between COD and Ca (r = 0.552) (Table 4).

ANOVA

The test of homogeneity shows the variance in the parameters as presented in Table 4. From Levene statistics value (0.019) it shows that there is no significance in the variance of the parameters for the period under study because the p-value (0.981) is more than 0.05 levels of significance. From the ANOVA in Table 5, the F statistics show 0.001 and the p-value is 0.999 which means that we cannot reject the null hypothesis (Ho) because the p-value is above 0.05 levels of significance.

The ANOVA results, therefore, show that there is no difference in the mean values of the parameters for the period of study. In multiple comparison analysis using Tukey HSD in Table 6, the result indicates possible areas where differences may exist. However, the result shows that there is no difference as the p-values are equal to one.

Conclusion

The physicochemical parameters, pH, BOD, and NO^-_3 were found to be slightly above the acceptable limits. DO, COD, alkalinity, phosphate, and Fe were below the WHO acceptable limits. Electrical conductivity, Cl^-, Mg, Ca, and Co were found to be two times higher than their acceptable limits. Turbidity, TSS, TDS, turbidity, and microbial population values were four times higher than acceptable limits and Pb concentrations were seven times higher than acceptable limits. The only parameter whose values were within the acceptable limits was temperature and it has a negative correlation with all the parameters that had values higher than the acceptable limits. pH had a high mean value and it has a positive correlation with all the other parameters whose values were also high. DO, COD, PO^{2-}_4, and alkalinity that have values within the acceptable limits were also found to have high positive correlations with each other and with the metals (Mg and Ca). This study has provided considerable insight into its water quality and the

Table 2. Correlation of the physicochemical parameters (pH, Temp. EC, Turbidity (TB), TSS, TDS, Fe, Co and Pb) for Ntawogba stream.

Correlation		pH	Temp	EC	TB	TS	TDS	Fe	Co	Pb
	Pearson Correlation	1								
pH	Sig. (2-tailed)									
	N	3								
	Pearson Correlation	-0.994	1							
Temp	Sig. (2-tailed)	0.070								
	N	3	3							
	Pearson Correlation	0.388	-0.285	1						
EC	Sig. (2-tailed)	0.747	0.816							
	N	3	3	3						
	Pearson Correlation	-0.996	0.981	-0.467	1					
TB	Sig. (2-tailed)	0.056	0.126	0.691						
	N	3	3	3	3					
	Pearson Correlation	-0.495	0.397	-0.993	0.569	1				
TS	Sig. (2-tailed)	0.670	0.740	0.076	0.614					
	N	3	3	3	3	3				
	Pearson Correlation	0.505	-0.596	-0.600	-0.427	0.500	1			
TDS	Sig. (2-tailed)	0.663	0.593	0.590	0.719	0.667				
	N	3	3	3	3	3	3			
	Pearson Correlation	0.006	-0.115	-0.920	0.082	0.866	0.866	1		
Fe	Sig. (2-tailed)	0.996	0.927	0.257	0.948	0.333	0.333			
	N	3	3	3	3	3	3	3		
	Pearson Correlation	0.972	-0.992	0.161	-0.948	-0.277	0.693	0.240	1	
Co	Sig. (2-tailed)	0.151	0.081	0.897	0.207	0.821	0.512	0.846		
	N	3	3	3	3	3	3	3	3	
	Pearson Correlation	-0.070	0.178	0.893	-0.018	-0.832	-0.896	-.998*	-0.302	1
Pb	Sig. (2-tailed)	0.956	0.886	0.298	0.988	0.374	0.293	0.041	0.805	
	N	3	3	3	3	3	3	3	3	3

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

Table 3. Pearson correlation for physicochemical parameters (DO, BOD, COD, Alkalinity, Cl^-, NO^-_3, PO^{3-}_4, Mg and Ca) for Ntawogba stream.

Correlation		DO	BOD	COD	Alk	Cl	NO_3	PO4	Mg	Ca
	Pearson Correlation	1								
DO	Sig. (2-tailed)									
	N	3								
	Pearson Correlation	-0.283	1							
BOD	Sig. (2-tailed)	0.817								
	N	3	3							

Table 3. cont.

COD	Pearson Correlation	0.608	0.589	1						
	Sig. (2-tailed)	0.584	0.599							
	N	3	3	3						
Alk	Pearson Correlation	0.687	0.503	0.995	1					
	Sig. (2-tailed)	0.518	0.665	0.066						
	N	3	3	3	3					
Cl	Pearson Correlation	-0.672	0.900	0.178	0.076	1				
	Sig. (2-tailed)	0.530	0.287	0.886	0.952					
	N	3	3	3	3	3				
NO3	Pearson Correlation	0.498	-0.973	-0.386	-0.288	-0.977	1			
	Sig. (2-tailed)	0.668	0.149	0.748	0.814	0.138				
	N	3	3	3	3	3	3			
PO4	Pearson Correlation	-0.967	0.030	-0.790	-0.849	0.463	-0.261	1		
	Sig. (2-tailed)	0.163	0.981	0.420	0.355	0.694	0.832			
	N	3	3	3	3	3	3	3		
Mg	Pearson Correlation	0.963	-0.016	0.799	0.857	-0.449	0.247	-1.000**	1	
	Sig. (2-tailed)	0.173	0.990	0.411	0.345	0.703	0.841	0.009		
	N	3	3	3	3	3	3	3	3	
Ca	Pearson Correlation	-0.326	.999*	0.552	0.463	0.919	-0.982	0.075	-0.060	1
	Sig. (2-tailed)	0.789	0.029	0.628	0.693	0.258	0.120	0.952	0.962	
	N	3	3	3	3	3	3	3	3	3

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

Table 4. Values of mean and standard error for the three months.

Month	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
July	19	365.4321	829.07585	190.20304	-34.1697	765.0339	0.03	2667.00
August	19	371.8032	779.06551	178.72989	-3.6944	747.3007	0.02	2667.00
September	19	364.2058	728.27627	167.07804	13.1879	715.2237	0.01	2333.00
Total	57	367.1470	765.84644	101.43884	163.9406	570.3534	0.01	2667.00

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	632.156	2	316.078	0.001	0.999
Within Groups	32844531.045	54	608232.056		
Total	32845163.201	56			

correlation between the various parameters. The test of homogeneity shows the variance in the parameters. Levene statistics shows that there is no significance in the variance of the parameters. The ANOVA results show no difference in the mean values of the parameters for the period of study. The high levels of Ca and Mg make Ntawogba stream unsuitable for washing, bathing, and any domestic use. There were high levels of waste generated from economic activities and domestic garbage with subsequent release into this body of water.

Table 5. Test of homogeneity of variances.

Variable		Levene Statistic	df1	df2	Sig.
Stream values	Based on Mean	0.019	2	54	0.981
	Based on Median	0.001	2	54	0.999
	Based on Median and with adjusted df	0.001	2	53.368	0.999
	Based on trimmed mean	0.001	2	54	0.999

Table 6. Multiple comparisons (Dependent Variable: Tukey HSD).

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
July	August	-6.37105	253.03049	1.000	-616.1705	603.4284
	September	1.22632	253.03049	1.000	-608.5731	611.0257
August	July	6.37105	253.03049	1.000	-603.4284	616.1705
	September	7.59737	253.03049	1.000	-602.2020	617.3968
September	July	-1.22632	253.03049	1.000	-611.0257	608.5731
	August	-7.59737	253.03049	1.000	-617.3968	602.2020

The stream now serves as a channel for transporting waste to the downstream which empties into Amadi Creek. This is a source of concern as this practice causes the stream to overflow its banks thereby causing flooding. The presence of solid wastes is responsible for the high values of TDS and TSS. The frequent collection of waste plastic bottles and other debris is a very serious environmental problem.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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