J. Int. Environmental Application & Science, Vol. **19**(2): 69-92 (2024)
Research Paper

Bed Sediment Analysis of Ntawogba River in Port Harcourt, Nigeria

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Received December 2;2023; Accepted June 25,2024

Abstract: The aim was the analysis of soil types, physico-chemical parameters of water and sediments, heavy metals, benthos, zooplankton and phytoplankton. Experimental research design and data were analysed using mean and standard deviation, Analysis of Variance (ANOVA) and one sample T-test. The result revealed that the soil type was mainly sandy clay. The mean value of the physico-chemical parameters were within the World Health Organization (WHO) standard prescribed limit; There is no significant variation in the mean distribution of physico-chemical parameters in Ntawogba creek along the ten locations (F 9, 110= 0.79, P >0.05); There is no significant variation in the mean distribution of heavy metals parameters in Ntawogba creek along the 10 locations (F 9, 50= .021, P > 0.05); There is significant difference in the concentration level of oil and grease in Ntawogba creek (DF= T = 42.037, P<0.05); There is no significant variation in the distribution of benthos in the ten locations of Ntawogba creek (F9, 80 = 1.307, P >0.05); There is no significant variation in the distribution of phytoplanktons in the ten locations of Ntawogba creek F(9,120) = 0.535, P > 0.05); There is no significant variation in the distribution of zooplankton in the ten locations of Ntawogba creek (F(9,70)= .0510, P <0.05). The study further revealed that the benthos, phytoplanktons and zooplanktons were varied in their distribution across the 10 locations in the study area. Conclusion of bed sediment characteristics of river system highly affected by anthropogenic activities. Recommendation of periodic analysis of bed sediment characteristics of the river.
Keywords: *Anthropogenic, Parameters, Physico-chemical Sediments, Urbanization*

Introduction

Sediment refers to the conglomerate of materials, organic and inorganic, that can be carried away by water, wind or ice. The term is often used to indicate soil-based, mineral matter (e.g. clay, silt and sandy). Decomposing organic substances and inorganic materials are also considered sediment. Most mineral sediment comes from erosion and weathering, while organic sediment is typically detritus and decomposing material such as algae. These particulates are typically small, with clay defined as particles less than 0.00195mm in diameter, and coarse sand reaching up only to 1.5mm in diameter. However, during a flood or other high flow event, even large rocks can be classified as sediment as they are carried downstream. Sediment is a naturally occurring element in many bodies of water, though it can be influenced by anthropogenic factors.

In an aquatic environment, sediment can either be suspended (floating in the water column) or bedded (settled on the bottom of the water). When both floating and settled particles are monitored, they are referred to as Suspended and Bedded Sediments (SABS). Suspended sediment can alter the water chemistry, and cause temperature decreases, and turbidity increases. Deposition of sediment may change the character of the substrate, block interstices, and reduce interstitial volume. Anthropogenic sediment in freshwaters is a by-product of several activities. These activities could be agricultural, industrial and commercial in both urban and rural areas. This problem has adverse effect on marine ecosystem. For instance, turbidity levels as low as 5NTU can decrease primary productivity by 3-13%. An increase of suspended sediment levels increases the drift fauna and may reduce benthic densities as well as alter community structure.

At any point on the surface of the earth where human activities are found belong to a particular basin area where sediment and water flows to a particular stream after a rain event (Oku, 2016). This

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means that all activities both natural and human induced impacting on the soil are transported to streams either as suspended sediment or bed sediment. Our contemporary world is increasingly faced with the challenges of managing the emerging risks impacting ecological niches due to its peculiar sediment chemistry. The negative processes feedback of diverse spatial activities has increasingly complex impact on sediment quality generated most especially in the urban area resulting from multiple land-use processes (Zhang, 2016).

Bed sediment and hydrobiological parameters such as benthos, phytoplanktons and zooplanktons are important aspect of the marine ecosystem. Their concentration and distribution have been affected by anthropogenic activities, especially in the urban areas of Ntawogba river basin in Port Harcourt metropolis as result of rapid increasing human activities especially urbanization and dumping of wastes of all kinds into the river. This has reduced and impacted on the microbial activity of the microorganisms in the river and as well as bed sediments transport and deposition along the river channel.

The aim of this study is to assess the bed sediment characteristics of the Ntawogba River in Port Harcourt Metropolis. Specific objectives include the following:

i. Investigate the physico-chemical parameters of Ntawogba river channel
ii Investigate the distribution of benthos species in Ntawogba rivers channel.
iii Determine the concentration level of heavy metal presence in Ntawogba river channel
iv Analyze the distribution of phytoplankton presence in Ntawogba river channel
v. Investigate the distribution of zooplankton presence in Ntawogba river channel
vi. Determine the presence of oil and grease in Ntawogba river channel
vii Manage the marine ecosystem in a sustainable manner to enhance the environmental quality of Port Harcourt metropolis.

Materials and Methods

Geographically, the Port-Harcourt metropolis is located between Latitudes 4°45′ N, and 4°55′N and Longitudes 6°55′E and 7°05′E (Fig. 1). Port-Harcourt metropolis is located at about 25km from the Atlantic Ocean and it is situated between the Dockyard Creek/Bonny River and the Amadi Creek (Oyegun & Adeyemo, 1999). Port-Harcourt, originally known, as "Igwe-Ocha" was founded in 1913 by the British in an area traditionally inhabited by the Ikwerres. It was named after Lewis Viscount Harcourt, the then Secretary of State for Colonies. The main City of Port Harcourt is the Port-Harcourt City Council. It serves as the capital state (Alagoa & Derefaka, 2012). Today, the Port-Harcourt metropolis is made up of two Local Government Areas, namely Port-Harcourt L.G.A and Obio-Akpor LGA.

This study used the experimental research design where reliance was on the collection of bed sediment samples from the field for strict laboratory analysis of the parameters being examine. This study depended heavily on primary data which was generated from the field through sample collection and analysis. This means that the primary data generated from the field formed the focus of evaluating the variables of interest in line with the conjectural statement earlier posed for the study. Similarly, the study utilized secondary information, which was derived from gazettes of regulatory agencies, government, works of scholars in textbooks, journals, and monographs among others.

The Ntawogba river channel overall length was difficult to deduce due to rapid urban land use processes affecting first and second order streams. Hence, the study used 1km of the lower course of the mainstream channel before entering the sea, that is, its freshwater section outside the tidal range. This section enabled the researcher to document the net impact of urban processes on bed sediment characteristics of the Ntawogba river channel. The study took a sampling interval of 10m apart, which gave a sampling frame of 100 sampling points. This constituted the sampling frame of the present study.

The parameters of the study constituted all biological, physical and chemical characterization of the bed sediments to establish the probable impact of urban processes on the variables of interest. Thus, the major samples collected for laboratory investigation were stream bed sediment. Data collection protocol was observed and bed sediments were collected with the aid of the crab. The crab is a device that goes underground to bring out sea soil. This enabled sample integrity within established sample collection protocol for sediment analysis. Hence, sterilized containers were used to collect sediment samples for biological parameters examination as well as foil containers for physical and sediment chemistry. These containers were dipped below the surface at designated sampling points for soil sample

collection for laboratory analysis. The samples collected were stored in a cool box for transportation to accredited laboratories for analysis of parameters of interest.

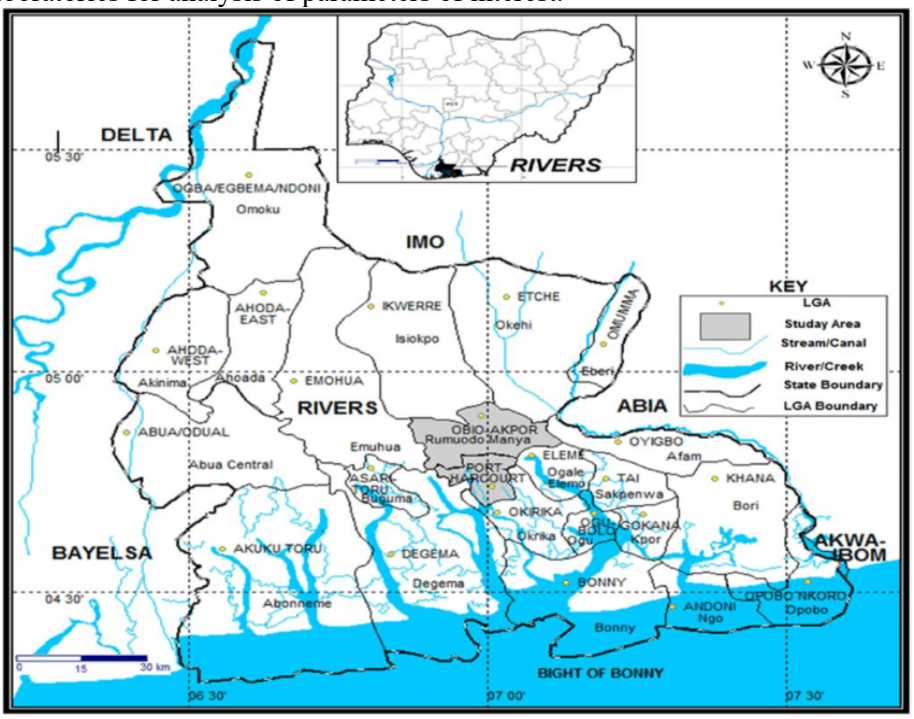

Figure 1. River's state showing port Harcourt metropolis. **Source:** Ministry of Land and Survey, 2017

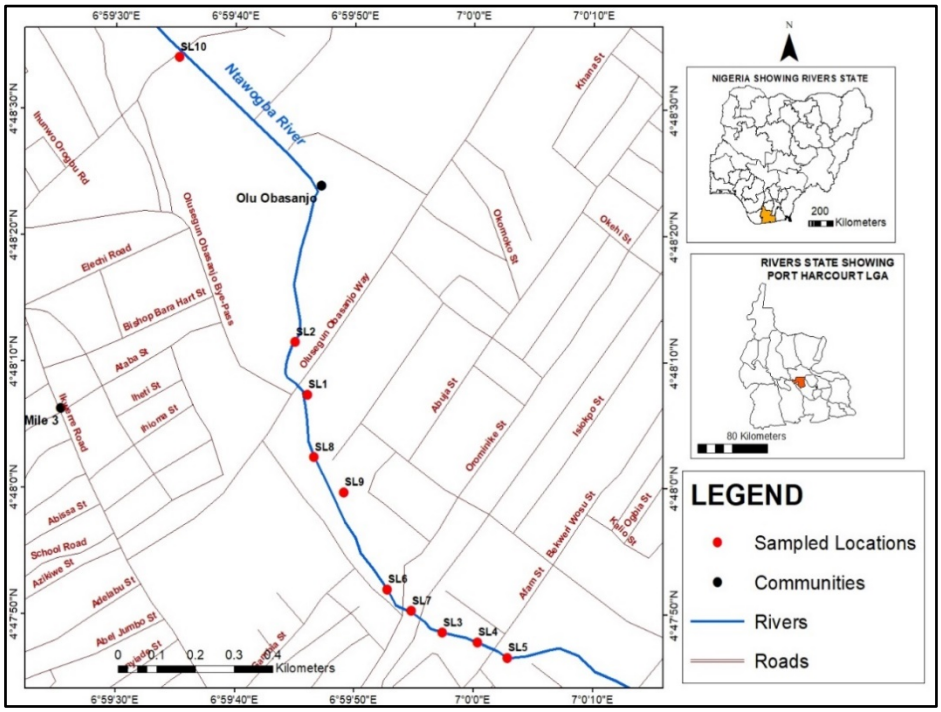

Figure 2. Ntawogba River Showing the sampled locations (SL). **Source:** Researchers' Fieldwork (2021)

Data was analysed by the combination of descriptive statistics and inferential statistics. Simple percentage was used to analyse soil particulate size distribution while mean and standard deviation were used to analyse the physico-chemical parameters, heavy metals, benthos, phytoplankton and zooplankton species. The hypotheses were analysed with the analytical tools of one-way analysis of variance (ANOVA) and one-sample t-test. The results were displayed in tables.

Results And Discussion of Findings

This section of the chapter deals with the result of the laboratory analysis carried out in respect to the physico-chemical parameters, heavy metals, benthos, parameters, soil parameters, phytoplankton parameters and zooplankton parameters of surface water samples in the ten locations across Ntawogba creek in Port Harcourt metropolis. This data presentation also includes the descriptive analysis of the aforementioned parameters across the ten locations and as well as in the individual location as contained in Table 1. The ten locations covered in the study were Olu-Obasanjo Point 1; Olu-Obasanjo Point 2; Railway/Okija; Afam/Library Point 1; Afam/Library Point 2; Okija Point 1; Okija Point 2, Between Okija and Olu-Obasanjo Point 1; Between Okija and Olu-Obasanjo Point 2; and behind Mile 3 (Timber Market). The geographical location characteristics of the ten locations are presented in Table 1.

Table 1. Geographical Coordinates of The Ten Locations Across Ntawogba Creek, Port Harcourt Metropolis
Source: Researchers' Fieldwork (2021)

S/n	Location	Latitude (0_1^o)	Longitude (0_1^o)	Altitude (m)
1	Olu-Obasanjo Point 1	$N4^0$, 48' 7.404"	$E.6^0$, 59' 46.313"	7m
2	Olu-Obasanjo Point 2	$N4^0$, 48' 11.559"	$E.006^0$, 59' 45.258"	6m
3	Railway/Okija	$N4^0$, 47' 49.731"	$E.006^0$, 59' 55.668"	5m
4	Afam/Library Point 1	$N4^0$, 47' 48.006"	$E.007^0$, 00' 58.212"	5m
5	Afam/Library Point 2	$N4^0$, 47' 47.139"	$E.007^0$ 05' 20.312"	5m
6	Okija Point 1	$N4^0$, 47' 50.867"	$E.006^0$ 59' 54.126"	5m
7	Okija Point 2	$N4^0$, 47' 50.292"	$E.006^0$ 59' 55.061"	5m
8	Between Okija & Olu-Obasanjo 1	$N4^0$, 48' 6.228"	$E.006^0$ 59' 46.223"	7m
9	Between Okija & Olu-Obasanjo 2	$N4^0$, 47' 59.685"	$E.006^0$ 59' 49.362"	7m
10	Behind Mile 3 Timber Market	$N4^0$, 48' 34.099"	$E.006^0$ 59' 35.531"	4m

The twelve physico-chemical parameters of the surface water quality investigated were temperature, pH, electrical conductivity, salinity, moisture content; nitrate, sulphate, calcium, phosphate, magnesium, potassium and sodium. The six heavy metals analysed were manganese, chromium, zinc, cadmium, iron, and lead. The benthos parameters of the study include Capitella-capitata and *Notomastus intereceus* (capitelliadae), *Nephathys hom*bergi (Nephthyldidae); nereisis diversicolor, *Nereis pelagic, Nereis virens* (Nereidae); *Polydora capensis* (spiondare); *Epidopatra gilchrist*i (Eanicidae); *Poyebia deltaura* (callianussipidae).

The phytoplankton parameters include *Melosira varians, Melosira distans, Cosinodiscus lacustris; Pragilaria vivenscens, Synedra ulna, Cyclotella operculata* (Baccilaoriophycene). *Tetraodon* sp; *Netrianodigitus*; (Chlorophycene); *Anabarenopsos anoldic, Rivalaria planctonica* (Cyanophyceae); *Ceratium hirudinella, Peridium pusillium* and *Peridinium cinatum* (Phyrophyceae). The eight Zooplankton parameters are *Temora longicornis, Eurytemora hivandoides* (Temondae); *Anomalocera petersoni* (Pontellidae); *Pareuchaeta norvegica* (Euchaetidae); *Calamus finmarchicus* (calanoidae); *Paracyclops affinis* (Cyclopidare); *Tintinnopsis sinensis* and *Tintinnopsis wanji* (protozoa).

With respect to soil texture distribution across the ten locations, this was done through sieving method and the result is presented in Table 2.

Soil Texture Distribution

The result of the soil texture analysis from the laboratory is presented in Table 2

Table 2. Soil texture characteristics across the ten stations. **Source:** Researchers' Laboratory Analysis Report (2021)

S/n	Location	Soil – texture
1	Olu-Obasanjo Point 1	Sandy-Clayey
2	Olu-Obasanjo Point 2	Sandy-Clayey
3	Afam library	Sandy-Clayey
4	Afam/Library Point 2	Sandy-Clayey
5	Between Okija & Olu-Obasanjo Point 1	Sandy-Clayey
6	Between Okija & Olu-Obasanjo Point 2	Sandy-Clayey
7	Okija Point 1	Sandy-Clayey
8	Okija Point 2	Sandy-Clayey
9	Railway/Okija	Sandy-Clayey
10	Behind Mile 3 Timber Market	Sandy-Clayey

The result of the laboratory soil texture analysis revealed that in the ten locations across the Ntawogba creek in Port Harcourt metropolis, the soil texture was sandy-clayey all through. This could be as a result of the geologic structure of the area weathering activities and as well as anthropogenic activities. The soils of this study area belong to the coastal plain sands which were deposited by receding water during the Miocene-pleistocene age. They noted that the coastal plain sands are continental deposits from a probably upper deltaic depositional environment; and were derived from unconsolidated sedimentary deposits.

The descriptive and inferential statistics of the study are analysed in this section. The descriptive statistics employed the analytical techniques of mean, standard derivation, standard error, variance, coefficient of dispersion, co-efficient of variation and range. The inferential statistics utilized one way analysis of variance (ANOVA) and one sample t-test to test the hypotheses for the study. This was achieved by using the raw data from the laboratory analysis of the various parameters investigated. This section is therefore divided into two sections which are descriptive analysis of data and testing of hypotheses.

The water sample from Ntawogba creek across the ten locations were analyzed for physico-chemical parameters, heavy metals presence, soil type, benthos presence, phytoplankton presence and zooplankton presence. The results of the water physico-chemical parameters concentration were compared with natural and international standards for water quality Nigeria's National Standard for Drinking Water Quality –(NSDWQ) (2015), and World Health Organization (WHO, 2017) for potable drinking water Quality because the study does not cover surface water drinking quality. The result of the soil type was not also compared with the Food and Agriculture Organization (FAO) standard for soil quality for crop planting as the study does not cover this aspect. These results are presented in Table 7-11.

Temperature: The measured water temperature values were in the range of 24.2ºC and 28.2ºC in Olu-Obasanjo point 2 and Okija point 1 respectively with a range value of 4ºC across the ten locations. The water mean temperature was 25.98ºC with a standard deviation of 1.399ºC and a coefficient of variation of 1, 940.3% and as well as a standard error of 8.219^{0}C. Water temperature may affect water quality through biological activities. However, the obtained temperature range is normal and thus imposes no risk. The increasing the temperature of water may affect the oxygen concentration in the water which may affect the living things in the water.

pH: The pH is an important indicator for assessing the quality and pollution of any aquifer System as it is closely related to other chemical constituents of water. The presence of hydrogen ion concentration is measured in terms of pH range. Thus, water in its pure form shows a neutral pH which indicates hydrogen ion concentration. When pH results are higher than 8.0 water is not proper for efficient disinfection by chlorine; however, results less than 6.5 increases attrition in the pipes. In the present study, the range of pH varies between 4.46 (minimum) at between Okija and Olu-Obasanjo point 2 to 6.10 (maximum) at Okija point 2 which is acidic. The result also revealed a range value of 1.64, a mean value of 5.313; a standard deviation of 0.617; a standard error of 1.680 and a coefficient of variation of 861.1% which is very high indeed. Generally, the study recorded low pH values across the ten locations. With respect to human consumption, the ideal range of pH is 6.5-8.5.

Table 3. Analytical report of sediment samples. **Source**: The Researchers' Fieldwork Laboratory Analysis (2021)

Parameters		Oluobasanjo Point 1 GPS N40,48' 7.404" E60,59' 46.313"	Oluobasanjo Point 2 GPS N40,48' 11.559" E0060,59' 45.258"	Railway/ Okija GPS N40,47' 49.731" E0060,59' 55.668	Afam/Library Point 1 GPS N40,47' 48.006" E0070,00' 58.212"	Afam/Library Point 2 GPS N40,47' 47.139" E0070,05' 20.312"	Okija Point 1 GPS N40,47' 50.867" E0060,59' 54.126"	Okija point 2 GPS N40,47' 50.292" E0060,59' 55.061"	B/w Okija & Oluobasanjo Point 1 GPS N40,48' 6.228" E0060,59' 46.223"	B/w Okija & Oluobasanjo Point 2 GPS N40,47' 59.685" E0060,59' 49.362"	Behind Mile 3 Timber GPS N40,48' 34.099" E0060,59' 35.531"	Total %
	METER											
1.	Temperature ^0C	Meter	26.5	24.2	27.2	26.1	24.3	28.2	27.1	26.6	25.3	24.3
2.	PH	PH Meter	5.85	4.48	5.12	5.10	5.08	6.10	6.10	5.82	4.46	5.02
3.	Electrical Conductivity,	Conductivity Meter	56.4	56.2	67.2	67.2	66.2	68.1	67.2	56.4	55.3	54.4
4.	Salinity mg/kg	Meter	16.1	15.0	19.2	19.0	18.99	19.2	18.3	16.0	15.9	16.2
5.	Moisture Content	Gravimetric Method	3.92	3.90	4.33	3.32	4.33	4.32	4.33	3.93	3.92	3.91
6	PSD% Clay	Sieving method	6.59	5.49	28.61	27.63	28.63	30.63	28.65	6.58	6.51	6.54
	Silt		14.11	14.8	29.43	29.44	30.01	30.47	30.44	14.10	14.2	14.08
	Sand		79.30	75.31	41.92	40.92	43.93	43.93	41.91	79.33	77.30	79.29
7.	Texture	Sieving method	Sandy-Clayey	Sandy-Clayey	Sandy-Clayey	Sandy-Clayey	Sandy-Clayey	Sandy-Clayey	Sandy-Clayey	Sandy-Clayey	Sandy-Clayey	Sandy-Clayey
8.	Nitrate, mg/kg	APHA 4500-$N0^3$	0.423	0.425	0.319	0.320	0.318	0.320	0.322	0.424	0.425	0.422
9.	Sulphate, mg/kg	APHA 4500-$S0^4$	9.104	9.100	7.217	7.219	6.299	8.218	7.220	9.102	9.104	9.100
10	Phosphate, mg/kg	APHA 4500-$P0^4$	2.552	2.532	2.813	2.815	2.810	4.816	4.915	2.551	2.554	2.550
11	Ca, mg/kg		105.62	106.60	124.89	124.87	124.88	126.89	125.85	105.62	106.64	105.60
12	Mg,mg/kg		92.57	92.51	107.51	106.52	107.51	107.52	105.50	92.55	92.53	92.51
13	K, mg/kg	APHA 3111b	30.20	29.21	39.00	40.01	38.99	40.02	41.04	31.19	30.22	30.20
14	Na, Mg/Kg		50.60	50.44	63.90	63.90	62.91	66.80	65.79	52.62	50.46	50.59
15	Mn, mg/kg		1.07	1.05	2.54	2.81	2.79	2.84	2.75	1.04	1.02	1.01
16	Cr, mg/kg		0.11	0.10	0.19	0.22	0.20	0.20	0.23	0.13	0.09	0.10
17	Zn,mg/kg		0.35	0.33	0.46	0.45	0.44	0.48	0.46	0.36	0.32	0.33
18	Cd, mg/kg		0.18	0.19	0.21	0.24	0.22	0.24	0.22	0.19	0.20	0.17
19	Fe, mg/kg		231.43	231.44	302.28	304.25	303.20	302.29	301.30	230.46	231.4	231.4
20	Pb, mg/kg		0.33	0.31	0.36	0.33	0.34	0.36	0.34	0.35	0.33	0.32
21	Oil & Grease	APR 45	0.45	0.43	0.55	0.52	0.51	0.54	0.53	0.51	0.52	0.50

Table 4. Benthos results. **Source:** The Researchers' Fieldwork Laboratory Analysis (2021)

Taxonomic Group	Oluobasanjo Point 1	Oluobasanjo Point 2	Railway/ Okija	Afam/library point 1	Afam/library point 2	Okija point 1	Okija point 2	B/w Okija & Oluobasanjo point 1	B/w Okija & Oluobasanjo point 2	Behind mile 3 timber	Total %
Polychaeta	.		.	.	.						
Capitellidae											
1. Capitellacapitata	3	2	4	3	1	2	2	3	3	2	
2. Notomastus latreiceus	3	1	6	4	5	2	5	4	2	3	
Nephthyididae											
3. Nephthys hombergi	4	3	1	1	1	0	1	0	1	1	
Nereidae											
4. Nereis diversicolor	2	1	5	3	1	4	3	2	3	3	
5. Nereis pelagic	3	2	5	4	.2	3	1	1	3	2	
6. Nereis virens	2	1	3	2	2	3	2	3	1	2	
Spionidae											
7. Polydora capensis	2	2	4	2	3	1	3	2	2	1	
Eunicidae											
8. Epidiopatra gilchristi	2	1	3	3	2	3	3	2	2	1	
Total CRUSTACEA											
Callianasspidae											
9 Pogebia deltaura	5	3	12	9	7	10	8	8	7	5	

Table 5. Zooplankton results. **Source:** The Researchers' Fieldwork Laboratory Analysis (2021)

	Taxonomic Group	Oluobasanjo Point 1	Oluobasanjo Point 2	Railway/ Okija	Afam/Library Point 1	Afam/Library Point 2	Okija Point 1	Okija Point 2	B/w Okija & Oluobasanjo Point 1	B/w Okija & Oluobasanjo Point 2	Behind Mile 3 Timber	Total %
	Copepoda	.		.	.	.						
	Temoridae											
1.	Temora Longicornis	23	20	17	14	13	15	14	10	13	8	
2.	Eurytemora hirundoides	14	10	18	12	11	16	11	15	14	9	
	Pontellidae											
3.	Anomalocera Patersoni	6	3	12	9	9	9	10	8	8	7	
	Euchaetidae											
4.	Parcuchaeta norvegica	5	4	10	10	7	9	7	8	8	6	
	Calanoidae											
5.	Calamus finmarchicus	7	5	5	3	5	4	4	3	3	2	
	Cyclopidae											
6.	Paracyclops affinis	8	8	10	10	8	8	6	5	4	3	
	Total =											
	Protozoa											
7.	Tintinnopsis Sinensis	2	2	0	0	0	0	0	0	0	0	
8	Tintinnopsis Wanji	6	4	2	2	1	2	2	2	2	1	
	Total =											
	Total No: Individuals											

Table 6. **Phytoplankton results. Source:** The Researchers' Fieldwork Laboratory Analysis (2021)

	Taxonomic Group	Oluobasanjo Point 1	Oluobasanjo Point 2	Railway/ Okija	Afam/Library Point 1	Afam/Library Point 2	Okija Point 1	Okija Point 2	B/w Okija & Oluobasanjo Point 1	B/w Okija & Oluobasanjo Point 2	Behind Mile 3 Timber	Total %
	Baccilariophyc eae	.		.	.	.						
1	Melosira varians	12	10	13	11	9	12	11	8	8	6	
2.	Melosira distans	18	15	23	21	23	20	20	18	16	13	
3	Cosinodiscus lacustris	5	3	11	11	9	11	10	9	10	7	
4	Fragilaria vivenscens	10	7	20	20	20	17	17	15	13	11	
5	Synedra ulna	6	5	13	11	10	8	9	8	10	8	
6	Cyclotella operculata	22	19	8	8	6	7	6	5	7	6	
	TOTAL CHLOROPHYCEAE											
7	Tetraodon sp.	1	1	0	0	0	0	0	0	0	0	
8	Netrium digitus	6	4	2	2	1	2	1	2	2	1	
	TOTAL CYANOPHYCEAE											
9	Anabaenopsos anoldic	2	2	8	7	5	7	5	4	4	2	
10	Rivularia planctonica	6	6	1	1	1	1	0	0	1	1	
	TOTAL PHYROPHYCEAE											
11	Ceratium hirudinella	3	2	7	6	7	5	7	6	5	4	
12	Peridium pusillium	8	8	3	3	2	3	2	4	1	1	
13	Peridinium cinatum	2	2	12	10	8	11	10	7	8	6	
	TOTAL											
	Total No: Individuals											
	Total number: Species.											

Electrical Conductivity: Electrical conductivity is a measure of the ability of any substance or solution to conduct electrical current through the water. Electricity conductivity is directly proportional to the dissolved material in a water sample as it has a direct relation with total dissolved solids (TDS). The values of electrical conductivity ranged from 54.4µs/cm to 68.1µs/cm with a range value of 13.7µs/cm and a mean value of 61.46µs/cm. The minimum EC value of 54.4µs/cm was recorded at behind Mile 3 Timber market while the maximum value of 68.1µs/cm was recorded at Okija point 1. Other descriptive statistics result revealed that the standard deviation is 6.024µs/cm; standard error of 19.437µs/cm and a

coefficient of variations of 1,011.9%. High EC in some locations might suggests the mixing of sewage in surface water at these locations as there are in very dense urbanization area.

Salinity: salinity generally describes the amount of salt in water. In this study, the salinity values generated from the ten locations of Ntawogba creek varies considerably from 16.0 ppt (minimum) at Okija and Olu-Obasanjo point 1 to 19.2 ppt (maximum) at Okija point 1. The mean value across the ten locations is 17.39 ppt, standard deviation of 1.682 ppt; standard error of 5.499 ppt; range of 3.2 ppt and a coefficient of variation of 1,033.8%.

Table 7. Descriptive statistics of water sample physico-chemical parameters across the ten locations in port Harcourt metropolis. **Source:** The Researchers' Fieldwork Laboratory Analysis (2021)

S/n	Location	pH	Temper-ative (O^C)	EC S/cm	Salinity (ppt)	Moisture (ppt)	Nitrate (mg/kg) (NO_3)	SO_4 (mg/kg)	Ca (mg/kg) PO_4	Mg (mg/kg) Ca	K (mg/kg) Mg	K (mg/kg)	Na (mg/kg)
1	Olu-Obsanajo Point 1	5.85	26.5	56.4	16.1	3.92	0.423	9.104	2.552	105.62	92.57	30.20	50.60
2	Olu-Obasanjo Point 2	4.48	24.2	56.2	15.0	3.90	0.425	9.100	2.532	106.60	92.51	29.21	50.44
3	Railway/Okija	5.12	27.2	67.2	19.2	4.33	0.319	7.217	2.813	124.89	107.51	39.00	63.90
4	Afam /Library Point 1	5.10	26.1	67.2	19.0	3.32	0.320	6.219	2.815	124.87	106.52	40.01	63.90
5	Afam/Library Point 2	5.08	24.3	67.2	18.99	4.33	0.318	6.299	2.810	124.88	107.51	38.99	62.91
6	Okija Point 1	6.10	28.2	66.2	19.2	4.32	0.320	8.218	4.816	126.89	107.52	40.02	66.80
7	Okija Point 2	6.10	27.1	68.2	18.3	4.33	0.322	7.220	4.915	125.85	105.50	41.04	65.79
8	Between Okija & Olu-Obasanjo Point 1	5.82	26.6	67.2	16.0	3.93	0.424	9.102	2.551	105.62	92.55	31.19	52.62
9	Between Okija & Olu-Obasanjo Point 2	4.46	25.3	56.4	15.9	3.92	0.425	9.104	2.554	106.64	92.53	30.22	50.46
10	Behind Mile 3 (Timber)	5.02	24.3	55.3	15.2	3.91	0.422	9.100	2.550	105.60	92.51	30.20	50.59
	Mean (x)	5.313	25.98	54.4	17.389	4.021	0.372	8.168	3.191	115.25	99.72	35.01	57.80
	SD	0.617	1.399	61.46	1.682	0.320	0.548	1.083	1.181	10.28	7.601	5.115	7.33
	Range	1.64	4	6.074	3.2	0.43	0.107	2.885	2.383	21.29	14.94	10.84	16.36
	CD	8.611	19.403	13.7	10.338	12.566	0.679	7.542	2.702	11.260	13.119	6.845	7.885
	CV (%)	861.1	1,940.3	10.12	1,033.8	1.256.6	67.9	754.2	27.0	1,126	1,311.9	684.5	788.5
	SE	1.680	8.216	19.44	5.499	1.272	0.118	2583	1.009	36.607	31.537	11.072	18.280
	NSDWQ	Ambient	6.0							0.20	-		6.0
	WHO	27-32	6.5-8.5	≤5750	5(psu)		50mg/l	500mg/l	≤0.05	2	200	-	50-200 mg/l

Moisture: Moisture refers to water content in a substance. In the soil along the Ntwogba Creek, moisture concentration along the ten locations varies between 3.98% and 4.33% with a range value of 0.43% and a mean value of 4.021%. The lowest moisture content was recorded at Okija point 2. Further result analysis reveal a standard deviation of 0.320% standard error of 1.272% and a coefficient of variation of 1,256.6%.

Nitrate: Nitrate is a naturally occurring ion and is a significant component of the Nitrogen cycle. In Table 4.7 the highest nitrate value is observed to be 0.425mg/kg at between Okija and Olu-Obasanjo point 2 with a range value of 0.107mg/kg. The mean value is 0.372mg/kg with a standard deviation of 0.548mg/kg. The standard error was 0.118mg/kg and a coefficient of variation of 67.9%.

Sulphate (SO_4): Sulphate is a major ion and most Sulphate compounds are readily soluble in water (Olorunfemi, et. al., 2011). Contaminated water and waste water are usually high in sulphate concentration. In the present study, the concentration of Sulphate ranges between 6.299mg/kg (minimum) at Afam/Library point 2 and 9.114mg/kg (maximum) in two locations Olu-Obasanjo point 1 and between Okija and Olu-Obasanjo point 2 with a range value of 2.885 and a mean value of 8.168mg/kg and a standard deviation value of 1.083mg/kg. The standard error is 2.885 while the coefficient of variations is 754.2% with respect to drinking water quality, sulphate in high concentration is responsible for gastrointestinal irritation in human beings. In groundwater, sulphate is dissolved and centred from rocks containing gypsum, iron sulphide and other sulphur bearing compounds.

Sodium (Na) Sodium is generally regarded as highly reactive alkali metal and is present in most of the surface water and groundwater. Many rocks and soil contain sodium compound. In the study area, sodium ranges from 50.44mg/kg at Olu-Obasanjo point 2 to 66.80mg/kg at Okija point 1. The range

value is 16.36mg/kg while the mean value is 57.80mg/kg with a standard deviation of 7.33mg/kg. The standard error is 18.28mg/kg while the coefficient of variation is 788.5%

Phosphate (PO_4): Phosphate is a cation. It sources include human sewage, agricultural run-off from crops, and sewage from animal feedlots within the area (Sokpuwu, 2017). The average value of phosphate recorded in this study was 8.168mg/kg. The minimum value was recorded at Olu-Obasanjo point 2 (2.532mg/kg) while the maximum value was recorded at Okija point 2 (4.915mg/kg), with a range value of 2.383mg/kg. Further results showed that phosphate had a standard deviation of 1.083mg/kg, a standard error of 1.009mg/kg and a coefficient of variation of 270.2%. As earlier stated, anthropogenic activities are the main contributors of excessive phosphate into a river channel; sewage discharge, runoff from agricultural sites, and the release of detergent during domestic washing especially along river channel sections are common practices. The load contribution of detergent raises the level of Phosphate in water channel due to the weight of inorganic condensed phosphates.

Calcium (Ca) - Calcium is also an important cation and in groundwater system, it enters into the aquifer system from the leaching of calcium bearing minerals. In drinking water quality, calcium serves in the body as vascular contraction, muscle contraction, blood clothing and nerve transmission. Less intake of calcium results in high risk of piephraliaisis, hypertension, obesity, etc.

The mean concentration level of calcium in Ntawogba creek is 111.575 mg/kg with a standard deviation of 10.28mg/kg less and a standard error 36.607mg/kg. The lowest concentration level of 105.60mg/kg was recorded at behind mile 3 (timber) while the highest concentration level of 126.89mg/kg was recorded at Okija point 1. The study also recorded a range value of 21.29mg/kg with and a coefficient of variation of 1.126%.

Magnesium (Mg): The average magnesium value recorded in this study was 99.72mg/kg with a standard deviation of 7.601mg/kg and a standard error of 31.537mg/kg. across the ten locations. Magnesium concentration level ranges between 92.51 mg/kg (minimum) at Olu-Obasanjo point 2 and 107.51mg/kg (maximum) at Olu-Obasanjo point 2 and 107.51mg/kg (maximum) at Railway/Okija with a coefficient of variation of 1,311.9%. With respect to groundwater, magnesium sources is due to ion exchange of mineral in rocks and soil by water. It is also an important parameter responsible for the hardness of water.

Potassium (K): Potassium is an important cation and is present in many minerals and most of the rocks available on Earth; and many of these rocks are relatively soluble and releases potassium. In this study, the concentration level of potassium varies between 29.21mg/kg (minimum) at Olu-Obasanjo point 2 and 41.04mg/kg (maximum) at Okija point 2. The mean value concentration is 35.01mg/kg with a standard deviation of 5.115mg/kg and a standard error of 11.072mg/kg. Furthermore, the result revealed a range value of 10.84mg/kg and a coefficient of variation 684%. In groundwater system, the concentration of potassium increases with the.

Heavy Metals Data Analysis

The results of the descriptive statistics of the six heavy metals investigated in the study is presented in Table 8.

Manganese (Mn): The average value of manganese in the study locations was 1.892mg/kg. The values obtained for all the sampling points ranged from 1.01mg/kg to 2.84mg/kg in locations 10 and 6 respectively (behind mile 3 and Okija point 1). The range value was 1.83mg/kg. Furthermore, the result revealed a standard deviation of 0.904mg/kg; a standard error of 0.598mg/kg, and coefficient of variation of 209.3% which is a measure of variation, and which implies that manganese varies considerably across the ten sampling points.

Chromium (Cr): Chromium is also another important heavy metal found in soil, groundwater and as well as surface water. In the present study, the distribution of chromium ranged between 0.09mg/kg (minimum) between Okija and Olu-Obasanjo points 2 with a range value of 0.14mg/kg. Chromium recorded a mean value of 0.157mg/kg, a standard deviation value 0.558mg/kg, a standard error value of 0.050mg/kg, a coefficient of dispersion value of 0.281 and a low coefficient of variation value of 28.1% which implies that chromium does not vary much across the ten locations.

Zinc (Zn): The concentration level of zinc in the present study ranges between 0.32mg/kg and 0.48mg/kg with a range value of 0.16mg/kg. The lowest concentration level was recorded at between Okija and Olu-Obasanjo point 2 while the highest concentration level was observed at Okija point 1. The record showed a mean value of 0.398mg/kg and a standard deviation of 0.065mg/kg in all the ten

locations. In addition, the result also showed a standard error value of 0.126mg/kg; a coefficient of dispersion value of 6.128mg/kg and a high coefficient of variation of 621.3% which signifies that zinc varies highly in Ntawogba creek across the ten sampling points. This high variation may be attributed to several factors.

Table 8. Descriptive statistics of heavy metals in Ntawogba creek. **Source:** Researchers' SPSS Analysis (2021).

S/n	Location	Mn	Cr mg/kg	Zn mg/kg	Cd	Fe	pb
1	Olu-Obasanjo Point 1	1.07	2.11	0.35	0.18	231.43	0.33
2	Olu-Obasanjo Point 2	1.05	0.10	0.33	0.19	231.44	0.31
3	Railway/Okija	2.54	0.19	0.46	0.21	302.28	0.36
4	Afam/Library Point1	2.81	0.22	0.45	0.24	304.25	0.33
5	Afam/library Point 2	2.79	0.20	0.44	0.22	303.20	0.34
6	Okija Point 1	2.84	0.20	0.48	0.24	302.29	0.36
7	Okija Point 2	2.75	0.23	0.46	0.22	301.30	0.34
8	Between Okija & Olu-Obasanjo Point 1	1.04	0.13	0.36	0.19	230.46	0.35
9	Between Okija & Olu-Obasanjo Point 2	1.02	0.09	0.32	0.20	231.4	0.33
10	Behind Mile 3 (Timber)	1.01	0.10	0.33	0.17	231.4	0.33
11	Mean (x)	1.892	0.157	0.398	0.206	266.945	0.337
12	SD	0.904	0.558	0.024	0.024	37.659	0.164
13	Range	1.83	0.14	0.16	0.07	73.79	0.05
14	CD	2.093	0.281	6.123	8.583	7.088	2.055
15	CV (%)	209.3	28.1	612.3	858.3	708.8	205.5
16	SE	0.598	0.050	0.126	0.065	84.422	0.107
17	NSDWQ	.	0.05	5mg/l	0.003	0.30	0.10
	WHO	01-0.4	0.05	5mg/l	0.003	0.30	0.10

Cadmium (Cd): According to Chemists, cadmium in its compound occurs as the divalent cadmium ion. Cadmium, together with mercury and lead, is one of the big three heavy metals poisons and is not known for any essential biological function. Cadmium is directly below zinc in the periodic table and has a chemical similarity to that of zinc which is an essential micronutrient for plants and animals. This may account in part for cadmiums toxicity, because zinc being an essential trace element, its distribution by cadmium may cause the malfunctioning of metabolic processes.

In the present study as seen in Table 4, cadmium concentration levels ranged between 0.17mg/kg (minimum) and 0.24mg/kg (maximum) at behind Mile 3 timber market and Afam/Library Point 1 respectively. Other descriptive statistics records include a range value of 0.07mg/kg, a mean value of 0.206 mg/kg; a Standard deviation value of 0.24mg/kg, a Standard error value of 0.065mg/kg, a Coefficient dispersion value of 8.583mg/kg and a Coefficient of variation of 858.3% which implies that cadmium varies considerably high in Ntawogba creek across the ten sampling points.

Iron (Fe): Iron occurs freely in both surface and groundwater. In groundwater, the most common sources of iron is weathering form ion bearing minerals and rocks while in surface water, it may be due to iron metals dropped in river water by human beings or by erosional activity. The concentration of ions in groundwater is often higher than those measured in surface water due to chemical reaction. If Fe^{2+} state is oxidized to Fe^{3+} state in contact with atmospheric oxygen or by the action of iron related bacteria, it forms insoluble hydroxides in groundwater.

The present study revealed that iron concentration level varies from 230.46mg/kg (lowest) to 304.25mg/kg respectively in location 8 and 4. The records showed a range value of 73.79mg/kg; a mean value of 266.945mg/kg; and Standard deviation value of 37.659mg/kg; a Standard error value of 84.422mg/kg. With respect to level of dispersion and variation, the result indicated a dispersion value of 7.088mg/kg and a high variation of 708.6% which implies that iron varies considerably along the ten locations in Ntawogba creek.

Lead (pb): Lead is a cation and is known to be the heaviest element in the world. According to Jarup (2003), lead in drinking water could have significant medical effect on renal functions. Other symptoms of acute lead concentration could result to headache, irritability and abdominal pain (Alasia, et. al., 2009). The present study revealed that the lead level concentration varies between 0.31mg/kg (minimum) at Olu-Obasanjo point 2 and 0.36 (maximum) at Okija point 1 and Railway/Okija. The result also revealed that three locations (Olu-Obasanjo point 1, Afam/Library Point 1 and between Okija and Olu-Obasanjo point 2) recorded the same value of 0.33mg/kg. The average mean value recorded across the ten sampling points was 0.337mg/kg with a standard deviation value of 0.164mg/kg. The results further revealed a range value of 0.05mg/kg which implies that the recorded values of the ten location. The results also showed a low standard error value of 0.107mg/kg; a low dispersion value of 2.055mg/kg and a low coefficient of variation of 205.5% which signifies that lead variation in the ten locations is low.

Benthos Data Analysis

Benthos is the assemblage of organisms inhabiting the sea floor. Benthic epifauna live upon the sea floor or upon bottom objects; the so-called infauna live within the sediments of the sea floor. Benthos are also known as benthos, is the community of organisms that live on, in or near the bottom of a sea, river, lake, or stream, also known as the benthic zone. This community lives in or near marine or freshwater sedimentary environments, from tidal pools along the foreshore, out to the continental shelf, and then down to the abyssal depths (*Maham et al*., 2012). The benthos identified in the study were *Capitellacapitata, Notomastus latrieiceus (Capitellidae); Nephthys (Nephthyididae). Polydora capensis (Spionidae); epidiopatra gilchristi (Eunicidae);* and *Pogebia deltaura (Callianasspidae*). The descriptive statistics of these benthos is presented in Table 9.

Table 9. Analysis of benthos distribution across the ten locations in Ntawogba creek **Source:** Researchers' SPSS Analysis (2021)

S/n	Location	Capitellacapitata	Notomastus latreiceus	Nephthys hombergi	Nereis virens	Polydora capensis	Epidiopatra gilchristi	Pogebia deltaura	Nereis diversicolor	Nereis pelagic
1	Olu-Obasanjo Point 1	3	3	4	2	2	2	5	2	3
2	Olu-Obasanjo Point 2	2	1	3	1	2	1	3	1	2
3	Railway/Okija	4	6	1	3	4	3	12	5	5
4	Afam/Library Point 1	3	4	1	2	2	3	9	3	4
5	Afam/Library Point 2	1	5	1	2	3	2	7	1	2
6	Okija Point 1	2	2	0	3	1	3	10	4	3
7	Okija Point 2	2	5	1	2	3	3	8	3	1
8	Between Okija & Olu-Obasanjo Point 1	3	4	0	3	2	2	8	2	1
9	Between Okija & Olu-Obasanjo Point 2	3	2	1	1	2	2	7	3	3
10	Behind Mile 3 (Timber)	2	3	1	2	1	1	5	3	2
	Total	**55**	**35**	**13**	**19**	**22**	**22**	**74**	**27**	**26**
	Mean	**5.5**	**3.5**	**1.3**	**1.9**	**2.2**	**2.2**	**7.4**	**27**	**26**
	SD	**3**	**5**	**4**	**2**	**3**	**2**	**9**	**4**	**4**

Capitallacapitata: The distribution of capitallacapitata across the ten location along Ntawogba creek ranges from 1 (lowest) at Afam /Library Point 2 to 4(highest) at Railway/ Okija with a range value of 3. A total number of 55 pieces of capitallacapitata was recorded with a mean value of 5.5.

Notomastus latrieiceus: Table 10 showed that a total of 35 samples of *Notomastus latrieiceus* were recorded on the ten stations along Ntawogba creek. The mean value was 3.5 with a range value of 5. The maximum value of 6 was recorded at railway/Okija while the minimum value of 1 was recorded at Olu/Obasanjo point 2.

Nephthys hombergi: The result of *Nephthys hombergi* revealed that there was low distribution of the microorganism in the ten locations. Okija point 1, and between Okija and Olu-Obasanjo Point 1 recorded while the largest samples of 4 was recorded at Olu-Obasanjo point 1. Six locations (Railway/Okija, Afam/Library Points 1 & 2; Okija point 2, between Okija & Olu-Obasanjo Point 2; Okija point 2, between Okija & Ou Obasanjo point 2 and behind Mile 3 market) recorded 1 piece of *Nephthys hombergi* each. The average mean value is 1.3 with a range of 4.

Nereis virens: *Nereis virens* distribution across the 10 locations along Ntawogba creek varies between 1 and 3 with a total of 19 samples recorded. The mean value is 1.9 while the range along is 2. Majority of the sampling points recorded 5 samples each. Sampling points 1 (Olu-Obasanjo point 2 and between Okija & Olu-Obasanjo point 2) recorded 1 sample each.

Polydora capensis: Across the ten locations along Ntawogba creek, the distribution of *Polydora capensis* varies between 1 and 3 with a range value of 2 and a mean value of 2.2. Most of the sampling points recorded 5 samples each. In all a total of 19 samples were recorded in the ten stations. Three sampling points recorded a maximum value of 3 samples while two sampling points recorded a minimum value of 1 sample each.

Table 10. Analysis of zooplankton distribution across the ten locations in Ntawogba creek. **Source:** Researchers' SPSS Analysis (2021)

S/n	Location	Temora longicornis	Eurytemora hirundoides	Anomalocera patersoni	Parcuchaeta norvegica	Calamus finmarchicus	Paracyclops affinis	Tintinnopsis sinensis	Tintinnoposis wanji
1	Olu Obasnajo Point 1	23	14	6	5	7	8	2	6
2	Olu-Obasanjo Point 2	20	10	3	4	5	8	2	4
3	Railway/Okija	17	18	12	10	5	10	0	2
4	Afam/Library Point 1	14	12	9	10	3	10	0	2
5	Afam /Library Point 2	13	11	9	7	5	8	0	1
6	Okija Point 1	15	16	9	9	4	8	0	2
7	Okija Point 2	14	11	10	7	4	6	0	2
8	Between Okija & Olu-Obasanjo Point 1	10	15	8	8	3	5	0	2
9	Between Okija & Olu-Obasanjo Point 2	13	14	8	8	3	4	0	2
10	Behind Mile 3 (Timber)	8	9	7	8	2	3	0	1
	Total	**287**	**130**	**81**	**76**	**41**	**70**	**4**	**24**
	Mean	**28.7**	**13.0**	**8.1**	**7.6**	**4.1**	**7.0**	**0.4**	**2.4**
	Range	**15**	**9**	**9**	**6**	**5**	**5**	**2**	**5**
	Minimum	**8**	**9**	**3**	**4**	**2**	**3**	**0**	**1**
	Maximum	**23**	**18**	**10**	**10**	**7**	**10**	**2**	**6**

Pogebia deltaura: A total of 74 pieces of *Pogebia deltaura* benthos were seen across the ten sampling points in Ntawogba creek with a mean value of 7.4 and a range value of 9. Among the nine benthos organisms investigated, *Pogebia deltaura* recorded the highest value. The lowest 3 samples of *Pogebia deltaura* was recorded at Olu-Obasanjo point 2 while the highest 12 samples were recorded at Railway/Okija.

Epidiopatra gilchristi: The distribution of *Epidiopatra gilchristi* in the study area recorded a total of 22 pieces with a mean value of 2.2 and a range value of 2. Olu-Obasanjo point 2 and behind mile 3 market recorded 1 piece each being the lowest while three sampling points/Railway/Okija, Afam/Library point1, Okija Points 1 and 2) recorded the highest values of 3 pieces of *Epidiopatra gilchristi* benthos. Four stations recorded 2 pieces of benthos each.

Nereis diversicolor: *Nereis diversicolor* distribution along the creek varies between 1 and 5 with a range value of 4 and a mean value of 2.7. Two sampling points (Olu-Obasanjo Point 2 and Afam/Library point 2) recorded the lowest value of 1 piece of *Nereis diversicolor* while Railway/Okija recorded the highest value of 5 pieces of the benthos. Furthermore, four sampling points recorded 3 pieces of the benthos, while, two sampling points Olu/Obasanjo point 2 and between Okija and Olu-Obasanjo 1 recorded 2 pieces of benthos per station.

Nereis pelagic: *Nereis pelagic* distribution ranges between 1 (minimum) and 5 (maximum) in the study area. It recorded a mean value of 2.6 and a range value of 4. A total of 26 pieces of *Nereis pelagic* benthos was recorded across the ten locations. Three locations points recorded 2 pieces of the benthos and as well 3 pieces of the benthos as well. Two location points recorded 1 piece each. One station Afam/library point 1 recorded 4 pieces of benthos. The same is also true for 5 pieces in one station. The distribution is seen not to be evenly distributed.

Zooplankton Data Analysis

The result of the descriptive statistics of the distribution of eight species of zooplankton in the ten stations across Ntawogba creek in Port Harcourt metropolis is shown in table 4.11. The zooplankton consists of two taxonomic groups (Copepoda and Protozoa). The Copepoda taxonomic group is made up of five (5) families (*Temoridae, Pontellidae*, *Euchaetide, Calanoidae* and *Cyclopidae*. The *Temoridae* family was made up of two species (*Temora longicoris* and *Eurytemora hirundoides*); the *Pontilidae* family is made up of one species (*Anomalocera patersoni*); the *Euchaetidae* is made up of one specie (*Parcuchaeta norvegica*); the *Calanoidae* family is made up of one specie (*Calamus finmarchicus*); the *Cyclopidae* family is made up of one specie *Paracyclops affinis*). On the other hand, the protozoa taxonomic group is made up of two species only which are *Tintinnopsis sinensis* and *Tintinnopsis wanji.*

Phytoplankton Data Analysis

The result of the phytoplankton distributed across the ten locations along Ntawogba creek in Port Harcourt metropolis is presented in Table 11. The phytoplankton microorganism consists of a total of thirteen species classified into four taxonomic groups. This taxonomic groups and species are: Baccilariophyceae group (*Melosira varians, Melosira distans, Cosinodiscus lacustris, Fragilaria vivenscens, Synedra ulna, Cyclotella operculata*), Chlorophyceae taxonomic group (*Tetraodon sp* and *Netrium digitus*); Cyanophyceae taxonomic group (*Anabaenopsos anoldic* and *Rivularia planctonica*); Phyrophyceae taxonomic group (*Ceratium hirudinella, Peridium pusillium* and *Peridinium cinatum*).

Melosira varians: The distribution of *Melosira varians* Plankton varies between 6 samples at behind mile 3 timber being the lowest and 13 samples at Railway/Okija being the highest with a range value of 7 samples. A total of 100 samples which implies that an average of 10 samples of *Melosira varians* were recorded in each location. Based on the mean result, it therefore concludes that *Melosira varians* is evenly distributed across the ten locations along Ntawogba creek.

Melosira distans: *Melosira distans* distribution ranges from 1 sample (minimum) at behind mile 3 Timber and 23 (maximum) at two locations (Railway/Okija and Afam/library point 2). Two locations (Okija points 1 and 2) paired up to produce 20 samples each. Furthermore, the result revealed that a total of 187 samples of *Melosira distans* were recorded in the ten stations with a mean value of 18.7 and a range value of 10. Based on the mean value of 18.7, the conclusion drawn here is that an average of 18.7 samples of *Melosira distans* were found in each location.

Cosinodiscus lacustris: The result of the distribution of *Cosinodiscus lacustris* across the ten locations along Ntawogba creek revealed that a total of 86 samples of the plankton was recorded. The minimum value of 3 samples was recorded at Olu-Obasanjo point 2 while the maximum value of 11 samples were recorded in three locations (Railway/Okija, Afam/Library point 2 and Okija point 1). Furthermore, the result analysis indicated a mean value of 8.6 and a range value of 8. It can be seen from the result on the above Table 11 that *Cosinodiscus lacustris* varies considerably along the ten locations in Ntawogba creek.

Table 11. Analysis of phytoplankton distribution across the ten locations in Ntawogba creek. **Source:** Researchers' SPSS Analysis (2021)

S/n	Location	Melosira varians	Melosira distans	Cosinodiscus lacustris	Fragilaria vivenscens	Synedra ulna	Cyclotella operculata	Tetraodon sp	Netrium digitus	Anabaenopsos anoldic	Rivularia planctonica	Ceratium hirudinella	Peridium pusillium	Peridinium cinatum
1	Olu-Obasanjo Point 1	12	18	5	10	6	22	1	6	2	6	3	8	2
2	Olu-Obasanjo Point 2	10	15	2	7	5	19	1	4	2	6	2	8	2
3	Railway/Okija	13	23	11	20	13	8	0	2	8	1	7	3	12
4	Afam/Library Point 1	11	21	11	20	11	8	0	2	7	1	6	3	10
5	Afam /Library Point 2	9	23	9	20	10	6	0	1	5	1	7	2	8
6	Okija Point 1	12	20	11	17	8	7	0	2	7	1	5	3	11
7	Okija Point 2	11	20	10	17	9	6	0	1	5	0	7	2	10
8	Between Okija & Olu-Obasanjo Point 1	8	18	9	15	8	5	0	2	4	0	6	4	7
9	Between Okija & Olu-Obasanjo Point 2	8	16	10	13	10	7	0	2	4	1	5	1	8
10	Behind Mile 3 (Timber)	6	13	7	11	8	6	0	1	2	1	4	1	6
	Total	**100**	**187**	**86**	**150**	**88**	**94**	**2**	**23**	**46**	**18**	**52**	**35**	**76**
	Range	**7**	**10**	**8**	**13**	**8**	**17**	**1**	**5**	**6**	**6**	**5**	**7**	**10**
	Mean	**10**	**18.7**	**8.6**	**15.5**	**8.8**	**9.4**	**0.2**	**2.3**	**4.6**	**1.8**	**5.2**	**3.5**	**7.6**

Fragilaria vivenscens: *Fragilaria vivenscens* is an important phytoplankton seen in most surface water. Its distributions vary from 7 samples (minimum) at Olu-Obasanjo point 2 to samples (maximum) at three locations (Railway/Okija and Afam/Library points 1 and 2). Two locations (Okija points 1 and 2) paired up to record 17 samples of *Fragilaria vivenscens* each. Furthermore, descriptive statistics result showed that a total of 150 samples of *Fragilaria vivenscens* were recorded in the ten locations with a mean value of 15.0 and a range value of 13. Based on the mean result of 15, it implies that an average of 15 samples of *Fragilaria vivenscens* were recorded in each location.

Synedra ulna: The result displayed in the table above shows that a summation of 86 samples *Synedra ulna* was observed in the ten locations where the hydro biological analysis was carried along Ntawogba creek. The mean value was 8.8 while the range value was 8. The distribution of the phytoplankton varies considerably from 5 samples (minimum) at Olu-Obasanjo point 2 to 13 samples (maximum) at Railway/Okija. The result also showed that two locations (Okija point 1 and between Okija & Olu-Obasanjo point 1 produced the same number of 8 samples each. Based on the mean value of 8.8, the overall distribution of the phytoplankton is 8.8 samples per location.

Cyclotella operculata: As can be seen from the result displayed on the above table, *Cyclotella operculata* distribution across the ten locations in Ntawogba creek varies between 5 and 22 samples with a range value of 17. Most of the locations recorded low samples of *Cyclotella operculata*, usually between 5 and 8 samples of the phytoplankton. The result revealed that the total samples of 94. *Cyclotella operculata* were observed in the ten locations with a mean value of 9.4 *Cyclotella operculata* per location. Two locations (Rail-ways /Okija and Afam /Library point 1) tied up to produce 8 sample and another two locations also (Okija point and between Okija & Olu-Obasanjo Point 2) paired up to produce 7 samples each. Furthermore, three locations (Afam/Library point 2; Okija Point 2; and Behind Mile 3 Timber) produced 6 samples of *Cyclotella operculata* each. The lowest sample of 5 was recorded at Olu-Obasanjo Point 2 and the highest 22 samples of the phytoplankton was recorded at Olu-Obasanjo Point 1).

Tetraodon sp: The result revealed that among the thirteen types of phytoplankton distribution analysed in this study, *Tetraodon sp* had the lowest rate of distribution across the ten stations. Apart from two locations (Olu-Obasanjo Point 1 and 2) that recorded one sample each of the phytoplankton, the rest eight locations produced 0 sample. A total of 2 samples of *Tetraodon sp* were recorded with a mean value of 0.2 and a range value of 1 Based on this finding, the inference deduced here is that *Tetraodon sp* is poorly distributed along Ntawogba creek in the ten locations identified. This calls for greater attention to the investigation of *Tetraodon sp* on surface water.

Netrium digitus: The phytoplankton, *Netrium digitus* was sparsely distributed as seen in Table 11. It recorded a total of 23 samples in the ten locations with a mean of 2.3 samples. Its distribution ranges from 1 to 6 samples with a range value of 5. Three locations (Afam/Library points 2, behind Mile 3 Timber and Okija, Point 2) recorded the lowest distribution of 1 sample each on the other hand, five locations (railway, Okija, Afam, Library Point 1, Okija Point 1, between Okija and Olu-Obasanjo Points 1 and 2) recorded 2 samples each. Lastly, Olu-Obasanjo Points 1 and 2 recorded 6 and 4 samples respectively.

Anabaenopsos anoldic: The result of Table 11 showed that *Anabaenopsos anoldic* was fairly distributed across the ten stations as it varies between 2 and 8 samples. The minimum distribution of 2 samples was recorded in three locations (Olu-Obasanjo Point 1 and 2 and Behind Mile 3 Timber) while the maximum distribution of 8 samples was recorded at Railway/Okija. The result also revealed that 12 locations each paired up to jointly produce 4.5 and 7 samples each. Their overall sum distribution was 46 samples with a mean of 4.6. The range value recorded was 6.

Rivularia planctonica: The result of *Rivularia planctonica* revealed that this phytoplankton varied sparsely across the ten locations. It recorded a total sum of 18 samples with a mean value of 1.8 per location. It varies between 0 and 6 with a range value of 6. Majority of the locations (6) recorded one sample per plot. Two locations (Okija Point 2 and between Okija and Olu-Obasanjo Point 1. Paired to record 0 while another two locations (Olu-Obasanjo Points 1 and 2) jointly recorded 6 samples per plot and as well is the maximum value recorded. The sparse variation recorded could be as a result of anthropogenic factors which are limiting the growth and expansion or *Rivularia planctonica* in the study area.

Ceratium hirudinella: As can be seen from Table 4.11, *Ceratium hirudinella* is evenly distributed across the ten stations. The result revealed that the minimum value of 2 samples was recorded at Olu-Obasanjo point 2 while the maximum value or 7 was recorded in three locations (Railway/ Okija, Afam, Library Point 2 and Okija Point 2). A total of 52 samples of *Ceratium hirudinella* was observed in the ten locations with a mean value of 5.2 sample per location. The range value was 5. The result also indicated that two locations (Afam/Library Point 1 and Between Okija & Olu-Obasanjo Point 1) jointly recorded 6 samples each while another two locations Afam/library point 2 and Between Okija & Olu-Obasanjo Point 1) paired up to record 6 samples each.

Peridium pusillium: *Peridium pusillium* distribution across the ten locations along Ntawogba creek varies between 1 (minimum) at two locations between Okija & Olu- Obasanjo point 2 and Behind Mile 3 Timber Market and 8 (maximum) at two locations also (Olu- Obasanjo points 1 and 2). It recorded a range value of 7. In the ten locations, a total of 35 samples were recorded with mean of 3.5 sample per plot. As can be seen also, three locations (Railway/Okija, Afam /Library Point 1 and Okija Point 1) jointly recorded 3 samples each while two locations (Afam/Library Point 2 and Okija Point 2) paired up to produce 2 samples each. However, only one location (Between Okija & Olu-Obasanjo Point 1) recorded 4 samples. The variation in the distribution of this phytoplankton could be attributed to the different human activities carried out along Ntawogba creek.

Peridinium cinatum: The result in Table 4.11 revealed that *Peridinium cinatum* was evenly distributed in the study area with a minimum of 2 samples and a maximum of 12 samples. The minimum and maximum values were recorded in three stations with two stations (Olu-Obasanjo Point 1 & 2) recording the minimum value while Railway/Okija recorded the maximum value. As can be seen from the result, a total of 76 samples were recorded with a mean of 7.6 samples per plot. Furthermore, the result revealed that two locations that are wide apart (Afam/Library point 1 and Okija Point 2) jointly recorded 10 samples each while another two locations that are equally distant apart (Afam/Library Point 2 and Between Okija & Olu-Obasanjo Point 2) paired up to produce 8 samples each.

Hypotheses Testing

This section deals with the analysis of data of the variables (physico-chemical parameters, heavy metals, Benthos, phytoplankton and zooplankton) across the ten locations in Ntawogba creek of Port Harcourt metropolis. This analysis involves testing of hypotheses using one way analysis of variance (ANOVA) and one sample t-test at 0.05 level of significance. The decision rule for accepting or rejecting the null alternate hypothesis is based on the p-value (sig) produced by the Statistical Package for Social Sciences (SPSS) software as against the chosen alpha level of significance of 0.05 on a two-tail test. If the p-value obtained by the SPSS software is greater than the chosen alpha value of 0.05, the null hypothesis was retained while the alternate hypothesis was rejected. One the other hand, if the P-value obtained by the SPSS is lower than the chosen alpha level of 0.05, the alternate hypothesis was retained while the null hypothesis was rejected. The results of the seven hypotheses are displaced on table.

Physico-chemical Parameters Hypotheses Testing

The twelve (12) physico-chemical parameters (pH, temperature, electrical conductivity, salinity, moisture contest, nitrate, sulphate, phosphate, calcium, magnesium, potassium, and sodium) hypothesis across the ten location of Ntawogba creeks are analysed using the one way ANOVA.

Null Hypothesis One (Ho_1): There is no significant variation in the distribution of physico-chemical parameters in Ntawogba creek along the ten location points.

Alternate Hypothesis One (Ha_1): There is significant variation in the distribution of physico-chemical parameters in Ntawogba creek along the ten location points.

The ANOVA result displayed in Table 13 shows a between group of 1118.250 with 9 degrees of freedom and a mean square, value of 124.250; and a within group sum of square of 172293.530 with 110 degrees of freedom and a mean square value of 1566.305. Their total sum of square was 173411.780 with 119 degrees of freedom. Furthermore, the result revealed the F-cal value of 0.079 with a P-value of 1.000. Based on the decision rule of the study, since the P-value produced by the SPSS software is 1.000 and is greater than the chosen alpha level of 0.05 of significance, the null hypothesis was retained while the alternate hypothesis was rejected. Thus, we conclude that there is no significant variation in the mean distribution of physico-chemical parameters in Ntawogba creek among the ten locations ($F9, 110 = 0.79$ $P > 0.05$). This result implies that the mean distribution of the twelve physico-chemical parameters do not vary considerably across the ten sampling points along the Ntawogba creek.

Null Hypothesis Two (Ho_2): There is no significant variation in the mean value distribution of heavy metals parameters in Ntawogba creek along the ten location points.

Alternate Hypothesis Two (Ha_2) There is significant variation in the mean value distribution of heavy metals in Ntawogba creek along the ten location points.

The data below was used to compute the one-way Anova.

Table 12. Physico-chemical parameters

	PARAMETERS	METER	Oluobasanjo Point 1 GPS N4^0,48' 7.404" E6^0,59' 46.313"	Oluobasanjo Point 2 GPS N4^0,48' 11.559" E006^0,59' 45.258"	Railway/ Okija GPS N4^0,47' 49.731" E006^0,59' 55.668	Afam/Library Point 1 GPS N4^0,47' 48.006" E007^0,00' 58.212"	Afam/Library Point 2 GPS N4^0,47' 47.139" E007^0,05' 20.312"	Okija Point 1 GPS N4^0,47' 50.867" E006^0,59' 54.126"	Okija point 2 GPS N4^0,47' 50.292" E006^0,59' 55.061"	B/w Okija & Oluobasanjo Point 1 GPS N4^0,48' 6.228" E006^0,59' 46.223"	B/w Okija & Oluobasanjo Point 2 GPS N4^0,47' 59.685" E006^0,59' 49.362"	Behind Mile 3 Timber GPS N4^0,48' 34.099" E006^0,59' 35.531"	Total %
1.	Temperature ^{0}c	Meter	26.5	24.2	27.2	26.1	24.3	28.2	27.1	26.6	25.3	24.3	
2.	PH	PH Meter	5.85	4.48	5.12	5.10	5.08	6.10	6.10	5.82	4.46	5.02	
3.	Electrical Conductivity,	Conductivity Meter	56.4	56.2	67.2	67.2	66.2	68.1	67.2	56.4	55.3	54.4	
4.	Salinity mg/kg	Meter	16.1	15.0	19.2	19.0	18.99	19.2	18.3	16.0	15.9	16.2	
5.	Moisture Content	Gravimetric Method	3.92	3.90	4.33	3.32	4.33	4.32	4.33	3.93	3.92	3.91	
6.	Nitrate, mg/kg	APHA 4500-N0^3	0.423	0.425	0.319	0.320	0.318	0.320	0.322	0.424	0.425	0.422	
7.	Sulphate, mg/kg	APHA 4500-S0^4	9.104	9.100	7.217	7.219	6.299	8.218	7.220	9.102	9.104	9.100	
8.	Phosphate, mg/kg	APHA 4500-P0^4	2.552	2.532	2.813	2.815	2.810	4.816	4.915	2.551	2.554	2.550	
9.	Ca, mg/kg		105.62	106.60	124.89	124.87	124.88	126.89	125.85	105.62	106.64	105.60	
10.	Mg,mg/kg	APHA 3111b	92.57	92.51	107.51	106.52	107.51	107.52	105.50	92.55	92.53	92.51	
11.	K, mg/kg		30.20	29.21	39.00	40.01	38.99	40.02	41.04	31.19	30.22	30.20	
12.	Na, Mg/Kg		50.60	50.44	63.90	63.90	62.91	66.80	65.79	52.62	50.46	50.59	

The result of the analysis is presented in Table 13

Table 13. A summary of ANOVA analysis on the mean distribution of physico-chemical parameter at the ten locations in Ntawogba creek. **Source:** Researchers' SPSS Computation (2022)

Sources of Variation	Sum of Square	Degree of Freedom	Mean Square	F-cal	P-Value	Alpha Level	Result	Decision
Between groups	1118.250	9	124.250	0.079	1.000	0.05	Not significant	Retained
Within Groups	172293.530	110	1566.305					
Total	173411.789	119						

Table 14. Heavy Metals

Parameters	Method	Oluobasanjo Point 1 GPS N4^0,48' 7.404" E6^0,59' 46.313"	Oluobasanjo Point 2 GPS N4^0,48' 11.559" E006^0,59' 45.258"	Railway/ Okija GPS N4^0,47' 49.731" E006^0,59' 55.668	Afam/Library Point 1 GPS N4^0,47' 48.006" E007^0,00' 58.212"	Afam/Library Point 2 GPS N4^0,47' 47.139" E007^0,05' 20.312"	Okija Point 1 GPS N4^0,47' 50.867" E006^0,59' 54.126"	Okija point 2 GPS N4^0,47' 50.292" E006^0,59' 55.061"	B/w Okija & Oluobasanjo Point 1 GPS N4^0,48' 6.228" E006^0,59' 46.223"	B/w Okija & Oluobasanjo Point 2 GPS N4^0,47' 59.685" E006^0,59' 49.362"	Behind Mile 3 Timber GPS N4^0,48' 34.099" E006^0,59' 35.531"	Total %
1 Mn, mg/kg		1.07	1.05	2.54	2.81	2.79	2.84	2.75	1.04	1.02	1.01	
2 Cr, mg/kg		0.11	0.10	0.19	0.22	0.20	0.20	0.23	0.13	0.09	0.10	
3 Zn,mg/kg		0.35	0.33	0.46	0.45	0.44	0.48	0.46	0.36	0.32	0.33	
4 Cd, mg/kg	APHA	0.18	0.19	0.21	0.24	0.22	0.24	0.22	0.19	0.20	0.17	
5 Fe, mg/kg	3111b	231.43	231.44	302.28	304.25	303.20	302.29	301.30	230.46	231.4	231.4	
6 Pb, mg/kg		0.33	0.31	0.36	0.33	0.34	0.36	0.34	0.35	0.33	0.32	

The result of the analysis is presented in Table 15.

Table 15. A summary of ANOVA analysis on the mean values distribution of heavy metals at the ten locations of Ntawogba creek. **Source:** Researchers' SPSS Computation (2022)

Sources of Variation	Sum of Square	Degree of Freedom	Mean Square	F-cal	P-Value	Alpha Level	Result	Decision
Between groups	2247.387	9	249.710					
Within Groups	601718.205	50	12034.364					
Total	603965.592	59		.021	1.000	0.05	Not significant	Retained

The result displayed in Table 15 show that in the ten locations where water sampled were taken, the between group had 2247.387 sum of squares with 9 degrees of freedom and a mean sum of square of 249.710; and within group sum of squares of 601718.205 and 50 degrees a freedom and a mean square value of 12034.364. Their total sum of squares was 603965.592 with 59 degrees of freedom. The F-cal value was .021 with a P-value of 1.000 which is greater than the chosen alpha value of 0.05 level of significance. Based on the decision rule, since the P-value obtained from the SPSS software is greater than the chosen alpha level of 0.05, the null hypothesis was retained while the alternate hypothesis was rejected. Therefore, the result revealed that there was no significant variation in the concentration level distribution of heavy metal in the ten locations along Ntawogba Creek (F9, 50 = 0.21, P> 0.05). The value of the heavy metals (Manganese, zinc, iron, lead, chromium and cadmium) do not vary considerably along the ten sampling points in Ntawogba creek. The alternate hypothesis was rejected at 0.05 alpha level of significance.

Null Hypothesis Three (Ho_3): There is no significant difference in the Concentration level of oil and grease in Ntawogba creek.

Alternate Hypothesis Three (Ha_3) There is significant difference in the Concentration level of oil and grease in Ntawogba creek.

Table 16. Oil and grease

			Oluobasanjo Point 1 GPS N4^0,48' 7.404" E6^0,59' 46.313"	Oluobasanjo Point 2 GPS N4^0,48' 11.559" E006^0,59' 45.258"	Railway/ Okija GPS N4^0,47' 49.731" E006^0,59' 55.668	Afam/Library Point 1 GPS N4^0,47' 48.006" E007^0,00' 58.212"	Afam/Library Point 2 GPS N4^0,47' 47.139" E007^0,05' 20.312"	Okija Point 1 GPS N4^0,47' 50.867" E006^0,59' 54.126"	Okija point 2 GPS N4^0,47' 50.292" E006^0,59' 55.061"	B/w Okija & Oluobasanjo Point 1 GPS N4^0,48' 6.228" E006^0,59' 46.223"	B/w Okija & Oluobasanjo Point 2 GPS N4^0,47' 59.685" E006^0,59' 49.362"	Behind Mile 3 Timber GPS N4^0,48' 34.099" E006^0,59' 35.531"	Total %
	Parameters	**Meter**											
21.	Oil & Grease	APR 45	0.45	0.43	0.55	0.52	0.51	0.54	0.53	0.51	0.52	0.50	

The result of the analysis is presented in Table 17.

Table 17. A summary of independent t-test analysis of difference in the concentration level of oil and grease in Ntawogba creek. **Source:** Researchers' SPSS Computation (2022)

Sources of Variation	N	Mean	SD	D.F.	T-Value	P-value	Alpha Level	Result	Decision
Oil and increase	10	.50600	.038064	9	42.037	.000	0.05	Significant	Rejected

The one sample t-test result displayed in Table 4.17 shows a sample size of 10, a mean value of 0.50600, a standard deviation value of 0.38064 and 9 degree of freedom. Furthermore, the result revealed a t-value of 42.037 with a P-value of 0.000 which is lower than the chosen alpha value of 0.05. Based on the above result obtained, from the SPSS software analysis, since the P-value produced by the SPSS is lower than the chosen alpha level (P 0.000 < alpha level 0.05), the alternate hypothesis of significant difference in the concentration level of oil and grease in Ntawogba creek is upheld (F9 = 42.037, P < 0.05) while the null hypothesis, was rejected.

The result is significant at 0.05 alpha level. The result of the significant difference in the concentration level of oil and grease implies that the concentration level varies considerably along the ten sampling points investigated. This might be true because along the Diobu area of the Ntawogba creek, motor mechanic workshops and other artesian drops qualities of grease and other petroleum products at different points and drains into the creek and seeps into the soil.

Null Hypothesis Four (Ho_4): There is no significant variation in the distribution of Benthos in the ten stations of Ntawogba creek.

Alternate Hypothesis Four (Ha_4) There is significant variation in the distribution of Benthos in the ten stations of Ntawogba creek.

Table 18. Benthos

	Taxonomic Group	Oluobasanjo Point 1	Oluobasanjo Point 2	Railway/ Okija	Afam/library point 1	Afam/library point 2	Okija point 1	Okija point 2	B/w Okija & Oluobasanjo point 1	B/w Okija & Oluobasanjo point 2	Behind mile 3 timber	Total %
	POLYCHAETA	.		.	.	.						
	Capitellidae											
1.	Capitellacapitata	3	2	4	3	1	2	2	3	3	2	
2.	Notomastus latreiceus	3	1	6	4	5	2	5	4	2	3	
	Nephthyididae											
3.	Nephthys hombergi	4	3	1	1	1	0	1	0	1	1	
	Nereidae											
4.	Nereis diversicolor	2	1	5	3	1	4	3	2	3	3	
5.	Nereis pelagic	3	2	5	4	.2	3	1	1	3	2	
6.	Nereis virens	2	1	3	2	2	3	2	3	1	2	
	Spionidae											
7.	Polydora capensis	2	2	4	2	3	1	3	2	2	1	
	Eunicidae											
8.	Epidiopatra gilchristi	2	1	3	3	2	3	3	2	2	1	
	Total											
	Crustacea											
	Callianasspidae											
9	Pogebia deltaura	5	3	12	9	7	10	8	8	7	5	

The result of the analysis is presented in Table 19.

Table 19. A summary of anova analysis on the benthos distribution in the ten location stations of Ntawogba creek.
Source: Researchers' SPSS Computation (2022)

Sources of Variation	Sum of Square	Degree of Freedom	Mean Square	F-cal	P-Value	Alpha Level	Result	Decision
Between Groups	51.611	9	5.735					
Within Groups	351.111	80	4.389					
Total	402.722	89		1.307	0.247	0.05	Not significant	Retained

Table 19 displayed the ANOVA analysis of Benthos distribution along the ten sampling points in Ntawogba creek. The result revealed a between groups sum of square of 51.611 with 9 degrees of freedom and a mean square value of 5.735 was 351.111 with 80 degrees of freedom and 9 mean square value of 4.389sum of squares was 402.722 with 89 degrees of freedom. The result further showed an F-value of 1.307 with a P-value of 0.247 which is higher than the chosen alpha level of 0.05. Based on the decision rule, since the P-value of 0.247 produced by the SPSS software is greater than the chosen alpha confidence level 0.05, the null hypothesis was retained while the alternate hypothesis was rejected. The result is that there is no significant variation in the distribution of benthos across the ten sampling locations (F 9.80 = 1.307, P> 0.05) at Ntawogba creek. The result is not significant.

Null Hypothesis Five (Ho_5): There is no significant variation in the distribution of phytoplankton in the ten stations along Ntawogba creek.

Alternate Hypothesis Five (Ha_5) There is significant variation in the distribution of phytoplankton in the ten stations along Ntawogba creek.

The result of the analysis is presented in Table 21.

As can be seen from the ANOVA result above, phytoplankton distribution across the ten sampling points along Ntawogba creek had a between group sum of squares of 171.700, 9 degrees of freedom with a mean square value of 19.078; while their within group sum of squares was 4218.308 with 120 degrees of freedom and a mean square value of 35.653. Their total sum of squares was 4,450. 008 with 129 degrees of freedom. In addition, the result displayed an F-value of 0.535 with a P-value of 0.847 which is higher than the chosen alpha level of the study. Based on this premise that the P-value of 0.847 that is higher than the chosen alpha level value of 0.05, the null hypothesis was retained that states that there is no significant variation in the distribution of phytoplankton across the ten sampled stations along Ntawogba creeks F(9.120) = 0.535, P>0.05). The alternate hypothesis was rejected at 0.05 alpha level of significance. The result is also not significant at 0.05 alpha level.

Null Hypothesis Six (Ho_6): There is no significant variation in the distribution of Zooplankton in the ten stations along Ntawogba creek.
Alternate Hypothesis Six (Ha_6) There is significant variation in the distribution of Zooplankton in the ten stations along Ntawogba creek.

Table 20. Phytoplankton

	Taxonomic Group	Oluobasanjo Point 1	Oluobasanjo Point 2	Railway/ Okija	Afam/Library Point 1	Afam/Library Point 2	Okija Point 1	Okija Point 2	B/w Okija & Oluobasanjo Point 1	B/w Okija & Oluobasanjo Point 2	Behind Mile 3 Timber	Total %
	Baccilariophyc EAE	.		.	.	.						
1	Melosira varians	12	10	13	11	9	12	11	8	8	6	
2.	Melosira distans	18	15	23	21	23	20	20	18	16	13	
3	Cosinodiscus lacustris	5	3	11	11	9	11	10	9	10	7	
4	Fragilaria vivenscens	10	7	20	20	20	17	17	15	13	11	
5	Synedra ulna	6	5	13	11	10	8	9	8	10	8	
6	Cyclotella operculata	22	19	8	8	6	7	6	5	7	6	
	TOTAL											
	Chlorophyceae											
7	Tetraodon sp.	1	1	0	0	0	0	0	0	0	0	
8	Netrium digitus	6	4	2	2	1	2	1	2	2	1	
	TOTAL											
	Cyanophyceae											
9	Anabaenopsos anoldic	2	2	8	7	5	7	5	4	4	2	
10	Rivularia planctonica	6	6	1	1	1	1	0	0	1	1	
	TOTAL											
	Phyrophyceae											
11	Ceratium hirudinella	3	2	7	6	7	5	7	6	5	4	
12	Peridium pusillium	8	8	3	3	2	3	2	4	1	1	
13	Peridinium cinatum	2	2	12	10	8	11	10	7	8	6	
	TOTAL											
	Total No: Individuals											
	Total number: Species.											

Table 21. A summary of anova analysis on the phytoplankton distribution in the ten location stations of Ntawogba creek. **Source:** Researchers' SPSS Computation (2022)

Sources of Variation	Sum of Square	Degree of Freedom	Mean Square	F-cal	P-Value	Alpha Level	Result	Decision
Between groups	171.700	9	19.078					
Within Groups	4218.308	120	35.653	0.535	0.847	0.05	Not significant	Retained
TOTAL	4450.008	129						

Table 22 Zooplankton

	Taxonomic Group	Oluobasanjo Point 1	Oluobasanjo Point 2	Railway/ Okija	Afam/Library Point 1	Afam/Library Point 2	Okija Point 1	Okija Point 2	B/w Okija & Oluobasanjo Point 1	B/w Okija & Oluobasanjo Point 2	Behind Mile 3 Timber	Total %
	COPEPODA	.		.	.	.						
	Temoridae											
1.	Temora Longicornis	23	20	17	14	13	15	14	10	13	8	
2.	Eurytemora hirundoides	14	10	18	12	11	16	11	15	14	9	
	Pontellidae											
3.	Anomalocera Patersoni	6	3	12	9	9	9	10	8	8	7	
	Euchaetidae											
4.	Parcuchaeta norvegica	5	4	10	10	7	9	7	8	8	6	
	Calanoidae											
5.	Calamus finmarchicus	7	5	5	3	5	4	4	3	3	2	
	Cyclopidae											

6.	Paracyclops affinis	8	8	10	10	8	8	6	5	4	3
	Total = PROTOZOA										
7.	Tintinnopsis Sinensis	2	2	0	0	0	0	0	0	0	0
8	Tintinnopsis Wanji	6	4	2	2	1	2	2	2	2	1
	Total = Total No: Individuals										

The result of the analysis is presented in Table 23.

Table 23. A summary of ANOVA analysis on the zooplankton distribution in the ten location stations of Ntawogba creek. **Source:** Researchers' SPSS Computation (2022)

Sources of Variation	Sum of Square	Degree of Freedom	Mean Square	F-cal	P-Value	Alpha Level	Result	Decision
Between groups	131.363	9	14.596					
Within Groups	2002.125	70	28.602	0.510	0.862	0.05	Not significant	Retained
Total	2133.488	79						

The ANOVA result displayed in Table 23 shows the distribution of zooplankton microorganism in the ten stations sampled along Ntawogba creek in Port Harcourt metropolis to have a between group sum of squares of 131.363, 9 degrees of freedom with a mean square value of 14.596; the within group sum of squares was 2,002.125 with 70 degrees of freedom and a mean square of 28.603, while 70 degrees of freedom and a mean square value of 28.602. Their total sum of squares was 2,133. 488 with 79 degrees of freedom. The result further revealed the F-calculated value of .510 with a P-value of 0.862. Since the P-value produced by the SPSS software is greater than the chosen alpha level of significance of 0.05. The null hypothesis was retained while the alternate hypothesis was rejected. Conclusively, the result implied that the nine Zooplankton identified in the study area does not vary in their distribution in ten stations along Ntawogba creeks in Port Harcourt metropolis F(9,70)= 1510, P> 0.05). The result is not statistically significant at 0.05 alpha level of significance.

Discussion of Findings

The discussion of findings is based on the parameters investigated which are;

- Physico-chemical parameters of the water samples
- Oil and grease concentration level
- Heavy metals concentration level
- Hydrobiological parameters
- Benthos identification and distribution
- Phytoplankton's identification and distribution
- Zooplanktons identification and distribution

Physico-chemical Parameters of Ntawogba River

The study examined twelve physico-chemical parameters (pH, temperature, electrical conductivity, salinity, moisture, nitrate, sulphate, phosphate, calcium, potassium, sodium and magnesium. Across the ten locations of Ntawogba river in Port Harcourt metropolis. The mean values of these parameters in the ten locations are as follows pH = 5.313, temperature = 25.93^{0}C; electrical conducitivity = 61.46µs/cm; salinity = 17.389ppt; moisture = 4.021%; NO_3 = 0.372mg/kg; SO_4 = 8.168mg/kg; PO_4 = 3.191mg/kg; Ca = 115.75mg/Kg; Mg = 99.72mg/kg; K= 35.01mg/kg and Na = 57.80mg/kg; mg/kg. These values are within the World Health Organization (WHO, 2017) permissible limits as shown in table 4. The physico-chemical parameter (temperature 27^{0}C; sulphate 4.0mg/l; phosphate 3.0mg/l, nitrate 2.0mg/l and electrical conductivity 520µs/cm) were also below the (WHO, 2017) permissible limits in a study of land use and surface water quality in an emerging urban city, Oshogbo, the capital of Osun State. With respect to electrical conductivity (EC), the high magnitude of EC within an urban area, especially in commercial and residential land use types is closely tied to the secretion of acidic substances such as sulphate, phosphate and nitrate, contained in solid wastes entering the water bodies as well effluent discharged from industries into water ways. The increasing levels of conductivity and cations are the products of decomposition and mineralization of organic materials. Electrical conductivity level

increases with the existence of inorganic suspended solids in runoff as well as the presence of chloride and nitrate from sewage systems by extension reduces the purity of the surface water.

In a similar vein, the findings of this study are also in tandem with the findings of Osinbajo, et. al. (2011) that recorded a temperature of 27^0C a mean pH value of 7.5; a mean sulphate of 6.0mg/l; a mean nitrate value of 5.0mg/l which were below (WHO, 2017) permissible level in a study of the impact of industries on surface water quality of River Ona and River Alaro in Oluyole industrial estate, in Ibadan. The authors argued that industrial discharge had negative impact on the surface water qualities of both rivers. This would also be true for Ntawogba River which runs at the heart of Port Harcourt metropolis especially in the Diobu area around Ikoku and Gambia Street where there are lots of mechanic workshops.

Benthos Parameters Distribution

The study identified nine species of benthos (*Capitellacapitata, Notomastus latrieiceus, Nephthys hombergi, Nereis virens, Polydora capensis, Epidiopatra gilchristi, Pogebia deltaura, Nereis diversicolor* and *Nereis pelagic*) with different numbers distributed along the Ntawogba river channel. However, it differs with that of (Maham et al., 2012) that identified only three species of benthos (Ephermeroptera, Plecoptera and Trichopetra) (EPT) in Boardman River, Michigan in the United States of America (USA). The two studies also differ in statistical tool analysis as the present study analyzed the data with one-way analysis of variance (ANOVA) while that of Mahan, et. al. (2021) employed PERMANOVA, which is a multivariate analog of the more commonly used ANOVA. Another area of difference observed is while (Maham *et al*., 2012) investigated composition of benthos in upstream and downstream area, and as well as the total density of all macro vertebrates, overall data richness and functional feeding groups, the present study did not embark on such investigations. These differences observed in the study could be as a result of the objectives of the two studies.

The result revealed that nine species of benthos were identified and that there is no significant variation in the distribution of benthos in the ten locations of Ntawogba creek. On the contrary, the study involved mapping variations on algae density using remote sensing technique in Buffalo National River in Arkansas in USA. Their study also employed ariel photographs alongside multi spectral satellite images. The result revealed spectral distinctions among algae cover values ranging from 6 to 100% and concluded that blooms of benthic algae have become increasingly common in many parts of Buffalo River.

Phytoplankton Identification and Distribution

The findings of this study revealed that thirteen species of phytoplankton were identified across the ten locations of Ntawogba creek and that there is no significant variation in their distribution in the study area. These findings differ with others. The study involved the characterization of phytoplankton biomass, primary production and community structure. The results of index analysis revealed that the dominant species shifted from freshwater diatoms to saline water diatoms. The differences observed in the results of the two studies could be as a result of the objectives of the study.

The findings of this study revealed that a total of 97 species as gamma diversity; a connectivity difference between systems highlighted difference in phytoplankton abundance and biomass and a significant difference in phytoplankton species richness between the systems during the low water in a study of phytoplankton abundance and biomass directly within and between various wetland inhabitants in South America. The conclusion drawn from that study was that local factors may be responsible for changes on phytoplankton community.

The abundance of phytoplankton was highest in zone I out of the three zones and that phytoplankton biomass was influenced by change movement in the sampling stretches in River Gangu in India. The result also revealed that a significant effect was found at three locations along the river channel and that a “barge movement” influence phytoplankton abundance and biomass. The “barge movement” is an aquatic food chain linkage in Bhagirathi-Ituoghlya river.

Zooplankton Identification and Distribution

The results of the study revealed that a total of eight different species of zooplankton across the ten locations of Ntawogba creek in Port Harcourt metropolis in five families in two groups. The result also revealed that there is no significant variation in the distribution of zooplankton across the ten stations.

These findings revealed that species composition of zooplankton communities determined by metabarcoding was consistent with the results based on the traditional morphological approach in a study of zooplankton community profiling in a freshwater ecosystem in Tai basin in China. This difference between the two studies in also as a result of the objectives and methodology adopted in the two studies. The findings of this study also revealed spatial distribution of common species while there was no significant distribution in the present study. Metabarcoding is an advanced technology used in determining hydrobiology samples in an aquatic environment which is yet to be deployed in this part of the world.

Summary

This study investigated bed sediment characteristics in ten locations along Ntawogba river channel in Port Harcourt metropolis. The investigation involved seven environmental variables (physico-chemical parameters of the water) in the river channel, concentration level of heavy metals presence, the distribution of benthos, phytoplanktons, zooplanktons and soil particulate size (PSD) and identification of oil and grease in the river system. The study consisted of seven objectives and seven hypotheses based on the seven environmental variables.

The results of the study revealed that;

- The soil texture along the river channel consists mainly of sandy-clayey
- The majority mean values of the physico-chemical parameters were within the World Health Organisation (WHO) and Nigeria Industrial Standard (NIS) prescribed limit.
- The mean values of the five heavy metals (manganese, chromium, zinc, cadmium, iron and lead) (1.892mgkg, 0.157mg/kg, 0.398mg/kg; 0.206mg/kg; 266.945mgkg and 0.377mg/kg respectively, were below the World Health Organisation permissible limit and Nigeria Industrial Standard acceptable limit
- The mean value of the nine benthos samples identified in the river channel were *Capitellacapitata* (5.5) *Notomastus latrieiceus* (3.5); *Nephthys hombergi* (1.3); *Nereis virens* (1.9) *Polydora capensis* (202); *Epidiopatra gilchristi* (2.2); *Pogebia deltaura* (7.4), *Nereis diversicolor* (2.7); and *Nereis pelagic* (2.6).
- The mean values of the eight samples types of zooplankton identified in Ntawogba creek were *Temora longicornis* (28.1) *Eurytemora hirundoides* (13-0), *Anomalocera patersoni* (8:1); *Parcuchaeta norvegica* (7.0); *Tintinnopsis sinensis* (0.4); and *Tintinnopsis wanji* (2.4).
- The mean values of the thirteen phytoplankton swamp identified along Ntawogba river channel were: *Melosira varians* (10.0), *Melosira distans* (18.7); *Cosinodiscus lacustris* (18.6) *Fragilaria vivenscens* (15.0), *Synedra ulna* (8.8); *Cyclotella operculata* (9.4), *Tetraodon sp* (0.2); *Netrium digitus* (2.3); *Anabaenopsos anoldic* (4.6); *Rivularia planctonica* (1.8); *Ceratium hirudinella* (5.2); *Peridium pusillium* (3.5); and *Peridinium cinatum* (7.6).
- There is no significant variation in the mean distribution of physico-chemical parameters in Ntawogba creek along the ten locations ($F_{9, 110}= 0.79$, $P>0.05$).
- There is no significant variation in the mean distribution of heavy metals parameters in Ntawogba creek along the ten locations ($F_{9, 50}= .021$, $P > 0.05$).
- There is significant difference in the concentration level of oil and grease in Ntawogba creek (DF= $T = 42.037$, $P<0.05$).
- There is no significant variation in the distribution of benthos in the ten locations of Ntawogba creek ($F_{9, 80} = 1.307$, $P>0.05$).
- There is no significant variation in the distribution of phytoplanktons in the ten locations of Ntawogba creek ($F(9,120) = 0.535$, $P. > 0.05$).
- There is no significant variation in the distribution of zooplankton in the ten locations of Ntawogba creek ($F(9,70)= .0510$, $P<0.05$).

Conclusion

This study examined bed sediment characteristics of a river channel system and such characteristics in any ecosystem especially aquatic ecosystem are many and varied. It could be argued that anthropogenic activities along such river channel could alter the marine life especially microbial

organisms such as benthos, phytoplankton and zooplankton. The study identified nine benthos organisms (*Capitellacapitata, Notomastus latrieiceus, Nephthys hombergi, Nereis virens, Polydora capensis, Pogebia deltaura, Epidiopatra gilchristi, Nereis diversicolor* and *Nereis pelagic*), eight zooplankton (*Temora longicornis, Eurytemora hirundoides, Anomalocera patersoni, Parcuchaeta norvegica; Calamus finmarchicus, Paracyclops affins, Tintinnopsis sinensis,* and *Tintinnopsis wanji*; thirteen phytoplankton organisms (*Melosira varians, Melosira distans, Cosinodiscus lacustris, Fragilaria vivenscens, Synedra ulna, Cyclotella operculata, Tetraodon sp, Netrium digitus, Anabaenopsos anoldic, Rivularia planctonica, Ceratium hirudinella, Peridium pusillium* and *Peridinium cinatum*); six heavy metal types (manganese (Mn), Chromium (Cr), Zinc (Zn), cadinium (Cd), iron (Fe), and lead Pb); three soil types (sand, silt and clay); and twelve physico-chemical parameters (pH, temperature, electrical conductivity, salinity, moisture, nitrate, sulphate, phosphate, calcium, magnesium, potassium, and sodium); and oil and grease along the ten locations of Ntawogba river channel in Port Harcourt metropolis.

The benthic invertebrate species as well as the phytoplanktons and zooplanktons function in different ways that are important to maintaining ecosystem functions such as energy flow in the food webs and is of very much concern to environmental managers that manage the environment, especially in an urban centre where this study was carried out. Many benthic and plankton species convert live plant and dead organic materials into prey items for larger consumers in complex food webs. In the process of maintaining energy flow, these benthic species simultaneously provide essential ecosystem services, such as nutrient cycling and aeration of sediments. Thus, different species comprise distinct functional groups that provide ecological integrity. In some cases, these functional groups may be represented by only a few species, so that any loss of species diversity could be detrimental to continued ecosystem functioning. Thus, it is increasingly important to protect the biodiversity of benthic and plankton communities to lower the risk of unexpected and unwanted consequences.

Sediments can be introduced into a river system either by natural and anthropogenic processes, but anthropogenic processes are very much common in urban areas where rivers and streams are located and residents of the urban centres find it very convenient to dispose of their wastes into the streams or rivers. In this respect, should be noted that streams and rivers have differing capacity to cope with suspended sediment depending upon (among other factors) their fauna, their gradient, and the nature of sediment. In many instances, especially at the lower end of any proposed standards, aesthetic considerations could well over-ride ecological ones. If there is sediment deposition, reduction in river productivity is likely to be greater than if the sediment remains in suspension. From all indications, it is likely that Ntawogba River is impacted by industrial, commercial and domestic activities and conscious efforts must be made to ensure that the river channel must be properly monitored to forestall further pollution. Thus, this study has shed in more light of bed sediment characteristics for proper environmental management in an urban centre.

Acknowledgment: *This article was compiled from the scope of the project "Bed sediment characteristics of the Ntawogba river in Port Harcourt Metropolis, Rivers State, Nigeria from Ignatius Ajuru University of Education.*

Compliance with Ethical Standards Ethical responsibilities of Authors: *T The authors have read, understood, and complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors".*

Funding: *No funding was received by the authors.*

Conflict of Interest: *The authors declare that they do not have any conflict of interest.*

Change of Authorship: *The author has read, understood, and complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors and is aware that with minor exceptions, no changes can be made to authorship once the paper is submitted.*

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