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Physico-Chemical Quality of Elechi Creek in Port Harcourt, Nigeria

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ABSTRACT: A total of six hundred and sixteen (616) water samples were collected at seven stations from three zones (A, B, and C) of Elechi creek during an eleven-month's investigation. The samples were analysed for physico-chemical parameters including heavy metals. Higher concentrations of phosphate and BOD in zone B ranging from 2.3 to 9.0 ppm and 3.92 to 8.80 mgL^{-1} respectively were observed and this reflects the eutrophic condition of the creek water in that zone . Concentrations of ammonia, total dissolved solids and salinity were higher in the dry season while those of sulphate, phosphate and electrical conductance were higher in the rainy season. Satistical analysis using analysis of variance (ANOVA) showed that, there were significant differences in concentrations of phosphate, total alkalinity, BOD, total dissolved solids, salinity and electrical conductivity at 5% level between the three zones of Elechi creek. These zonal differences were due to limited water exchange between the zones of the creek. The concentrations of heavy metals were generally low and no trends were observed along the stations of the creek. Except for iron (0.019 to 1.166 ppm) nickel (0.039 to 0.945 ppm) and zinc (0.002 to 4.345 ppm), the concentrations of the other heavy metals were within the range of less than 0.001 ppm to 0.718 ppm. The low concentrations of heavy metals may be due to lack of industrial discharges into the Elechi creek. @JASEM

Natural waters are relatively dilute aqueous solutions. The chemical composition of surface waters is derived from atmospheric, soil and rock sources. The relative contribution to surface waters from each of these sources is a function of the climate being modified increasingly by human activities (Zheng *et al.*, 1995).

The pace of urban development and industrial activity is increasing constantly in Port Harcourt so also is the amount of waste generated. Approximately, 96,000 ton of municipal solid waste is generated annually in Port Harcourt (Moffat and Linden, 1995). Municipal waste is not properly collected and disposed of anywhere in the Niger Delta (Moffat and Linden, 1995). Domestic sewage and industrial wastewater containing large quantities of chemical substances drained into rivers without treatment causes serious water pollution (Yang, 1996).

As environmental damage from human activities due to urban industrialization and developments increasingly affects the water quality of surface waters, there is an acute societal and global need to monitor water quality characteristics of some waters.

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MATERIALS AND METHODS

Description of study area

The study area from which water samples were obtained is the Elechi Creek, close to the Eagle Island, extending to the Iloabuchi Street water bank in Diobu, Port Harcourt. The Eagle Island is located on the South-West of Port Harcourt and bounded on the North by the Rivers State University of Science and Technology in Nkpolu-Oroworukwo area of Diobu.

The Elechi creek is a brackish water system influenced by tidal fluxes. It has mangrove vegetation. The configuration of the creek basin, which widens in some regions and narrows in some other areas, restricts the tidal flow height close to the Nkpolu-Oroworukwo area of Diobu. The Elechi creek water is important as it serves as a means of transportation for humans, fell logs of wood and building materials. The surrounding terrestrial environment is marked with various human activities such as saw milling of timber, waste disposal and frequent defecation on the banks of the creek. Pig breeding on a free-range basis, is also practiced in the area.

In 1992, a road was constructed to provide an access route to the Eagle Island from the Iloabuchi Street in Diobu. During the construction, sand and dredged spoil deposited into one half of the creek into two halves. Consequently water in one half was still free flowing, having its regular bidirectional tidal cycles, while the other half was without obvious tidal fluxes. Frequent precipitation is a common occurrence in the study area and in Port Harcourt as a whole.

Description of Sampling Stations

Based on the peculiarities and features observed around the study area, three sampling zones, A, B and C were recognized. A total of Seven (7) sampling stations were designated from these zones. Sampling Stations were chosen approximately 6 to 10 meters from the creek banks and about 40 to 60 meters apart from each other. The descriptions of the Stations are as follows:

Zone A (Stations 1 and 2). This zone covers the waterbody on both sides of the culvet on the road from Agip Oil Company to Eagle Island. The water flowed beneath the culvet into Station 2. The water had bi-directional flow. Station 1, is located to the right side while Station 2, is located within the water body on the left side of the culvet. Fish, very small in sizes, were visible in Station 2. Small mud huts with human settlements surrounded the water body in this zone.

Zone B (Stations 3, 4 and 5). This zone covered the water body situated to the left side of the newly constructed road when approaching the Iloabuchi Street from the Eagle Island. The water body in station 3, was visibly shallow to the extent that much of the mangrove vegetation extends high above the water surface. On the other hand from Stations 4 to 5, the water surface appeared more turbid, and was densely inundated by blooms of floating macrophytes of Pistia species and by growth of the Nipa palm at shallow areas near the banks. The water flow was uni-directional due to blockage by deposited sand during the road construction.

Furthermore, between Stations 4 and 5, was an area where fell timber logs were pulled by manual labour across the road from the other half of the creek (Zone C), and pushed into the water body in Zone B, for transport to the timber sawmill located after Station 5, at the water bank of the Iloabuchi Street. Municipal solid waste materials were openly dumped by the banks of the new road near Station 5 in this zone.

Zone C (Station 6 and 7). This zone is the area of the creek water on the right side of the new road when approaching Iloabuchi Street from the Eagle Island. The flow of water was bi-directional in this zone, and was fed frequently with water from the Bonny river and water from this zone empties into the Bonny River, when the tide changes. The sources of contamination were very similar to those of Zone B, as open dumping of waste was also practiced on the banks of the new road near Station 7. The open waste dump on both sides of the road, consist of materials ranging from domestic waste, agricultural residues, metal and plastic, scrap, materials, empty cans to discarded waste in Polythene bags. The Waste materials are dumped on a daily basis and some over flowed into the waterbody on both sides of the road (Zone B and C). Pigs feed on components of some of the deposited waste materials.

Collection of Water samples

Water samples were collected from the seven stations twice a month at two weeks intervals during low tide; in order to effectively cover both the dry and wet seasons.

The shoreline sampling method as described by Milne (1989) was employed. The collection of sample was accomplished by wading to slightly above knee depth and samples were taken approximately 20-30cm below the water surface. Each sampling bottle was held at its base, dipped downwards below water surface, opened and allowed to full up and the corked while still under water (APHA, 1985).

Two sets of water samples were collected with 500ml sterile glass bottles for the determination of physico-chemical parameters and heavy metals. Two sets of water samples for dissolved oxygen (DO) determination were also collected with sterile 250ml Winchester bottles. After the collection, one set of the DO determination samples was fixed with 2ml each of Winkler 1 and Winkler 11 reagents.

A total of 4 samples were collected from each stations and a total of 28 samples were collected from all seven stations during each visit.

Sample bottles were appropriately labelled stored in a portable cool box after collection at each station before transportation to the laboratory for analysis. A total of six hundred and sixteen (616) samples were analysed during the study.

Physico-chemical determinations

Physico-chemical parameters determination on the creek water samples included temperature, pH, total alkalinity, ammonia, sulphate, phosphate, total dissolved solids, salinity, electrical conductance, DO, and oil and grease.

The temperature of the samples was determined using a mercury thermometer while the pH was determined using a pH glass electrode meter (Model No. Kem H-112), attached to the potentiometric Automatic Titrator (Model No. AT-210). The Winkler or Iodometric method was used for the DO analysis while total alkalinity was determined by titration using the Potentiometric Automatic Titrator (Model No. AT-120). The physico-chemical parameters were determined using methods adopted from ASTM (1986).

Heavy metal determination
Heavy metal analyses were performed at the Eleme Petrochemical Company Limited Laboratory using the Atomic Absorption Flame Emission Spectrophotometer (AAFES, Model No. AA-670).

RESULTS AND DISCUSSION

The Elechi creek has been subjected to various contaminating materials, capable of initiating the impairment of the water quality. The present investigation has revealed the concentration of certain physico-chemical parameters as well as heavy metals.

The range of the monthly average concentrations of the physico-chemical parameters of the Elechi creek during the eleven months study is as presented in Table 1.

The temperature values ranged from 28°C to 32°C. Temperatures were noted to be higher (30°C to 32°C) between the dry and rainy seasons.

The temperature of the water body are believed to have been influenced by the intensity of sunlight as temperature rose from 30°C to 32°C on relatively hot days particularly in the months of the dry season and lower during the months of rainy season. Variation of temperature in water bodies attributable to sunlight was reported to occur particularly in estuaries due to their general shallowness, which exposed the water and mudflats to sunlight. (Mulusky, 1974; Alabaster and Lloyd, 1980) reported temperatures between 26°C and 30°C and attributed it to the insulating effect of increased nutrient load resulting from input of industrial discharge.

The pH values ranged from pH 6.3 to 7.7. Both high and low values were obtained in station 7. Total alkalinity values ranged from 47.1ppm in Station 6 in December 1995 to 225.8ppm in Station 5 in June 1996.

Table 1: Range of Physico-chemical parameters of Elechi Creek

Parameter	ZONE / STATION						
	A			B		C	
	1	2	3	4	5	6	7
Temperature (°C)	29-32	28-32	28-32	28-31	28-32	29-32	28-32
pH	6.5-6.9	6.6-7.4	6.4-7.5	6.7-7.3	6.6-7.3	6.5-7.4	6.3-7.7
Total alkalinity (ppm)	48.9-96.7	76.1-189.3	101.6-175.6	112.0-196.9	116.8-225.8	47.1-148.2	52.7-99.3
Ammonia (mg L^{-1})	0.3-2.9	0.11-4.2	0.2-2.3	0.2-2.4	0.7-4.2	0.4-3.4	0.8-4.89
Sulphate (mg L^{-1})	107.4-636.5	40.5-788.8	55.6-271.0	37.7-471.3	18.4-246.4	110.4-782.2	119.4-688.6
Phosphate (ppm)	0.3-2.0	1.1-14.2	2.3-7.0	2.3-6.6	4.2-9.0	0.5-1.8	0.6-2.7
TDS mg L^{-1}	5700-13800	1400-8460	1708-4128	1436-4040	1235-3148	5672-17556	8442-19846
DO (mg L^{-1})	5.28-6.52	5.03-6.22	4.32-5.48	4.72-5.43	4.16-5.32	5.22-6.62	5.02-6.62
BOD (mg L^{-1})	2.07-3.32	2.12-3.86	4.35-8.62	3.92-8.80	5.22-8.17	1.43-3.43	2.04-3.46
Salinity (‰)	0.07-0.35	0.06-0.18	0.05-8.62	0.04-0.14	0.04-0.13	0.16-0.53	0.19-0.59
EC (μscm^{-1})	486-2450	123-1290	324-1080	291-514	265-449	1230-2850	1522-3230
Oil and grease (ppm)	0.19-0.17	0.16-0.33	0.09-0.23	0.37-0.56	0.44-0.76	0.54-1.1	0.78-1.22

The pH range of 6.3 to 7.7 reported for Elechi creek could be considered as being within acceptable range for a brackish water system. The pH of brackish water bodies stated by Imevbore (1983) ranged from 6.5 to 7.4, which fall within the range, reported in this investigation. Zheng *et al* (1995) also reported a pH range of 7.48 to 8.89.

Generally higher alkalinity values were obtained in Stations 3, 4 and 5 (Zone B). The higher total alkalinity values recorded in Stations 3, 4 and 5 (Zone B) irrespective of the season, may have been influenced by the presence of domestic waste and the absence of normal tidal action, which would have had flushing and diluting effect on dissolved constituents as well as bi-carbonates which could increase alkalinity levels. However, Stations of Zones A and C recorded higher alkalinity values during the rainy season. Seasonal influence resulting to higher alkalinity values during the rainy season, over levels in the dry season was also reported by Alabaster and Lloyd (1980). This was attributed to increased nutrient load probably rich in carbonates. Stations 5, 6 and 7 recorded higher concentrations of ammonia. This is perhaps due to decomposition of organic matter in the domestic waste dump. The concentration of ammonia ranged from 0.11mg L^{-1} to

4.89mg L^{-1}. On the average, Station 7 recorded the highest ammonia concentrations Sulphate concentrations ranged from 18.4mg L^{-1} to 788.8mg L^{-1}. Stations 1 and 2 (Zone A) and Stations 6 and 7 (Zone C) recorded higher Sulphate concentrations than Stations 3, 4 and 5 (Zone B). Generally, ammonia concentrations were higher in the dry season months than in the rainy season months. Sulphate concentrations were higher in Stations 1, 2, 6 and 7 (Zones A and C) in the rainy season. This is perhaps due to the combined effect of imputed materials from the open waste dump sites and greater influence of marine water from the Bonny river. Marine water is known to have sulphate as one of the chief dissolved ions (Rheinheimer, 1974). Phosphate concentrations ranged from 0.3mg L^{-1} to 9.0mg L^{-1}. In contrast to Sulphate concentrations the Stations 3, 4 and 5 of Zone B recorded the highest Phosphate concentrations, during the rainy season months.

Values were also higher in the rainy months and the lowest concentration of 1.87mg L^{-1} was recorded in Zone C. Phosphate concentrations reported for Elechi creek are higher than those reported by Odokuma and Okpokwasili (1993) and by Zhang *et al.*, (1995). Thus suggesting that the amount of phosphate entering the Elechi creek probably from components of domestic wastes and excreta was high. Calley *et al.*, (1977) reported the quantity of phosphorus produced in pig excreta to be about 15.5gm per day. The higher concentrations of phosphate in Stations of Zone B may have been due to the confinement of inputted phosphate rich waste materials entering the Zone.

This was accentuated by the absence of tidal action, which would have dispersed such impacted materials. The concentration of phosphate were lower than those of ammonia in Stations 1, 6 and 7 (zone A and C) which shows that the domestic waste in Zone B are rich in phosphorus relative to nitrogen.

The blooms of floating macrophytes of the *Pistia* species on the water surface in Zone B, is probably an indication that the water in the zone had become eutrophic due to limited water exchange in this zone. Gross changes mostly commonly observed as a result of eutrophication include increased growth of littoral vegetation, development of algal blooms and eventual de-oxgenation of waters (Sykes and Skinner, 1971). Arulananthan *et al* (1995) also reported that eutrophication ensued mainly due to limited water exchange as was observed for Zone B in this investigation.

The dissolved oxygen (DO) values ranged from 5.03mg L^{-1} to 6.52mg L^{-1}; 4.16mg L^{-1} to 5.48mg L^{-1}; and 5.02mg L^{-1} to 6.62mg L^{-1} for Stations of Zones A, B and C respectively. On the other hand, the Biochemical oxygen demand (BOD) values as calculated from the DO values after five days of incubation ranged from 2.07mg L^{-1} to 3.86mg L^{-1}; 3.92mg L^{-1} to 8.80mg L^{-1} and 1.43mg L^{-1} to 3.46mg L^{-1} for the Stations of Zones A, B and C respectively. The concentration of oil and ranged from 0.16ppm to 0.71ppm; 0.09ppm to 0.76ppm; and 0.54ppm to 1.22ppm for Zones A, B and C respectively.

The dissolved oxygen (DO) content in Zone B depleted fasted than DO content in other zones which could be attributed to the presence of degradable organic matter which resulted in a tendercy to be more oxygen demanding as the BOD values in Zone B were far higher that those of Zones A and C. The low BOD values of Zones A and C may have been influenced by tidal flow of water from the Bonny river which effectively flushed and diluted oxidizable organic matter out of these zones. This is made apparent when one realises that organic matter imputted into Elechi creek probably from human and faecal matter was a daily affair in all zones. Ekundayo (1977) and Imevbore (1983) reported that the contamination of water with faeces, increases the BOD because it contains mainly organic matter making oxygen less available to desirable organisms.

Total dissolved solids concentrations ranged from 1235.0mg L^{-1} to 19846.0mg L^{-1}. The salinity values ranged from 0.040‰ to 0.591‰. Salinity values in Stations 3, 4 and 5 (Zone B) did not exhibit wide variations or flunctuations.

Electrical conductance (conductivity), which is strongly influenced by the concentration of dissolved constituents ranged from 123 µs cm^{-1} to 3,230 µs cm^{-1}. Generally the values of TDS, salinity and electrical conductivity were higher in Stations of Zones A and C that in Stations of Zone B. The concentrations of oil and grease were generally low and values ranged from 0.09mg L^{-1} to 1.22mg L^{-1}.

The high concentrations of total dissolved solids (TDS) in Stations 1, 6 and 7 of Zones A and C is attributable to the influx of sodium chloride and other dissolved ions into these zones by tidal action from the Bonny river. The concentrations of TDS reported for Elechi creek are far higher than those reported by Zheng *et al* (1995) for Tibetan waters. Similarly, salinity values were higher in Stations 1, 6 and 7 (Zones A and C) with decreasing values towards stations of Zone B due to the absence of tidal action and limited water exchange in Zone B. This phenomenon probably accounted for the same trend in the electrical conductivity values recorded for Elechi creek. Not surprisingly, the mean values of TDS, salinity and Electrical conductivity strongly reflect this influence of higher values in Stations of Zones A and C which received direct flushes from Bonny river.

Seasonal changes in parameters such as pH, BOD and salinity during the rainy season are attributable to increased effects of surface run-off soil erosion and effluent discharges into the receiving water body (Odukuma and Okpokwasili, 1993).

The concentration of oil and grease were generally low throughout the Stations of the Elechi creek. Such minimal values (0.09 to 1.22ppm) were not surprising as there were no noticeable oil films on the water surface, neither were there petroleum or oil related activities around the Elechi creek. Odokuma and Okpokwasili (1993) reported increases in oil and grease content at sites near oil related industries. High levels of oil and grease raises great concern especially in an aquatic environment because of its possible adverse effect on the biotic community. Values less than 10ppm as reported in this study falls within permissible limit in industrial effluent samples.

The range of the average monthly concentrations of heavy metals for Elechi creek during the eleven-month's study is presented in Table 2.

Table 2: Heavy metal concentrations of Elechi Creek

Sample Stations	Heavy metal ranges (ppm)						
	Fe	Cu	Ni	Pb	Zn	Cd	Cr
1	0.037-0.602	0.017-0.186	0.039-0.642	<0.001-0.087	0.003-1.215	<0.001-0.061	<0.001-0.718
2	0.033-0.512	0.059-0.185	0.084-0.496	<0.001-0.160	0.002-1.354	<0.001-0.067	<0.001-0.258
3	0.027-0.938	0.005-0.262	0.103-0.525	<0.001-0.015	0.002-0.822	<0.001-0.230	<0.001-0.163
4	0.019-0.699	<0.001-0.581	0.101-0.783	<0.001-0.080	0.002-1.211	<0.001-0.047	<0.001-0.171
5	0.025-1.166	<0.001-0.320	0.027-0.804	<0.001-0.001	0.026-0.942	<0.001-0.041	<0.001-0.542
6	0.031-0.874	<0.001-0.303	0.114-0.703	<0.001-0.001	0.002-1.031	<0.001-0.080	<0.001-0.288
7	0.019-0.527	<0.001-0.321	0.131-0.945	<0.001-0.001	0.005-4.354	<0.001-0.254	<0.001-0.375

The concentrations of iron, copper and nickel ranged from 0.019ppm to 1.166ppm; <0.001 to 0.262ppm; and 0.027ppm to 0.945ppm respectively. The concentrations of lead, zinc and cadmium ranged from <0.001 to 0.160ppm; 0.002 to 0.822ppm and <0.001 to 0.254ppm respectively, while concentrations of chromium ranged from <0.001ppm to 0.718ppm. Except for concentrations of iron in Stations 3 and 5 (Zone B), the concentration of zinc at the upper limit was higher than for other heavy metals in all the Stations of the Elechi creek.

Heavy metal concentrations were generally low throughout the Stations of the Elechi creek. Except for the concentrations of iron (0.019 to 1.166ppm) nickel (0.039 to 0.945ppm) and zinc (0.002 to 4354ppm), the concentrations of copper, lead, cadium, and chromium were within the range of less than 0.001ppm to 0.718ppm. Heavy metal concentrations were not higher as may have been expected in Zone B, which is a zone where materials which entered the zone were not readily dispersed.

Concentrations of heavy, metals reported in this investigation are far lower than those reported by Rivail Da Silva *et al.*, (1996) in a mangrove ecosystem. However, the concentrations of copper, nickel, lead, zinc, cadmium and chromium are similar to those reported by Zheng *et al.*, (1995) for Tibetan rivers while their concentrations of iron are higher than those reported in this study.

The low concentrations of heavy metal reported in this investigation may be due to lack of industrial discharges into the Elechi creek. On the other hand, the abundant suspended matter and high pH values (6.4 - 7.7) may have effectively scavenged metals through adsorption and precipitation. Zhang *et al.*, (1995) also reported a high pH in their finding.

The statistical analysis of variance (ANOVA) carried out on the physico-chemical parameters showed that there were significant differences on pH, total alkalinity, phosphate, total dissolved solids, salinity and electrical conductivity at 5% level between Zones A, B and C. These zonal differences amongst other factors are attributable to limited water exchange in Zone B, which led to a high BOD, blooms of littoral vegetation and eutrophication of the water in this zone.

The deposited and dredged spoils in the Zone B area during the construction of the new road leading to Eagle Island, as well as the absence of an open channel into Zone B, is responsible for the limitation of tidal action from the Bonny river to the water bodies of only Zones A and C. There is therefore a need to construct a channel through which the creek water can flow through the blocked zone for easy water exchange.

Furthermore, there is the need for possible impact assessment before embarking on new projects such as road construction in this case inspite of the perceived beneficial intent.

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