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Water Quality of Streams Receiving Municipal Waste Water in Port Harcourt, Niger Delta, Nigeria

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1. Introduction

The Niger Delta environment was relatively a pristine area some 100 years ago and consists of several ecological zones mainly lowland forest, freshwater swamp forest, prominent in the northern limit while the mangrove and barrier island zones dominate the southern stretch (RPI, 1985, NDES, 2000 and NDDC, 2004). Settlements were of small population and largely in pockets around these ecological zones. The people are agrarian and indulge mostly in farming, fishing and exploitation of timber and non timber forest products. With the relative small nature of the populations in the settlements their wastes generated and discharged into the environment had little or no significant impact on the environment (Onuoha, *et. al.,* 1991).

With the absence of pipe borne water they depended on the stream system for the potable water use, recreation, washing, bathing and fishing (Amadi *et. al.*, 1997).

The advent of civilization has attracted human population to the major urban centres for white collar jobs and more also the crude oil found in commercial quantity in the region has accelerated the pace of development in terms of human population, urban growth, industrial activities, infrastructural development, intensive farming and other economic activities (NDDC,2004, Petrarova *et. al.*, 2009, Onderka *et. al.,* 2010).

The growth of human population and rapid industrialization led to increasing use of urban waters as sewers, compromising their other uses. The discharge of industrial effluents has led inevitably, to alterations in the quality and ecology of receiving water bodies (Sheikh, and Irshad. 1980 and Wahid *et. al.*, 1999). This results into new challenges to water resource managers and aquatic ecologists. Several attempts have been made to regulate/control the quality of effluents that are discharged from waste generating industries into the water systems with little effort on urban discharges. Today, most urban areas of the developing world remain inadequately served by sewage treatment infrastructure (NDDC,2004). Untreated wastes pose serious threats to associated environment including human health risks. Commonly cited effects of industrial effluents on the receiving waters are high turbidity, reduced transparency, increased suspended solids and oxygen depletion (Rafiu *et. al.*, 2007). The area study covers over 94.72 km^2 with a population of about 1.9 million.

The tremendous spatial spread of the Port Harcourt city has resulted in land take for various purposes, encroached, and converted to build up area with concrete buildings by both the government and private agencies without providing open spaces and corridors. Consequently, the natural water bodies (stream) draining the forest seawards are left bare including the stream banks especially in Port Harcourt area where this study was undertaken. As a result the water bodies now lack ecotonal characteristics required to undertake self-purification through biological processes (Lakatos et al 1997, Soler et al. 1991, Chindah *et. al*., 2007).
It is known that these water bodies have that drain Port Harcourt Municipality played a crucial role in growth and sustaining the development of human communities; however, it is paradoxical that they have undergone degradation in modern times due to various anthropogenic activities (Chindah *et. al*., 2009). With the attendant increase in population, industrial and commercial activities, untreated municipal, industrial solid wastes and effluents discharged have led to the total degradation of the water quality in many of the stream systems(Ogan, 1988, Ogamba *et. al*., and Omunakwe *et. al*., 2009). The consequences include the problem of water pollution rendering water no longer fit for drinking, recreation, as well as for aquatic life. As a result, thousands of children die everyday from diarrhoea and other water, sanitation and hygiene related diseases and many suffer and are weakened by illness (Pandey, 2006). Streams and rivers are vital and vulnerable freshwater systems that are critical for the sustenance of all life. However, the declining quality of the water in these systems threatens their sustainability and is therefore a cause for concern despite their importance in providing various water resources for domestic, industrial, and agricultural purposes (Musaddiq, 2002, Qureshi and Dutka, 1979).
The objective of this research is to find out the pollution level of different streams located in these catchments. The pollution level was determined by examining different physical and chemical parameters of waste water such as Temperature, pH, alkalinity, hardness, dissolved oxygen, BOD, Ammonia, Nitrate, Sulphate and phosphate, and microbiological properties.

2. Materials and methods

2.1 The study area:

Geographically, Port Harcourt is situated at the eastern flank of the New Calabar River, the study streams are located within the lowland and freshwater swamp zones that accommodate the northern limits of Port Harcourt City and lie between latitude 4^o 43′E – 4^o 50′ E and longitude 6^o 57′N – 7^o 05′N. The catchments cover an estimated area of 94.72km^2 made of flat ground with lithosphere and hydrosphere are interrelated and consequently involved closely related problems including non point source pollutants.
The five streams that drain this catchment and finally empty into Bonny estuary include:-

- Ntawogba Stream
- Miniweja Stream
- Miniokoro Stream
- Minichida Stream and
- Agbonchia Stream.

Ntawogba Stream

Ntawogba stream lies on the extreme west of the municipality and drains the marshy swamp forest up stream of (Rumueme and Rumuepirikom) empties into Amadi creek.

Large ares of the catchment are developed with concrete structures and the lower reach of the stream is concreted.

Miniweja Stream

This stream system drains the Freshwater (Rumuigbo/Rumuola) forest and through various communities and empties into Diobu Creek of Bonny estuary. The greater stretch of the stream channel is degraded while the middle and lower reaches have been more developed with concrete structures.

Miniokoro Stream

Miniokoro stream drains the freshwater swamp forest into Woji creek from where it eventually empties into the Bonny estuary. The entire stream stretch is degraded, built up area with concrete structures and paved roads.

Minichida Stream

Minichida drains the freshwater swamp forest, meanders through communities and empties into Elelenwo creek in Bonny estuary. All the reaches of the stream are degraded by human activities with concrete structures along the water course.

Agbonchia Stream

Agboncha which lies in the east flank of Port Harcourt drains the freshwater swamp forest and empties through Obufe /Elelenwo creek into the Bonny estuary. Development and degradation is fairly low compared with other stream systems but the water body also read recieives effluent of a petrochemical plant.

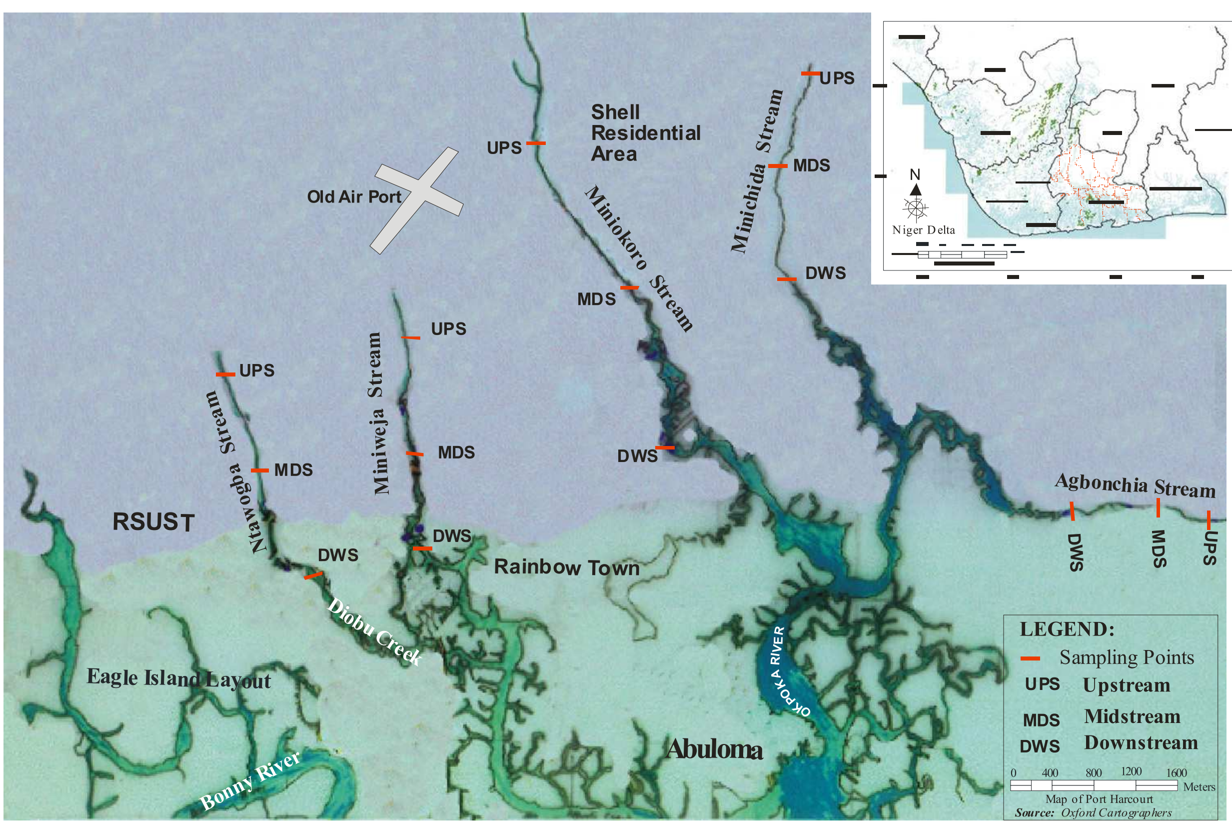

Fig. 1. Map of Niger Delta, Port Harcourt environment showing the 5 study streams

The climatic condition is humid typical of the semi hot equatorial type (Gobo, 1988 and Gobo *et. al*., 2008). The area experiences heavy rainfall from April to October. Sporadic rainfalls are however experienced during the dry season months of November to March. The mean annual rainfall is estimated to be about 2,405 mm. The prime cause of critical unsanitary conditions of the water bodies is due to the lack of facilities for collection and disposal of waste effectively such that municipal untreated effluent wastewater are discharged into natural surface water drains and sometimes on land and finally through storm water to the stream systems

2.2 Sampling strategy

Samples were collected monthly for 12 months to cover the two main seasons from 6 designated locations from each of the 5 streams (Agboncha stream, Minichida stream, Miniokoro stream, Miniweja stream and Nta-wogba stream). Each of the stream systems, were strategically divided into three segments (upper limit, middle reach and down stream) along the water course considering flow, stretch and human activities. For each segment, two stations were located at an interval of 0.5km. The parameters sampled include temperature, pH, alkalinity, hardness, conductivity, dissolved oxygen, BOD_5, sulphate, ammonia, nitrate, phosphate and microbial properties.

2.3 Physicochemical parameters

In the field, samples for each station were collected with clean 2ml plastic containers at sub-surface level and stored in an ice chest (-4oC). The samples was immediately transferred to the Institute of Pollution Studies (IPS) laboratory for analysis. In the laboratory, analysis was done using procedures as outlined in Standard Methods for the Examination of water and wastewater (1 and 10). Temperature was measured in-situ using a mercury bulb thermometer. pH was measured with a pH meter (Hanna instrument model HI8314). The conductivity was measured using the Horiba water checker model U-10 and Carbon dioxide was measured by the tirimetric method as described in APHA (1998). Dissolved oxygen (DO), and biochemical oxygen demand (BOD_5) were determined using Winkler's method as described in APHA (1998). Other parameters such as ammonia-nitrogen (NH_3-N), nitrate-nitrogen (NO_3-N), sulphate (SO_4^{-2}), and phosphate (PO_4^{-3}) concentrations were determined spectrophotometrically (Spectronic Spectrophotometer 21D), following the procedures as described in APHA (1998). The media used for the bacteriological analysis of water include plate count agar (PCA), nutrient agar (NA), lactose broth (LB), and Eosin Methylene blue agar (EMB). All the media used were weighed-out and prepared according to the manufacture's specification, with respect to the given instructions and directions. A serial dilution method was used for total viable count and the presumptive test for coliforms (APHA,1998).

3. Results

3.1 Minichida

Water temperature was generally high, as expected in the dry season (26.75 ± 1.1 - 27.25 ± 1.27°C) value slightly higher than that of wet season (26.79 ± 0.99 - 26.93 ± 1.32°C). The differences in temperature amongst stations were significant (R^2 = 1) but not significant during the wet season (R^2 = 0.25) Table 1.

Table 1. The mean and standard deviation of the physicochemical and microbial variables for the 3 main ecological limits of the 5 streams for wet and dry seasons

Parameter	Season	Nta-Wogba Upstream	Nta-Wogba Middle Reach	Nta-Wogba Down Stream	Miniweja Upstream	Miniweja Middle Reach	Miniweja Down Stream	Miniokoro Upstream	Miniokoro Middle Reach	Miniokoro Down Stream	MiniCh Upstream	MiniCh Middle Re
T °C	DRY	28.00	28.50	31.00	28.13	30.17	30.58	26.84	28.17	30.33	26.75	27.00
	SD	1.00	1.05	1.91	0.93	1.60	1.49	1.04	1.94	1.12	1.10	1.26
	WET	28.07	27.50	28.64	26.72	28.29	28.32	26.22	27.29	29.25	26.86	26.79
	SD	2.83	1.44	2.63	1.13	2.06	2.49	1.42	1.60	1.40	1.08	0.99
pH	DRY	6.17	6.19	6.29	6.24	6.55	6.58	6.10	5.90	6.57	6.46	5.97
	SD	0.03	0.04	0.05	0.35	0.30	0.39	0.38	0.54	0.41	0.30	0.38
	WET	6.46	6.55	6.57	6.25	6.33	6.37	6.18	6.00	6.35	6.25	6.30
	SD	0.16	0.13	0.18	0.27	0.16	0.34	0.33	0.41	0.45	0.53	0.46
CO_2	DRY	24.42	11.79	12.66	35.10	26.39	24.33	23.90	31.75	18.57	43.55	33.98
(mg/l)	SD	16.48	4.49	8.90	9.59	4.63	9.02	9.87	12.28	5.50	14.54	8.91
	WET	36.96	38.10	25.83	40.88	37.67	36.74	38.67	39.67	25.23	32.89	37.96
	SD	16.20	19.52	11.88	13.37	13.62	17.07	26.63	26.97	6.23	9.51	12.07
ALKALINITY	DRY	28.10	155.33	60.50	11.84	28.00	32.50	7.17	11.00	31.84	7.17	7.67
(mg/l)	SD	21.62	144.35	18.06	2.86	13.86	23.65	1.87	2.45	8.31	2.89	1.51
	WET	21.72	46.29	51.50	12.07	20.57	24.72	7.00	7.43	23.86	7.57	7.71
	SD	10.24	22.22	19.48	3.22	10.05	10.88	2.56	3.41	10.31	2.33	2.69
CONDUCTIVITY	DRY	250.30	1215.00	25565.00	2263.85	13165.00	17190.85	33.34	221.00	1831.67	29.59	26.00
(µS/cm)	SD	271.46	1029.56	13961.91	2433.75	14532.40	16075.35	7.34	211.34	1223.84	5.77	5.55
	WET	99.14	224.29	12895.72	543.00	5994.30	7888.60	35.72	89.86	1053.57	33.86	28.86
	SD	38.13	87.53	10074.36	1196.95	11684.30	9742.30	16.22	132.68	1205.89	7.13	8.93
HARDNESS	DRY	38.50	184.96	2297.60	333.12	1076.80	1438.72	10.88	32.96	161.20	8.32	6.40
(mg/l)	SD	25.09	165.11	1128.16	335.97	1150.57	1367.80	9.88	20.73	80.45	5.02	3.36
	WET	27.02	63.36	1392.00	183.41	751.54	1380.35	19.06	20.30	137.62	12.21	9.34
	SD	11.52	24.51	848.51	287.88	857.59	1575.43	18.40	17.83	86.91	6.99	5.23
DO	DRY	1.45	0.44	5.80	3.24	5.97	6.91	2.10	5.16	5.36	1.48	1.10
(mg/l)	SD	1.59	0.71	4.45	1.01	2.25	3.06	1.02	0.93	1.89	0.71	0.71
	WET	6.03	4.41	6.41	3.64	6.24	6.44	2.56	4.99	5.12	4.10	3.05
	SD	7.67	2.62	3.04	1.20	2.11	2.93	0.88	0.94	1.55	2.56	2.62
BOD	DRY	26.45	34.82	55.25	18.72	23.82	25.56	23.28	29.16	33.85	11.78	18.66
(mg/l)	SD	9.67	9.43	7.44	5.74	4.84	6.58	3.59	4.17	5.85	6.55	3.41
	WET	13.45	26.23	37.86	11.65	13.07	14.62	12.92	19.16	22.66	9.52	12.64
	SD	3.50	8.66	8.54	5.83	5.53	6.67	4.67	2.05	5.63	2.74	2.57
NH_4-N	DRY	0.79	3.39	1.35	0.45	0.19	0.33	0.42	0.31	0.18	0.39	0.59
(mg/l)	SD	0.89	3.73	1.78	0.42	0.18	0.33	0.50	0.31	0.14	0.40	0.91
	WET	0.68	1.34	0.82	0.31	0.29	0.38	0.40	0.38	0.38	0.33	0.31
	SD	0.73	1.49	1.11	0.27	0.21	0.42	0.45	0.30	0.37	0.29	0.30
NO_3-N	DRY	0.67	0.43	0.53	0.81	0.71	0.68	0.55	0.91	0.66	0.56	0.46
(mg/l)	SD	0.41	0.20	0.28	0.31	0.22	0.18	0.24	0.39	0.28	0.17	0.20
	WET	0.52	0.55	0.71	0.91	0.61	0.69	0.43	0.35	0.49	0.41	0.35
	SD	0.14	0.21	0.21	1.33	0.27	0.24	0.17	0.16	0.22	0.21	0.25
SO_4^{2-}	DRY	15.50	13.38	275.32	61.81	414.50	603.06	0.91	1.12	45.53	0.76	0.75
(mg/l)	SD	13.15	6.44	194.26	70.84	359.93	486.01	0.20	0.31	29.30	0.38	0.37
	WET	9.92	6.29	227.50	18.64	165.04	199.91	0.92	1.03	34.25	0.95	0.90
	SD	8.74	3.94	124.57	42.17	288.78	272.36	0.19	0.10	21.78	0.09	0.00
PO_4- P	DRY	0.18	0.33	0.14	0.13	0.14	0.15	0.20	0.12	0.14	0.11	0.13
(mg/l)	SD	0.16	0.35	0.17	0.12	0.13	0.15	0.26	0.09	0.07	0.05	0.06
	WET	0.32	0.47	0.32	0.15	0.19	0.25	0.38	0.18	0.10	0.10	0.09
	SD	0.17	0.37	0.25	0.08	0.19	0.24	0.29	0.11	0.06	0.06	0.03
	SD	8.74	3.94	124.57	42.17	288.78	272.36	0.19	0.10	21.78	0.09	0.00
Total Coliform	DRY	677.00	578.00	986.00	342.00	459.00	533.00	235.12	298.82	466.81	189.67	311.56
(cfu/100ml)	SD	102.64	87.12	134.00	45.34	101.23	76.80	45.23	12.23	56.41	34.22	57.84
	WET	452.00	582.00	811.00	621.86	782.15	698.45	302.33	523.45	588.77	342.28	427.28
	SD	65.00	79.00	122.00	76.33	95.83	54.81	52.18	105.22	96.42	24.78	58.91
Faecal Coliform	DRY	192.66	225.66	328.67	114.00	153.00	177.54	78.37	99.61	155.60	63.22	103.85
(cfu/100ml)	SD	22.80	19.36	29.78	10.07	22.49	17.06	10.05	2.71	12.56	7.64	12.83
	WET	151.67	272.14	195.30	208.63	296.39	262.46	201.45	175.65	197.56	114.85	143.38
	SD	19.11	23.23	35.88	22.45	28.18	16.12	15.34	30.94	28.35	7.25	17.35

pH was acidic for both seasons with values slightly more acidic in the dry season (5.97 ± 0.38- 6.46 ± 0.30) than in the wet (6.19 ± 0.19 - 6.30 ± 0.46). Concentrations of alkalinity increased from the upstream to the down stream stations for wet and dry seasons, Seasonal trend demonstrated higher concentrations in the wet season (7.57 + 2.33 - 11.14 ± 4.25mg/l) than during the dry (7.17 ± 2.89 - 8.10 ± 2.43mg/l) season. Spatial differences between the stations in dry season (R^2 = 0.06) were not significant but significant differences were observed during the wet season (R^2 = 0.78) amongst the stations. Carbon dioxide concentrations were relatively higher in the dry season (33.98 ± 8.91 - 43.55 ± 14.54mg/l) than in the wet season (32.61 ± 10.86 - 37.96 ± 12.07mg/l) Table 1.

Conductivity was relatively higher in the wet season (28.86 ± 8.93 - 42.29 ± 8.93μS/cm) than in the dry season (26.0 ± 5.55 - 29.59 ± 5.77 μS/cm) with no clear spatial trend along the water course. Alkaline value was higher in the wet season (7.57 ± 2.33 – 11.14 ± 4.16mg/l) than during the dry season (7.0 ± 2.43 - 7.67 ± 1.51mg/l) with concentrations increasing down stream in the wet but in the dry season no defined sequence was observed and the spatial distributions were not significant in the dry season (R^2 = 0.06) but significance was observed in the wet season (R^2 = 0.78).

Hardness values were higher in the wet season (9.34 + 5.23 - 16.46 + 12.43mg/l) than during the dry season (6.4 ± 3.36 - 8.32 ± 5.02mg/l) and there were no clear spatial patterns between wet and dry seasons Affinity between the stations for wet and dry seasons were not significant but the dry season (R^2 = 0.35) values indicated closer affinity between stations than in the wet season (R^2 = 0.17). Dissolved oxygen concentrations were low in the dry season (1.1 ± 0.71 - 1.48 ± 0.71mg/l) than during the wet season (2.19 ± 1.52 - 4.1 ± 2.58 mg/) with the upstream having the highest dissolved oxygen concentrations than the other limits for both seasons.

BOD_5 on the other hand recorded higher concentrations in the dry season (11.78 ± 6.55 - 27.76 ± 7.47mg/l) than in the wet season (9.52 ± 2.74 - 16.49 ± 3.13mg/l).in both seasons, concentrations increased down stream.

Sulphate concentrations tended to decrease down stream for both seasons with wet season (0.85 ± 0.20 - 0.95 ± 0.09mg/l) concentrations being higher than dry season values (0.75 ±0.37 - 0.76 ± 0.38mg/l). However, the distribution of concentrations between the stations indicated closer affinity in the wet season (R^2 = 1) than during the dry season (R^2 = 0.75)

Ammonia nitrogen concentrations were relatively higher in the dry season (0.28 ± 0.34 - 0.59 ± 0.91mg/l) than in the wet season (0.31 ± 0.30 - 0.38 ± 0.49mg/l) and the spatial distribution demonstrated that the middle reach had higher concentrations followed by the upstream and the down stream in that respective order (Table 1).

Nitrate nitrogen concentrations declined downstream with concentrations being relatively higher in the dry season (0.45 ± 0.17 - 0.56 ± 0.17mg/l) than during the wet season (0.35±0.25 - 0.41 ± 0.21mg/l). Also differences between the stations in dry season (R^2 = 0.79) were significant but significance was not observed in the wet season (R^2 = 0.29). Phosphate concentrations were low for both seasons dry season concentrations (0.11± 0.05 - 0.13 ± 0.06mg/l) being slightly higher than wet season concentrations (0.01 ± 0.03 - 0.15 ± 0.08mg/l) Table 1.

The total coliform concentrations were high for both seasons and concentrations consistently increased down stream. Dry season (189.67 ± 34.22 – 289.34 ±48.93 cfu/100ml) concentrations were higher than values observed in the wet season (342.28 ±24.78 – 462.93 ±95.32cfu/100ml). Spatial distribution amongst the three zones indicated significance but with closer affinity between the zones in dry season (R^2 = 0.95) than in the wet season

(R^2 = 0.59). Correspondingly, the faecal coliform concentrations followed similar seasonal and spatial pattern as observed but concentrations were lower by a magnitude of about 4 times with concentrations for dry season (63.22 ± 7.64 – 103.85 ± 12.83cfu/100ml) being higher than of the wet season (114.85 ± 7.25 – 155.34 ±28.01cfu/100ml) Table 1.

3.2 Agbonchia

Temperature values were high with wet season (26.43 ± 1.13 - 26.47 ± 1.12^oC) values not remarkably different from the dry season (26.83 ± 1.38 - 27.17 ± 0.73^oC) but spatially distribution amongst the study stations indicated significant difference in wet season (R^2 = 0.75) while dry season temperature distributions were not significant (R^2 = 0.39) Table 1. In dry season water pH ranged from slightly acidic to neutral while wet season pH was for all the stations, above neutral value. Spatial distributions amongst the stations were significant in dry season (R^2 = 0.99) indicating differences in distribution while wet season values were not significant (R^2 = 0.25).

Carbon dioxide concentrations were considerably higher in the dry season than in the wet season with values almost increasing down stream for both seasons and differences between the stations were significant for wet (R^2 = 0.79) and dry season (R^2 = 0.60). Dy season concentrations demonstrated closer affinity than that of wet season (Table 1).

Alkalinity values for both seasons increased down stream and were relatively higher in the dry season (4.50 ± 1.45 - 7.0 ± 3.05 mg/l) than during the wet season (4.22 ± 2.1 - 6.57 ± 2.46mg/l). Spatial differences between stations were positively significant for wet (R^2 = 0.95) and dry season (R^2 = 0.93). Similarly water hardness increased down stream for both seasons and concentrations were higher in the wet season (4.93 ± 4.50 - 107.66 ± 131.78mg/l) than during the dry season (5.12 ± 2.87 - 60.80 ± 76.12mg/l). The distribution between the stations were significant for wet (R^2 = 0.75) and dry (R^2 = 0.76) seasons.

Highest conductivity concentrations were observed at the down stream stations which are about 40 - 50 times higher than values observed for the other stations for both seasons. Concentrations for wet season were relatively higher in the wet (27.67 ± 30.88 - 459 ± 755.54μS/cm) than in the dry season (22.50 ± 8.48 - 409 ± 459.15 μS/cm). Spatial differences between the stations was significant in wet season (R^2 = 0.56) but not significant in the dry season (R^2 = 0.20) Table 1.

Dissolved oxygen concentrations were low and generally increased down stream for both seasons with dry season concentrations generally higher (2.88 ± 0.94 - 5.46± 1.21mg/l) than in the wet (2.97 ± 0.85 - 4.90 ± 0.64mg/l). Spatial differences between the stations for wet (R^2 = 0.78) and dry seasons were significant (R^2 = 0.87) Table 1.

BOD_5 values were considerably high for both wet (5.75 ± 3.77 - 16.83 ± 5.90mg/l) and dry (9.62 ± 0.95 - 17.32 ± 0.90mg/l) seasons. The values consistently season increased down stream in dry season, similarly wet season concentrations at the down stream stations the recorded highest values. However spatial variations between the stations indicated marked differences between the stations for dry (R^2 = 0.92) and wet season (R^2 = 0.69) Table 1.

Ammonia concentrations were low for both seasons with wet season (0.26 ± 0.20 - 0.31 ± 0.23mg/l) concentrations being higher than in of the dry season (0.20 ± 0.19 - 0.25 ± 0.22mg/l). However spatial distribution of concentrations amongst stations were significant in the wet season (R^2 = 0.66) but not significant during the dry season (R^2 = 0.16) Table 1. Conversely, nitrate concentrations were relatively higher in the dry season (0.53 ± 0.28 - 0.60 ± 0.23mg/l) than during the wet season (0.33 ± 0.19 - 0.45 ± 0.51mg/l) and difference amongst stations were not significant for wet (R^2 = 0.01) and dry season (R^2 = 0.43) Table 1.

Sulphate concentrations did not demonstrate any defined spatial distribution pattern within the seasons but wet season concentrations (1.36 ± 0.76 - 57.51 ± 38.72mg/l) were observably higher than that of dry season (1.69 ± 1.58 - 21.90 ± 24.24 mg/l). However, the distribution of concentrations for dry season amongst the stations was significant (R^2 = 0.89) but wet season distribution was not significant (R^2 = 0.01) Table 1.

Amongst the nutrient variables phosphate had the highest concentrations and values increased down stream especially during the wet season (Table 1). In addition, wet season concentrations (3.9 ± 2.4 - 60.25 ± 59.35 mg/l) were higher than values observed for dry season (8.80 ± 1.65 - 10.25 ± 8.90 mg/l) and the variations amongst the stations for wet (R^2 = 0.76) and dry (R^2 = 0.95) seasons were significant.

The microbial properties defined by total coliform concentrations were relatively higher in the wet season (85.43 ± 23.78 – 299.51 ± 68.42cfu/100ml) than during the dry season (78.69 ± 34.12 – 210.63 ± 98.57cfu/100ml). The spatial distribution of concentrations amongst the zones for both seasons demonstrated significant positive relationship with the wet season (R^2 = 0.83) having closer affinity than the dry season (R^2 = 0.78) The faecal coliform concentrations demonstrated similar increasing concentration down stream and concentrations were higher in the wet season (28.66 ± 6.99 – 100. 56 ± 20.12 cfu/100ml) than during the dry (26.23 ± 7.58 – 70.21 ± 21.90cfu/100ml) with affinity between zones being significant for both season

3.3 Miniokoro

Temperature values as characteristics of equatorial tropical latitude were high for both dry (26.84 + 1.04 - 30.33 ± 1.12°C) and wet (26.22 ± 1.42 - 29.25 ± 1.40°C) seasons with dry season values being relatively higher than in the wet season. The values also increased slightly down stream (Table 1). Regression analysis indicated that dry and wet season distributions between the locations were positively significant with affinity between the stations in the dry (R^2 - 0.98) than in the wet (R^2 = 0.97). pH was acidic and values were almost uniform for dry (5.9 ± 0.54- 6.57 ± 0.41) and wet (6.0 ± 0.41 - 6.35 ± 0.45) seasons(Table 1). The distribution amongst the stations were not significant for both seasons but dry season values (R^2 = 0.46) demonstrated closer affinity between stations than during the wet season (R^2 = 0.23).

Carbon dioxide concentration a measure of water acidity was considerably high with values relatively higher in the wet season (25.23 ± 6.23 - 39.67 ± 26.97mg/l) than in the dry season (18.57 ± 5.50 - 31.75 ± 12.28mg/l). The distribution of values amongst the stations was not significant in the dry season (R^2 = 0.16) but significant in the wet season (R^2 = 0.69) Table 1.

Conductivity values increased consistently down stream for both seasons and dry season (33.34 ± 7.34 - 1831.67 ± 1223.84 μS/cm) values were higher than wet season (35.72 ± 16.22 - 1053.57 ±1205. 89 μS/cm). Similarly alkalinity values increased down stream with dry season (7.17 ± 1.87 - 31.84 ± 8.31mg/l) concentrations being higher than that of wet season (7.0 ± 2.56 - 23.86 ± 10.31mg/l) Table 1.

Chloride concentrations increased down stream by several magnitudes as was observed for alkalinity and conductivity. However, wet season (1.0 ± 0.65 - 314.66 ± 133.93mg/l)concentrations were higher than dry season (1.07 ± 0.74 - 192.48 ± 167.27mg/l) and distribution amongst the stations were similar for wet (R^2 = 0.76) and dry (R^2 = 0.77)seasons were significant . Hardness concentrations were higher in the dry season (10.88 ± 9.88 - 161.20 ± 80.45mg/l) than in the wet (19.06 ± 18.4 - 137.62 ± 86.91mg/l). The relationship between the stations indicated significance between the stations for both seasons but dry season (R^2 = 0.86) had closer affinity between the stations than in the wet season (R^2 = 0.76)

Dissolved oxygen concentrations were generally high and increased exponentially from upstream to the down stream for dry and wet seasons. Concentrations were slightly higher in the dry season than in the wet season (2.56 ± 0.88 - 5.12 ± 1.55mg/l) and distribution for both dry(R^2 = 0.80) and wet (R^2 = 0.79) seasons demonstrated similar close affinity between station (Table 1).

Biochemical oxygen demand followed a similar sequence of increased concentrations down stream relatively higher concentration being observed in the dry season (23.28 ± 3.59 - 33.85 ± 5.85mg/l)than in the wet (12.92± 4.67 - 22.66 ± 5.63mg/l) Table 1.

Generally nutrient concentrations are low and amongst the nutrient variables only Sulphate demonstrated increasing concentrations from up to down stream. Others such as Phosphate, and Ammonia, had higher concentrations upstream than in other stations. Sulphate had the highest concentrations amongst the nutrient variables with dry season (0.91 ± 0.2 - 45.53 ± 29.30mg/l) concentrations being higher than the wet season (0.92 ± 0.19 - 34.25 ± 21.78mg/l) concentrations and distribution of concentrations amongst the stations for both season were significant (R^2 = 0.75) Table 1.

Nitrate concentrations for dry and wet seasons, were 0.55 ± 0.24 - 0.66 + 0.28mg/l and 0.35 ± 0.16 - 0.49 ± 0.22mg/l respectively. The differences in distribution for wet and dry seasons were not significant with wet season (R^2 = 0.22) demonstrating closer affinity between the stations than the dry season (R^2 = 0.09). Ammonia concentrations were higher in the dry season (0.42 ± 0.5 - 0.91 ± 0.39mg/l) than in wet season (0.35 ± 0.16 - 0.49 ± 0.22mg/l) with the middle reach stations having the highest concentrations for both seasons. The relationship between the stations for wet (R^2 = 0.89) and dry (R^2 = 0.99) seasons where significant with dry season having closer affinity than the wet season. The differences in phosphate concentrations for dry (0.12 ± 0.09 - 0.2 ± 0.26mg/l) and wet season (0.10 ± 0.38 ± 0.29mg/l) seasons were not remarkable but the affinity between the stations were more in the wet season (R^2 = 0.95) than in the dry season (R^2 = 0.50)

As was observed in the other stream systems total coliform concentrations recorded higher counts during the wet season (302.33 ± 52.18 – 588.77 ± 96.42cfu/100ml) than in the dry (235.12 ± 45.23 – 466.81 ± 56.41cfu/100ml) and spatial distribution of concentrations amongst the three zones for both wet (R^2=0.91) and dry(R^2=0.94) seasons were significant(Table 1). The faecal coliform count followed the same increasing concentration pattern down stream in dry season with somewhat different order in the wet season but wet season (201.45± 15.34 – 197.56 ± 28.35cfu/100ml) concentrations being higher than those of dry season (78.37 ± 10.05 – 155.60 ± 12.56 cfu/100ml). In spite of the relative high values recorded in the wet season differences between the zones were not significant (R^2 = 0.02) but dry season distribution were significant(R^2 = 0.94) Table 1.

3.4 Miniweja

Surface water temperatures were high with dry season (28.13±0.98 – 30.58±1.49°C) values being relatively higher than in the wet season (26.72±1.13 -28.29±2.49°C) and temperature tended to increase down stream for both seasons (Table 1). Dry season values (R^2 = 0.87) amongst the stations displayed closer affinity than during the wet season (R^2 = 0.76). pH was slightly acidic for wet(6.25 ± 0.27- 6.37 ± 0.34) and dry (6.24 ± 0.35 - 6.58) seasons and differences between stations were significant with wet season(R^2 = 0.95) demonstrating closer affinity between stations than the dry season (R^2 = 0.80) Table 1. Carbon dioxide concentrations were higher in wet season (36.74 ± 17.07 - 40.88 ± 13.37mg/l) than during the dry season (26.39 + 4.63 - 35.10 + 9.59mg/l) and distribution of concentrations between the stations showed closer affinity in the wet season (R^2 = 0.91) than in the dry season (R^2 = 0.89). Surface water alkalinity generally increased down stream and ranged from 11.84 ± 2.86 - 32.50 ± 23.65mg/l and 12.07 ±3.22 - 24.72 ± 10.88mg/l for dry and wet seasons respectively (Table 1). The relationships between the stations were positively significant with stations in the wet season (R^2 = 0.;96) having closer affinity than in the dry season (R^2 = 0.90). Similarly conductivity values were exceptionally high and increased down stream with higher concentrations occurring during the dry season (2263.85 ± 2433.75 - 17190.85 ± 16075.35µS/cm) than at the wet period (543 ± 1196.95- 7888.60 ± 9742.30µS/cm) Table 1. Affinity between stations was significant for wet (R^2 = 0.93) and dry (R^2 = 0.93) season. Hardness concentrations were high and spatial and seasonal concentrations pattern of increasing values down stream and higher concentrations in the dry season (333.12 ± 335.97 - 1438.72 ± 1367.80mg/l) against the wet season (183.41 ± 287.88 - 1380.35 ± 1575mg/l)as was observed for conductivity. The relationships between the stations for wet (R^2 = 0.99) and dry (R^2 = 0.96) seasons were positively significant.

Dissolved oxygen concentrations for wet and dry seasons were in the ranges of 3.64 ± 1.20 - 6.44± 2.93mg/l and 3.24 ± 1.01 - 6.91 ± 3.01mg/l respectively (Table 1).. Differences between stations were significant with dry season (R^2 = 0.93) having closer affinity than wet season values (R^2 = 0.80). Similarly BOD_5 concentrations increased downstream and concentrations were relatively higher during the dry season (18.72 ± 5.74 - 25.56 + 6.58mg/l) than in the wet season (11.65 ± 5.83 - 14.62 ± 6.67mg/l) Table 1.

High chloride concentrations were observed with relatively higher concentrations in the dry season (446.03 ± 495.13 - 2708.49 ± 2391.26mg/l) than during the wet season (99.15 ± 243.18 - 1380.35 ± 2118.31mg/l) and differences between stations for wet (R^2 = 0.99) and dry (R^2 = 0.97) seasons were significant. Suphate for dry season (61.81 ± 70.84 - 603.01 ± 486.05mg/l) were higher than concentrations in the wet season (18.64 ± 42.17 - 199.91 ± 272.36mg/l) and variations amongst stations for wet (R^2 = 0.89) and dry (R^2 = 0.97) seasons were significant. Ammonia concentrations were relatively higher in the dry season (0.19 ± 0.18 - 0.45 ± 0.42mg/l) than during the wet season (0.29 ± 0.21 - 0.38 ± 0.42mg/l) and variations between stations were only significant in the wet season (R^2 = 0.55) but not significant during the dry season (R^2 = 0.22). Nitrate concentrations appeared relatively higher in the wet season than in the dry and ranged from 0.68 ±0.18 - 0.81 ± 0.31mg/l and 0.61 ± 0.27 - 0.91 ± 1.33mg/l for dry and wet seasons respectively. The affinity between stations were higher in the dry season (R^2 = 0.93) than during the wet season (R^2 = 0.50). Similarly phosphate concentrations spatially tended to increase down stream and wet season concentrations were higher than that of the dry season (0.13 ± 0.12 - 0.15 ± 0.14mg/l),seasonal differences amongst the stations were significant (R^2 = 0.99) for both seasons(Table 1).

Total coliform distributions exhibited obvious seasonal changes (Table 1) with Dry season (342.00 ± 45.34 – 533.00 ± 76.80cfu/100ml) concentrations being relatively lower than wet season concentration (621.86 ± 76.33 – 782.15 ± 95.83cfu/100ml). However the distribution of concentrations amongst the stream course was significant in dry season (R^2 = 0.98) but not significant in wet season (R^2 = 0.98). Faecal coliform recorded lower concentrations against the total coliform with similar seasonal trend such that dry season (114.00 ± 10.07 – 177.54 ± 17.06 cfu/100ml; R^2 = 0.98) concentrations were lower than that of wet season (208.63 ± 22.45 – 296.39 ± 28.18 cfu/100ml; R^2 = 0.37)

3.5 Ntawogba

surface water temperature values were generally high with mean values ranging from 26.83 ± 0.44 -27.08 ± 0.21 in wet season while dry season values ranged from 27.75 ± 0.32o -28.17 ± 0.31oC(Table 1). Spatial variation between stations demonstrated significance for both seasons with affinity between the stations being closer in the wet season (R^2 = 0.96) than during the dry season (R^2 = 0.57).

The pH was slightly acidic for both seasons and differences between the seasons were minimal and values ranged from 6.46 ± 0.16 - 6.57 ± 0.18 and 6.17 ±0.03 - 6.29± 0.05 for wet and dry seasons respectively (Table 1). Spatial differences between the study stations for wet (R^2= 0.10) and dry (R^2=0.10) seasons were not significant. Carbon dioxide concentrations for wet and dry seasons stood at 25.82 ± 11.88 - 38.1 ± 19.52mg/l and 11.79 ± 4.49 - 24.42 ± 16.48mg/l and differences amongst the stations were significant demonstrating more affinity in the dry season (R^2 = 0.69) than during the wet season (R^2 = 0.67).

Conductivity values were high, ranging from 188.25 +15.17 - 265.0 ±25µS/cm in the wet season and 251.67 ± 17.69 - 375.08µS/cm in dry season (Table 1). There were relative differences on spatial basis with values increasing down stream and seasonal differences amongst stations were significant with dry season (R^2 = 0.90) demonstrating closer affinity amongst the stations than during the wet season (R^2 = 0.90).

Alkalinity values for wet and dry seasons increased down stream with higher concentrations recorded in the dry (62.83 + 13.10 - 89.67 + 16.67mg/l) than during the wet season (10.08 ± 1.76 - 14.00 ± 2.25mg/l) and spatial differences between the stations demonstrated significance for wet (R^2 = 0.96) and dry season (R^2 = 0.97).

There was no clear spatial trend demonstrated in the dissolved oxygen distribution other than the fact that the highest concentrations occurred at the upper limit station for both seasons (Table 1) differences between the stations were significant (R^2 =0.61) while dry season differences between stations were not significant (R^2 = 0.26). In all, concentrations were relatively higher in the wet season (6.50 ± 0.50 - 8.42 ± 0.80 mg/l) than during the dry (5.55 ± 0.48 - 7.35 ± 0.65mg/l). BOD_5 concentrations increased almost exponentially down stream with differences in concentrations between wet and dry seasons being 13.45 ± 3.50 - 37.86 ± 8.54mg/l and 26.45 ± 9.67 - 55.25 ± 7.44mg/l respectively. The stations demonstrated similar significant differences for wet (R^2 = 0.98) and dry (R^2 = 0.99) seasons

Ammonia concentrations similarly increased downstream for wet and dry seasons and concentrations were higher in the dry season (0.85±0.14 - 2.10 ± 0.22mg/l) than during the wet season (0.41 ± 0.15 - 0.47± 0.23mg/l) Table 1. Spatially, concentrations between stations were significant during both seasons with stations having closer affinity during the wet season (R^2 = 0.98) than during the dry season (R^2 = 0.57). Sulphate concentrations were in magnitude of about two times higher in the dry (10.40 ± 2.40 - 13.69 ±3.99mg/l) than in the wet season (4.34 ± 1.60 - 5.78 + 1.36mg/l) and concentrations increased down stream during both seasons. Significant differences were observed amongst the stations for both seasons with affinity between stations being observed during the dry season (R^2 = 0.98) than during the wet season (R^2 = 0.53). Nitrate concentrations were comparably high with steady increase in concentration from upstream to down stream station. The differences between stations were significant with closer affinity being observed in the dry season (R^2= 99) than in the wet (R^2= 98). Similarly, phosphate concentrations demonstrated an increasing concentrations from upstream to the downstream limit and differences between stations were significant with closer affinity being observed in the wet season (R^2 = 0.91) than during the dry (R^2 = 0.81). Dry season (0.62 ± 0.09 - 0.99 ± 0.20mg/l) concentrations were higher than that of the wet season (0.41 ± 0.15 - 0.70 ± 0.23mg/l) Table 1.

4. Discussion

Generally, the stream systems maintained high temperature values for both wet and dry seasons and this is a common characteristic reported for the Niger Delta waters (RPI, 1985, NES, 2000) which are located at the equatorial latitude where temperature is consistently high all the year round. In all, a number of associations emerged with temperature such that during the wet season, a strong positive correlation between temperature and Alkalinity (r = 0.69), conductivity (r^2 =0.61), hardness (r =0.60), DO (r^2 =0.73), BOD (r^2 =0.55), So_4 (r^2 =0.61) TC (r^2 =0.76) and FC (r^2 =0.58) Table 2. Similarly, in dry season temperature had significant positive correlation with conductivity (r^2 =0.82), Hardness (r^2 =0.82), DO (r^2 =0.63), BOD (r^2 =0.72), SO4 (r^2 =0.76) Total coliform (r^2 =0.77) and faecal coliform (r^2 =0.78) but negative association was observed for dry season period between temperature and carbon dioxide (r^2 = -0.56) Table 3.

The acidity of a water body is an important factor that determines the suitability of water for various purposes, including toxicity to animals and plants. With the exception of Agbonchia stream whose ph varied from slightly acidic to neutral, the stream systems under study were slightly acidic , showing no consistent spatial and seasonal trends. It is pertinent to observe that while the general values of the water bodies may appear alright comparable to WHO (19 84)limits for potable water the values for such systems in the past had been in the range of 4.5 – 6.0 and 4.8 – 6.5 for wet and dry seasons respectively(NDBDA,1987, Igbinosa and Okoh, 2009). The present pH values are considered high for such soft acid water bodies draining forested wet land with leaf litter that impact humic acid substances that give it the low acidity. The change in pH observed which rather tended toward neutrality might be due to decreased forest floor drainage area, washing of concrete structures during storm and increasing draining of domestic effluent water to the stream.as well as influence of brackish water. pH in the wet season was observed to have significant positive correlation with PO_4 (r^2 =0.58), and negatively correlated with total coliform (r^2 =-0.61) and FC (r^2 =-0.65)Table 2 while in the dry season, pH positively correlated only with PO_4 (r^2 =0.53) and negatively correlated with CO_2 (r^2 =-0.57) Table 3.

Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility, as well as valence; and the temperature of measurement. The relationship with other parameters of note are the positively correlated with hardness (r^2 =0.97), DO (r^2 =0.65), BOD_5 (r^2 =0.58), NO_3(r^2 =0.55), SO_4 (r^2 =0.96), TC (r^2 =0.69) in the wet season but in the dry season, significant positive associations were observed between conductivity and DO (r^2 =0.60), BOD_5 (r^2 =0.64), SO_4 (r^2 =0.84), TC (r^2 =0.72) and FC (r^2 =0.72) (Table 2 and 3)

Total hardness of all the water bodies showed higher concentration in the dry season than in the wet season. this is primarily due to reduced inflow and evaporation, while the relative lower concentrations observed may be attributed to increasing inflow and dilution. However to high hardness generally observed in the water bodies may in part be associated the the concrete structure covering the path of the stream. Hardness was found to positively correlation with DO (r^2 =0.67), NO3 (r^2 =0.60), SO4 (r^2 =0.97),TC (r^2 =0.69), and FC (r^2 =0.50) in wet season but in dry season slight variation in the relationships between the attributes such as the positive correlation with DO (r^2 =0.58), BOD (r^2 =0.66), SO4 (r^2 =0.81), TC (r^2 =0.74) and FC (r^2 =0.75) Tables 2 and 3.

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Table 2. The correlation coefficient between the physicochemical and biological variables in the wet season

Wet season													
	T °C	*pH*	*CO_2*	*ALKALINITY*	*CONDUCTIVITY*	*HARDNESS*	*DO*	*BOD_5*	*NH_4-N*	*NO_3-N*	*SO_4^{2-}-*	*PO_4- P*	T
T °C	*1*												
pH	-0.33	1											
CO_2	-0.21	-0.49	1										
ALKALINITY	0.69	-0.14	-0.12	1									
CONDUCTIVITY	0.61	-0.11	-0.22	0.66	1								
HARDNESS	0.60	-0.14	-0.12	0.60	0.97	1							
DO	0.73	0.05	-0.03	0.54	0.65	0.67	1						
BOD_5	0.55	-0.13	-0.21	0.81	0.58	0.47	0.42	1					
NH_4-N	0.31	-0.06	0.07	0.82	0.20	0.14	0.21	0.63	1				
NO_3-N	0.41	-0.24	0.23	0.53	0.55	0.60	0.43	0.26	0.23	1			
$SO_4$2-	0.61	-0.05	-0.15	0.58	0.96	0.97	0.72	0.43	0.09	0.58	1		
PO_4- P	-0.32	0.58	-0.12	-0.25	-0.14	-0.13	0.06	0.07	-0.21	-0.29	-0.15	1	
Total Coliform	0.76	-0.61	0.25	0.70	0.69	0.69	0.56	0.58	0.35	0.68	0.65	-0.32	
Faecal Coliform	0.58	-0.65	0.49	0.59	0.44	0.50	0.37	0.38	0.41	0.58	0.45	-0.35	

Table 3. The correlation coefficient between the physicochemical and biological variables in the dry season

	T °C	*pH*	*CO_2*	*ALKALINITY*	*CONDUCTIVITY*	*HARDNESS*	*DO*	*BOD_5*	*NH_4-N*	*NO_3-N*	*SO_4^{2-}*
T °C	1										
pH	0.25	1									
CO_2	-0.56	-0.57	1								
ALKALINITY	0.40	0.46	-0.67	1							
CONDUCTIVITY	0.82	0.33	-0.43	0.25	1						
HARDNESS	0.82	0.34	-0.44	0.28	1.00	1					
DO	0.63	0.28	-0.19	-0.17	0.60	0.58	1				
BOD_5	0.72	0.17	-0.63	0.56	0.64	0.66	0.22	1			
NH_4-N	0.16	0.38	-0.57	0.95	0.11	0.14	-0.40	0.47	1		
NO_3-N	0.27	-0.31	0.23	-0.30	0.06	0.05	0.52	-0.04	-0.41	1	
$SO_4$2-	0.76	0.18	-0.24	0.13	0.84	0.81	0.65	0.29	-0.08	0.21	
PO_4- P	-0.42	0.53	0.02	-0.26	-0.26	-0.26	0.21	-0.49	-0.23	-0.14	-0.2
Total Coliform	0.77	0.26	-0.59	0.57	0.72	0.74	0.18	0.88	0.49	-0.01	0.4
Faecal Coliform	0.78	0.29	-0.64	0.67	0.72	0.75	0.16	0.90	0.58	-0.06	0.4

Dissolved oxygen is one of the most vital factors in assessing stream quality. Its deficiency directly affects the ecosystem of a stream due to several factors which include physical, chemical, biological and microbiological processes. DO is needed to support biological life in aquatic systems. The levels observed for the study streams are so low that they may not sufficiently support aquatic life including fish. This objectionable low concentration occurred at both seasons, may be associated with the municipal discharges and the attendant organic load and utilization in bacterial decomposition of organic matter. DO in wet season correlated significant with SO_4 (r^2 =0.72), and TC (r^2 =0.56) and in the dry season such associations were observed with NO_3 (r^2 =0.52) and So_4 (r^2 =0.65) Tables 2 and 3.

Biological oxygen demand, being a measure of the oxygen in the water that is required by the aerobic organisms and the biodegradation of organic materials exerts oxygen pressure in the water and increases the biochemical oxygen demand (Abida, 2008). Streams with low BOD_5 have low nutrient levels; and this may account for the general low nutrient status of the stream in most cases.

The increased concentration of BOD_5 implies that oxygen is swiftly depleted in the streams. The consequences of high BOD_5 concentrations are the same as those for low dissolved oxygen: thus organisms are prone to stress, suffocate, and possibly death. In wet season, BOD_5 correlated with NH_4 (r^2 =0.63)and TC (r^2 =0.58) while in dry season the relationships that emerged were significant positive correlation with TC (r^2 =0.88) and Fc (r^2 =0.90) Tables 2 and 3.

Ammonia, a transitional nutrient, generally recorded higher values in the dry season than in the wet season. The distribution of concentration followed a pattern of Nta Wogba > Minchida > ,Minweja > Minikoro > Agboncha in the dry season and in the wet season a slight shift was observed such that the concentration sequence being Nta Wogba > Miniokoro> Minichida > Miniweja > Agboncha

Similarly the same seasonal differences were observed in the distribution of nitrate with higher concentrations in the dry season than in the wet season and the distribution of concentrations being in the decreasing order of Miniweja > miniokoro > Agboncha > Nta wogba > Minichida and Minweja > Ntawogba > Miniokoro >Minichida =Agboncha for dry and wet season periods respectively

The sulphate was the highest of all the nutrients in the different stream and it is considered major composition of seawater following the role of municipal and industrial wastes on sulphate addition to of surface water bodies. The distribution of sulphate concentrations followed a decreasing order of Miniweja stream > Ntawogba stream > Miniokoro stream > Aboncha stream > Minichida stream and Miniweja stream > Ntawogba stream > Agbonchia stream > Miniokoro stream > Minichida stream for dry and wet seasons. However, it is pertinent to note that values observed for Miniweja and Ntawogba were by hundreds of magnitude higher than values observed in the other stream systems

Phosphates as with nitrates are important in assessing the potential biological productivity of surface waters. Increasing concentration of phosphorus and nitrogen compounds in streams or rivers may lead to eutrophication. In this study higher concentrations were recorded in the wet season than in the dry seasons for all the streams and concentrations were considered normal for all the streams except at Agboncha stream in which the distribution of concentration followed a declining order of Agboncha stream > Nta wogba stream > Miniokoro stream >Miniweja stream > Minichida stream and Agboncha stream > Ntawogba stream > Miniokoro stream > Miniweja stream > Minichida stream for dry and wet seasons respectively. The high phosphate value in Agboncha stream may be related in part to Abattoir discharges and petrochemical waste discharges into the system.

The comparison of the variables for the streams using 2 -way Analysis of variance (ANOVA) for the upper limit stations in the wet season demonstrated non significance between the variables (ANOVA = 2.06 , < F ($2.08_{(0.05)}$) and between streams (ANOVA = 1.88 < F = $2.61_{(0.05)}$) Table 4. The middle reach limits of the streams also demonstrated non significance for the variables (ANOVA= 1.15 < F = $2.08_{(0.05)}$) and between streams (ANOVA = 1.34 < F = $2.61_{(0.05)}$) Table 4. The downstream limits demonstrated a contrary pattern with significance been observed for the variables (ANOVA = 3.06 > F = $2.15_{(0.05))}$ but stream differences were also not significant (ANOVA = 1.33 < F = $2.63_{(0.05)}$) Table 4.

Upstream limits						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Variables	97035.61	10	9703.561	2.06	0.05	2.08
Water bodies	35111.77	4	8777.944	1.879257	0.13	2.61
Error	186838.6	40	4670.966			
Total	318986	54				
Middle Reach limits						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Variables	7180969	10	718096.9	1.15	0.35	2.08
Streams	3346749	4	836687.2	1.34	0.27	2.61
Error	24964554	40	624113.9			
Total	35492272	54				
Down Stream limits						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Variables	87980538	9	9775615	3.06	0.01	2.15
Stream	16958067	4	4239517	1.325206	0.28	2.63
Error	1.15E+08	36	3199139			
Total	2.2E+08	49				

Table 4. The 2 way Analysis of variance comparing the variables and the streams at different limits in the wet season

Similar trend was observed in the dry season with differences between variables (ANOVA = 1.38 < F = $2.08_{(0.05)}$) and the streams (ANOVA = 1.40 < F = $2.61_{(0.05)}$) for the upper limit stations were not significant. The middle reach limits also demonstrated same pattern as observed with the upper limit with differences between the variables (ANOVA = 1.30 < F = $2.08_{(0.05)}$) and the streams (ANOVA = 1.25 < F = $2.61_{(0.05)}$) not being significant. The down stream limit demonstrated that the differences between the variable (ANOVA = 2.96 < F = $2.08_{(0.05)}$) were significant but differences between the streams (ANOVA = 1.24 < F = $2.61_{(0.05)}$) were not significant (Table 5).

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Upstream limits						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Parameters	1185660	10	118566	1.38	0.23	2.08
Streams	482331.8	4	120582.9	1.40	0.25	2.61
Error	3441178	40	86029.46			
Total	5109170	54				
Middle stream limits						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Parameters	38261014	10	3826101	1.30	0.27	2.08
Streams	14808576	4	3702144	1.25	0.30	2.61
Error	1.18E+08	40	2950478			
Total	1.71E+08	54				
Down stream limits						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Parameters	3.63E+08	10	36281955	2.96	0.01	2.08
Streams	60805895	4	15201474	1.24	0.31	2.61
Error	4.91E+08	40	12271158			
Total	9.14E+08	54				

Table 5. The 2 way Analysis of variance comparing the variables and the streams at different limits in the dry season

The five streams have similar physiochemical characteristics apparently because they drain from analogous freshwater systems upstream through the stretch of the city into brackish water systems of the Bonny estuary downstream. The study shows that conductivity values are only higher in dry season in Miniweja out of other streams where the values are generally lower in dry season. The reason could be as a result of the study area of Miniweja being more influenced by brackish water than in any other stream. Minichinda, Nta wogba, Miniokoro and Agboncha streams appear to have more influence of the municipal waste water during wet season.

The similarities in characteristics of the streams are further demonstrated by apparently similar pH values obtained. Naturally, the upstream stations are expected to have much more acidic pH values as a result of vegetation and humic substance released into the forest systems (RPI, 1985, Chindah *et. al.*, 1999, Chindah, 2003, Obunwo, *et. al.*, 2004). Then the pH value increases gradually to become more alkaline as the down stream stations of are approached to the influence of brackish water (RPI, 1985, NDES, 2000, NDDC, 2004 and Izonfuo *et. al.*, 2005). However, in the study, the pH values are apparently uniform with only slight spatial differences indicating that the wastes along the course of the stream have altered the characteristics (Brion and Billen (2000).

Nutrient concentrations are generally low except at the down stream of Miniweja stream where phosphate concentrations were very high. The reason for the general low nutrient concentrationin-spite of the organic load received by the systems may be due to both the high temperature and microbial properties of the water body. Organisms in tropical water bodies are known to quickly use up the nutrients under high temperature condition (Chindah and Braide, 2004 and Chindah *et. al.*, 2005).

This effect is also observed in other parameters. For example, the general low dissolved oxygen concentrations in most streams and the relatively higher values of oxygen recorded in the upstream stations comparative to the mid and down stream stations implies the depletion of oxygen along the water course as it flows down stream. This may suggest that the more waste inputs are received by the streams the more its dissolved oxygen concentration declines. Conversely the BOD_5 values are very high and generally increased down stream. This supports the contention that the increased waste load into the system degrades the water quality as the BOD_5 values far exceed concentrations reported in the baseline studies of some of these streams (NDBDA 1987, and Ogan 1988) Therefore it is our contention that the low oxygen concentrations recorded and the high BOD_5 values for all the streams are strong evidence to suggest the impact of organic load introduced from municipal waste into the streams (Rim-Rukeh *et. al.*, 2007, Hill *et. al.*, 2005 and Chen, 2010). Similarly other indices implicating municipal waste discharges on the stream systems are the high total coliform and faecal coliform concentrations observed in the water bodies which are below concentrations recorded in most of the systems in the past studies (Amadi *et. al.*, 1997, Odokuma and Okpokwasili, 1997 and Ogan 1988). The present total coliform and faecal coliform concentrations indicate the seriousness of the impact of municipal waste water on receiving surface waters and the health hazards implication to ignorant users especially children (Braide *et. al.*, 2004, Okoh *et. al.*, 2005 and 2007). The study shows that the rapid growth of Port Harcourt and associated municipal wastes introduced into the five main steams have caused the deterioration of the water quality of the streams and therefore presents the need for a better waste management system (Chen, 2010).

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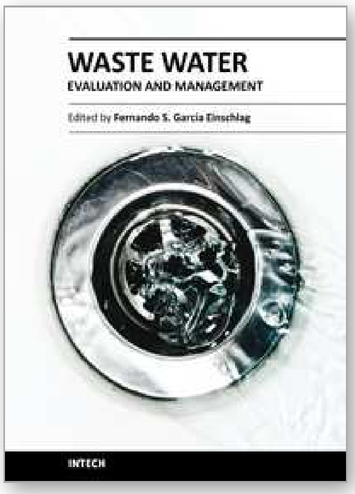

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Fresh water resources are under serious stress throughout the globe. Water supply and water quality degradation are global concerns. Many natural water bodies receive a varied range of waste water from point and/or non point sources. Hence, there is an increasing need for better tools to asses the effects of pollution sources and prevent the contamination of aquatic ecosystems. The book covers a wide spectrum of issues related to waste water monitoring, the evaluation of waste water effect on different natural environments and the management of water resources.

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