Original Research Article

POLLUTION STATUS OF INLAND WATERWAYS SERVING AS RECEPTACLES TO PLASTIC WASTE IN RIVERS STATE, NIGERIA

Abstract

This study aimed at ascertaining the physicochemical characteristics of selected water bodies receiving solid plastic waste in Rivers State, Nigeria. Surface water and sediment samples were analysed for physicochemical parameters. Water, sediment and fish samples were monitored for presence of polychlorinated bisphenols (PCBs) and polycyclic aromatic hydrocarbons (PAHs). All physicochemical parameters monitored in Bonny River water and sediment samples were within WHO acceptable. However, the concentrations of nitrate and phosphate (62.675 and 1.28 ppm) in New Calabar River water samples were above WHO limits of 10 and 1 ppm respectively.. The Cd values (0.045-8.27 mg/l) at both locations exceeded WHO 0.003 mg/l limit. Likewise Mn concentrations (6.02-15.5 mg/l) exceeded WHO 5.5 mg/l (WHO, 2006). Mercury (0.075-1.39 mg/l) was the lowest occurring heavy metal in the water samples but the concentration was still high enough for concern, as the possibility for bioaccumulation in fish species in the river was high. Chloride levels (318.375-423.045 mg/l) in the water samples exceeded WHO limit of 250 mg/l for drinking water. The samples also had high iron content (0.635-16.19 mg/l). PAHs concentrations (252.0155-3533.14 ppm) in the water samples far exceeded the safe level of 10 mg/l for drinking water standard. PCBs levels in all fish samples (21.56-83.08 ppm) exceeded WHO maximum limit of 0.2 mg/kg Surface water, sediment and fish sampled contained objectionable concentrations of heavy metals, PCBs and PAHs.

Keywords: Polyaromatic hydrocarbons, polychlorinated bisphenol, heavy metals, Bonny River, New Calabar River

1. INTRODUCTION

Urbanization has stimulated pillage of resources and consumption pertain that creates tonnes of waste by people and industries. Man is clearly overwhelmed by the increasing amounts of municipal solid waste generation, given the inadequacy to manage this problem globally. Although deficiency in waste management system is a global issue that emanates from unsustainable method of waste disposal, the problem is worst in developing countries lacking capacity and resources for adequate planning and implementation waste disposal system. The overwhelming rate of waste generation in developing countries has resulted in open dumping in waterways and any available space within vicinities of human occupation [1].

Nigeria, with a population surpassing 200 million, generates close to 50 million tonnes annually, translating to about 1kg solid waste per person per day [1]. As at today, one of Nigeria's biggest problem is waste management, as documented by researchers in different parts of the country [2,3]. It is without dispute that the most widespread practice of waste handling is open dumping, which has made many urban cities brim with waste [4,5]. The problem assumes a different dimension in Rivers State (so named because of the numerous water courses criss-crossing many part) as waterways have now become the endpoint for also sorts of waste, because they conceal what is dumped into them or ferry them faraway, either ways, keeping the problem out of sight.

Many solid waste material are non-degradable, and depending on how they handled after intended use, they end up posing momentous burden to the environment. Global estimates show that about three-quarter of used plastics get dumped in the environment were they persist for very long time, leaching out toxic additives that can adversely affect biota [6.7]. Electronic waste, waste building materials, industrial effluents, used automobile parts, and several other non-reusable waste also accumulate in the environment and leach toxic pollutant into the environment [8,9].

The danger of inland waterways pollution for the sub-Saharan region looks worrisome going by forecast of plastic consumption and waste generation when matched with future pollution and the challenges of lack of environmental compliance in this region. Also worrisome is the fact that the risk perception for insidious pollution is generally low, as there are other environment concerns such as hydrocarbon pollution and even the concern for food availability, which is placed above the safety of food, like the fishes for instance, which are the most likely to be affected by water pollution. This study aimed to unravel the extant ecological impacts of anthropogenic pollution of inland waterways in River State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

Two river courses (New Calabar River by Choba axis and Bonny River by Bonny jetty) were sampled in this study, these locations are situated between latitude 4°44'N - 4°55'20'N and longitude 6°53'32'E-7°3'E (Figure 1 and 2) in Rivers State, South-South geographical zone of Nigeria.

The New Calabar River is a freshwater habitat with salinity of 2.85 ppt while the Bonny River is a marine habitat with salinity of 19.64 ppt. The topography of the deltaic plain through which the rivers transverse is flat; with average height of about 11m above sea level. The flat terrain encourages water stagnation after rains and no good drainage system to channel runoff to the river.

The climate is humid tropical /equatorial zone with a mean annual temperature of about 29°C. The temperature ranges from about 22°C - 35°C within the rainy and dry seasons respectively. The highest rainfall occurs between the month of July and September and decrease as dry season approaches between December and January with mean annual rainfall of 2500mm.

The anthropogenic activities around areas bordering the New Calabar River include manufacturing, oil servicing work yard, dredging, markets, schools and residential area. The Bonny River is a major transport channel that receives wastewater from its metropolis, market, dockyard of the Ibeto cement factory and from transportation of artisanal refined crude oil, timber and other goods.

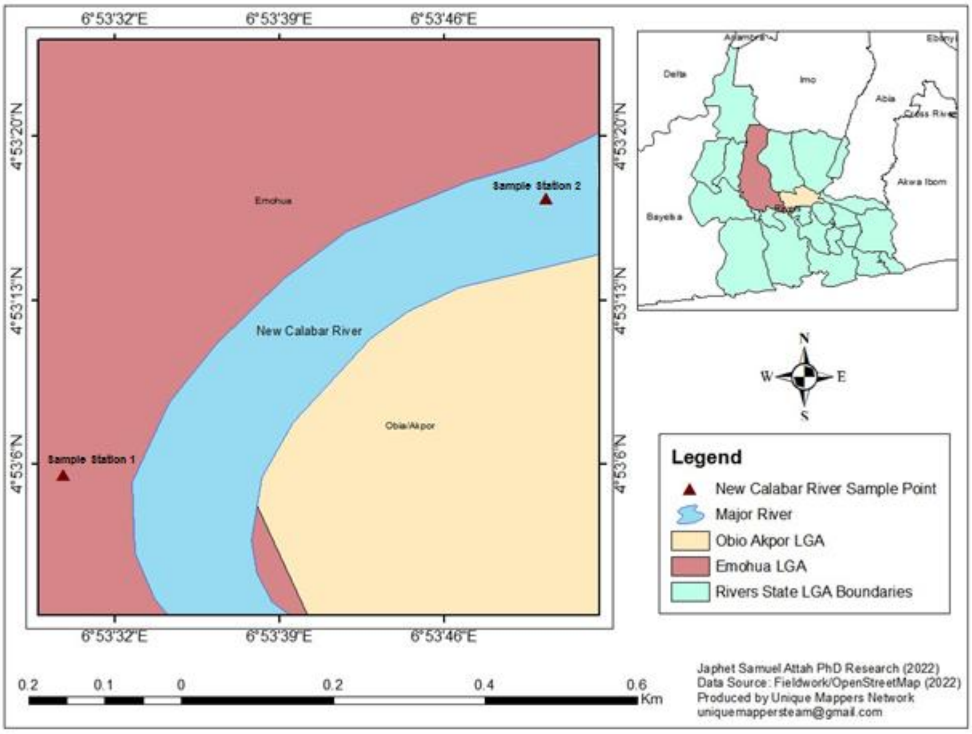

Figure 1: Sampled stations in New Calabar River, Emohua/ Obio-Akpor LGA, Rivers State

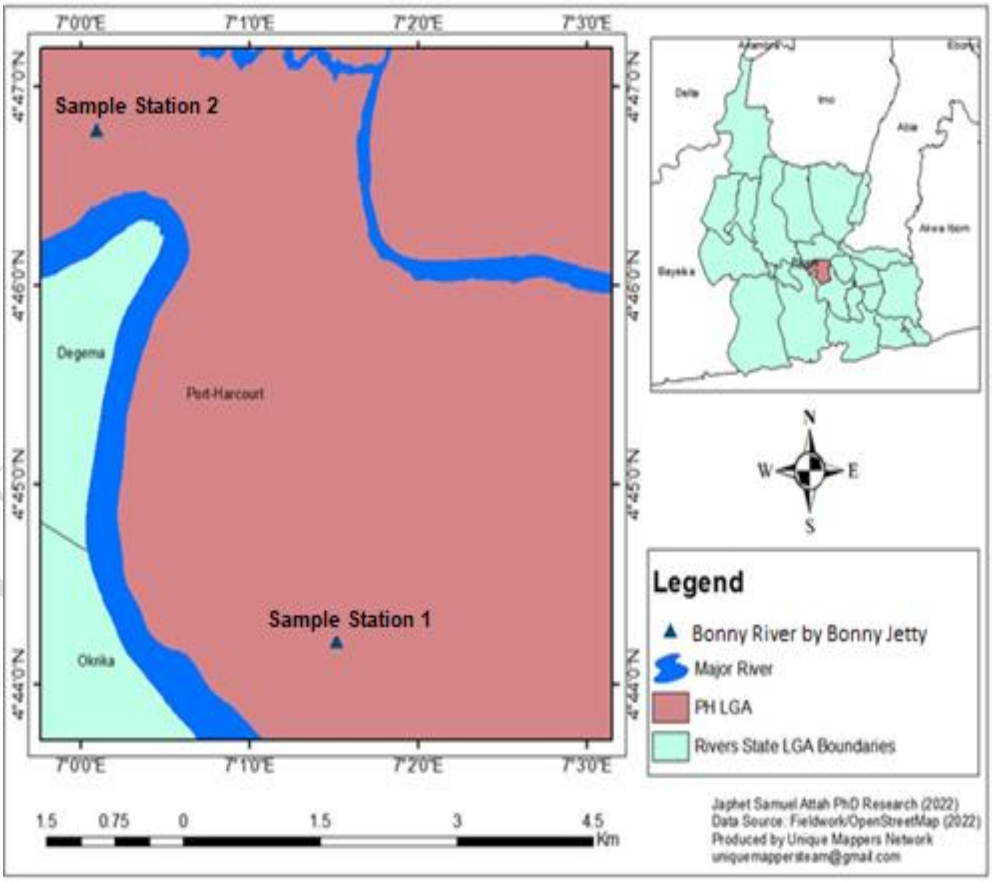

Figure 2: Sampled stations in Bonny River by Bonny Jetty, Rivers State, Nigeria

2.2 Determination of Physicochemical characteristics of the selected water bodies

pH, Temperature, Conductivity, Turbidity, Dissolved Oxygen, Salinity, Total Dissolved Solids were determined using Hanna Multi-parameter Water Checker. Total Suspended Solid (TSS), Chemical Oxygen Demand (COD),Biochemical Oxygen Demand (BOD_5), Chloride, Sulphate, Phosphate Nitrate determination was by standard APHA and ASTM methods.

2.3 Determination of metals

Atomic Absorption Spectrometer (AAS) with flame technique was used for the determination of Ca, Mn, Mg, Fe, Cd and Hg.in the samples.

2.4 Determination of PCBs and PAHs in Water and Sediment samples

Analysis of PAHs and PCB was done using Gas chromatography - Mass Spectroscopy (GCMS) (Agilent 5975).

3. RESULTS

3.1 Physicochemical parameters of water and sediment samples

Table 1 shows variations in physicochemical parameters monitored in water and sediment samples. Values of pH ranged from 6.73-6.9; turbidity ranged from 5.24-2529.33 NTU; salinity 716.67 – 10458.33 ppm; conductivity ranged from 17.47-538.25 µS/cm; TDS was lower in Bonny Water, 3.23 mg/l and highest in New Calabar Water 6.54 ppm; TSS ranged from 22.47-32.67 ppm; density ranged from 1-3 g/cm^3; BOD ranged from 15.7-33.33 ppm and COD ranged from 23.67-76.33 ppm.

Table 1 shows the result of multiple comparisons using Duncan statistic. Analysis of Variance (ANOVA) results revealed that samples are significantly different ($p<0.05$) for all physico-chemical parameter except pH**.**

Figure 3 shows the heavy metals concentrations in the New Calabar and Bonny Rivers water and sediment samples. The mean values in ppm of Mn, Ca, Mg, Fe, Cd and Hg in Bonny River sediment are 11.535, 21.58, 10.03, 8.27, 1.39 and 0.11 ppm respectively; while in the New Calabar River sediment samples the values are 6.02, 14.54, 5.965, 4.72, 0.635 0.045 and 0.10881 ppm respectively.

The mean values in ppm of Mn, Ca, Mg, Fe, Cd and Hg in in Bonny River water samples are 11.555, 30.555, 19.92, 16.19, 1.05 and 0.095 respectively; while in the New Calabar River 15.5, 20.04, 18.575, 14.675, 0.81 and 0.075 ppm respectively.

3.2 PAHs in water, sediment and fish samples

Table 2 shows concentrations in ppm of PAH in all samples. Concentration of naphthalene ranged 0.68±0.03 (BF) - 382.03±0.29 (CS); acenaphthylene 0.01±0.01 (CF) - 209.97±0.17 (CS), acenaphtene 0.0±0 (NW) - 358.11±0.1 (BS); Fluorene 0±0 (CS) - 9.5±0.01 (CW); phenanthrene 1.49±0.09 (BW) - 221.94±0.06 (CS); anthracene 0±0 (CF) - 308.47±0.11 (BS); fluoranthene 0±0 (BS) – 353.82±0.2 (CS); pyrene 0.7±0.17 (CF) - 339.52±0.05 (BS); Benz(a)anthracene 0±0 (CF, CS, BF and BS) -0.78±0.28 (BW); Chrysene 1.37±0.14 (BF) - 268.36±0.23 (CS); Benzo(b)flouranthene 0±0 (CF, CW and BF) - 309.57±0.15 (CS); Benzo(k)flouranthene 0±0 (CF, CW and BF) – 273.44±0.2 (BS); Benzo(ba pyrene 0±0 (CF, CW and BF) - 334.99±0.35 (CS); Indeno(1,2,3-cd) pyrene 0±0 (CF, CW, BW and BF) - 198.43±0.48 (CS) and Benzo (g,h,i) perylene 0±0 (CF, CW, BW and BF) - 240.4±0.38 (BS).

Analysis of variance (ANOVA) result revealed that samples are significantly different for all PAH. Also, multiple comparisons using Duncan statistic revealed significant difference between sample pairs.

Table 1: Physiochemical Parameters of Samples

Samples	pH	Turbidity (NTU)	Salinity (ppm)	Conductivity µS/cm	TDS (ppm)	TSS (ppm)	Density g/cm^3	BOD (ppm)	COD (ppm)
BS	6.81±0.1ab	897.05±964.85b	1941.67±111.43b	1±0a	-	-	3±1.07b	-	-
CS	6.73±0.1a	2529.33±266.53c	716.67±103.67a	1±0a	-	-	1.76±1.74a	-	-
BW	6.89±0.1b	7.5±4.79a	10458.33±320.03c	17.47±0.45a	3.23±1.39a	32.67±1.21b	1.1±0.11a	33.33±1.29b	76.33±2.16b
CW	6.9±0.17b	5.24±0.91a	818.33±119.9a	538.25±410.7b	6.54±0.21a	22.47±0.98a	1±0a	15.7±0.5a	23.67±1.21a
ANOVA (F-Statistic)	2.48	18.82	3760.251	10.067	389.49	258.23	4.887	978.46	2713.47
p-value	0.091	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	0.01	<0.0000	<0.0000
Decision	Not Significant	Significant	Significant	Significant	Significant	Significant	Significant	Significant	Significant

Row mean ± standard-error with different alphabet is significant

Keys: BS-Bonny Sediment; CS-New Calabar River Sediment; BW-Bonny Water; CW-New Calabar River Water

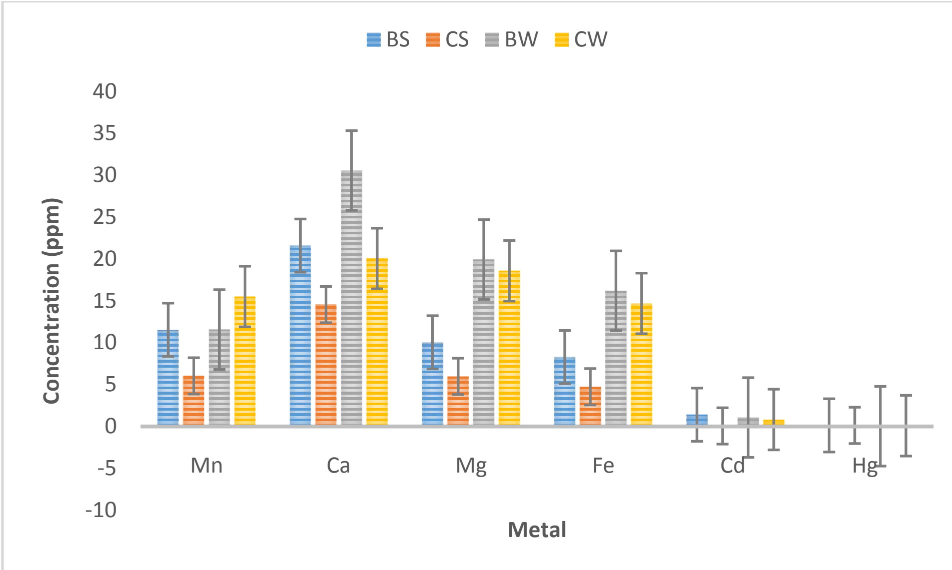

Figure 3: Mean concentration of heavy metals in water and sediment samples

3.3 PCBs in water, sediment and fish

Table 3 shows PCB concentrations in water sediment and fish samples in ppm. 2-Chlorobiphenyl 1.47±0.11 (CW) - 10.64±0.08 (CS); 3-Chlorobiphenyl 0.47±0.08 (CW) - 7.74±0.08 (CS); 4-Chlorobiphenyl 1.27±0.06 (CW) - 4.58±0.06 (CS); 2, 2'-Dichlorobiphenyl 0.2±0.02 (CW) - 4.75±0.06 (CS); 2, 3-Dichlorobiphenyl 0.23±0.07 - 7.53±0.08 (BS); 2, 4-Dichlorobiphenyl 0.98±0.08 (CF) - 4.98±0.03 (CS); 2, 5-Dichlorobiphenyl 0.15±0.02 (BF) - 8.31±0.01 (CS); 3, 3-Dichlorobiphenyl 0.95±0 (BF) - 4.59±0.06 (BW); 3, 4-Dichlorobiphenyl 0.46±0.08 (CF) - 6.95±0.03 (BW); 3, 5-Dichlorobiphenyl 0.16±0.03 (BF) - 5.58±0.01 (CS); 4, 4-Dichlorobiphenyl 1.43±0.04 (CW) - 3.8±0.11 (NS); 2,2,3-Trichlorophenyl 0.29±0.11 (BF) - 3.56±0.18 (CS); 2,2,5-Trichlorophenyl 1.01±0.02 (BF) - 6.17±0.07 (CS); 2,2,6-Trichlorophenyl 0.41±0.06 (CF) - 4.72±0.02 (CS); 2,3,4 Trichlorophenyl 0.66±0.01 (CW) - 5.34±0.08 (CS); 2,3,6-Trichlorophenyl 0.4±0.06 (CF) - 4.72±0.02 (CS); 2,4,4-Trichlorophenyl 0.33±0.04a (CF) - 3.81±0.01 (CS); 2,3,4-Trichlorophenyl 0.69±0.08 (CF) - 2.7±0.07d (CS); 2,3,5-Trichlorophenyl 0.04±0.01 (CF) - 3.63±0 (CS); 3,3,5-Trichlorophenyl 0.13±0.0 (CF) - 2.38±0.04 (NW); 3,4,5-Trichlorophenyl 0.51±0.06 (CW) - 3.59±0.2 (BW); 2,2,3,3-Tetracrichlorophenyl 0.52±0.04 (BF) - 5.65±0.03 (CS); 2,2,3,5-Tetracrichlorophenyl 0.43±0.02 (BW) 4±0.01 (CS); 2,3,3,4-Tetracrichlorophenyl 0.17±0.06 (BF) - 5.37±0.02 (BS) ; 2,3,4,5-Tetracrichlorophenyl 0.15±0.05 (BF) - 3.11±0.16 (BW) and 2,2,3,5,6-Pentachlorophenyl 0.01±0.01 (BF) - 2.75±0.01 (CS).

Analysis of variance (ANOVA) result revealed that samples are significantly different for all PCBs. Also, multiple comparisons using Duncan statistic revealed significant difference between sample pairs.

Table 2: PAH concentrations in different in samples (ppm)

Samples	CF	CW	CS	BF	BW	BS	ANOVA (p-value)
Naphthalene	3.8±0.11c	6.69±0.16d	382.03±0.29f	0.68±0.03a	1.77±0.28b	307.37±0.07e	<0.000
Acenaphthylene	0.01±0.01a	0.58±0.02a	209.97±0.17c	2.42±0.4a	2.63±0.09a	127.69±27.48b	<0.000
Acenaphtene	1.07±0.02b	2.68±0.18c	247.31±0.2d	2.36±0.29c	0.0±0.0a	358.11±0.1e	<0.000
Fluorene	1.85±0.11c	9.5±0.01e	0±0a	0.72±0.15b	2.21±0.06d	0±0a	<0.000
Phenanthrene	7.9±0.03c	8.09±0.03d	221.94±0.06f	1.88±0.09b	1.49±0.09a	153.36±0.06e	<0.000
Anthracene	0±0a	0.54±0.03b	260.79±0.28c	0.9±0.07b	0.69±0.18b	308.47±0.11d	<0.000
Fluoranthene	1.25±0.23c	11.21±0.23d	353.82±0.2e	0.56±0.04b	0.87±0.15bc	0±0a	<0.000
Pyrene	0.7±0.17a	8.44±0.18d	279.41±0.3e	3.1±0.39c	2.23±0.21b	339.52±0.05f	<0.000
Benz(a)anthracene	0±0a	0.14±0.11a	0±0a	0±0a	0.78±0.28b	0±0a	<0.000
Chrysene	3.46±0.05b	10.08±0.11c	268.36±0.23e	1.37±0.14a	3.06±0.5b	113.95±0.42d	<0.000
Benzo(b)fluoranthene	0±0a	0±0a	309.57±0.15d	0±0a	0.69±0.25b	153.42±0.08c	<0.000
Benzo(k)flouranthene	0±0a	0±0a	170.44±0.31c	0±0a	1.13±0.05b	273.44±0.2d	<0.000
Benzo(a)pyrene	0±0a	0±0a	334.99±0.35d	0.6±0.02b	0±0a	250.83±0.32c	<0.000
Indeno(1,2,3-cd) pyrene	0±0a	0±0a	198.43±0.48c	0±0a	0±0a	151.45±0.45b	<0.000
Dibenz (a,h) anthracene	0±0	0±0	0±0	0±0	0±0	0±0	<0.000
Benzo (g,h,i) perylene	0±0a	0±0a	295.92±0.19c	0±0a	0±0a	240.4±0.38b	<0.000

Table 3: PCB concentrations in different samples in ppm

Samples	CF	CW	CS	BF	BW	BS	ANOVA (p-value)
2-Chlorobiphenyl	2.43±0.06b	1.47±0.11a	10.64±0.08e	3.3±0.04c	6.93±0.11d	6.8±0.03d	<0.000
3-Chlorobiphenyl	0.85±0.03b	0.47±0.08a	7.74±0.08e	0.75±0.15b	2.46±0.02c	4.76±0.01d	<0.000
4-Chlorobiphenyl	1.45±0.04b	1.27±0.06a	4.58±0.06e	1.47±0.08b	4.09±0.03d	3.32±0.02c	<0.000
2,2'-**Dichlorobiphenyl**	0.2±0.02a	0.82±0.05c	4.75±0.06f	0.69±0.06b	3.77±0.02e	2.89±0.04d	<0.000
2, 3-Dichlorobiphenyl	1.79±0.07b	0.23±0.07a	2.48±0.06c	2.98±0.03d	1.59±0.21b	7.53±0.08e	<0.000
2, 4-Dichlorobiphenyl	0.98±0.08a	3.22±0.08d	4.98±0.03f	1.61±0.02b	4.08±0.06e	2.32±0.06c	<0.000
2, 5-Dichlorobiphenyl	0.97±0.06b	1.75±0.09c	8.31±0.01f	0.15±0.02a	2.35±0.01d	5.31±0.13e	<0.000
3, 3-Dichlorobiphenyl	1.57±0.04b	1.96±0.18c	3.25±0.02d	0.95±0a	4.59±0.06f	3.99±0.04e	<0.000
3, 4-Dichlorobiphenyl	0.46±0.08a	1.17±0.01c	3.43±0.04d	0.98±0.08b	6.95±0.03e	1.29±0.08c	<0.000
3, 5-Dichlorobiphenyl	1.07±0.11b	1.88±0.08c	5.58±0.01f	0.16±0.03a	3.12±0.04e	2.47±0.05d	<0.000
4, 4-Dichlorobiphenyl	1.85±0.03b	1.43±0.04a	2.37±0.01c	2.57±0.01d	3.62±0.04e	3.8±0.11f	<0.000
2,2,3-Trichlorophenyl	1.68±0.03c	0.73±0.18b	3.56±0.18d	0.29±0.11a	0.89±0.05b	1.56±0.08c	<0.000
2,2,5-Trichlorophenyl	1.24±0.09b	2.2±0.11c	6.17±0.07e	1.01±0.02a	2.98±0.08d	3.14±0.05d	<0.000
2,2,6-Trichlorophenyl	0.48±0.09a	0.43±0.04a	3.43±0.18b	0.41±0.06a	4.58±0.04c	5.65±0.08d	<0.000
2,3,4-Trichlorophenyl	0.79±0.04b	0.66±0.01a	5.34±0.08f	1.24±0.02c	2.3±0.01d	2.84±0.04e	<0.000
2,3,6-Trichlorophenyl	0.4±0.06a	1.1±0.1b	4.72±0.02f	2.2±0.12e	1.62±0.03c	1.95±0.01d	<0.000
2,4,4-Trichlorophenyl	0.33±0.04a	0.92±0.03b	3.81±0.01f	2.39±0.21d	3.38±0.04e	1.55±0.01c	<0.000
2,3,4-Trichlorophenyl	0.69±0.08a	1.7±0.1c	2.7±0.07d	0.93±0.03b	0.8±0.03ab	0.86±0b	<0.000
2,3,5-Trichlorophenyl	0.04±0.01a	0.12±0.02b	3.63±0f	0.61±0.05c	2.58±0.04e	2.39±0.01d	<0.000

4. Discussion

Water remains a vital resource for human and other life forms that depend on it. Therefore it is incumbent to periodically assess the status of water bodies prone to anthropogenic pollution as is the case with waterways in urban settlements in developing countries. This study assessed the physicochemical parameters of the New Calabar River and Bonny River, Rivers State, Nigeria, with particular emphasis on heavy metals, PAHs and PCBs.

4.1 Physicochemical Parameters of Water and Sediment

The pH, turbidity, salinity, conductivity, TDS, TSS, BOD and COD monitored were within WHO acceptable limits. The mean concentrations of chloride, sulphate, nitrate, phosphate, Mn, Ca, Mg, Fe, Cd and Hg in Bonny River water samples were 330.05, 257.755, 46.865, 0.75, 11.555, 30.555, 19.92, 16.19, 1.05 and 0.095 ppm respectively; while in New Calabar River water samples, the concentrations were 423.045, 337.925, 62.675, 1.28, 15.5, 20.04, 18.575, 14.675, 0.81 and 0.075 ppm respectively. The mean concentrations of chloride, sulphate, nitrate, phosphate, Mn, Ca, Mg, Fe, Cd and Hg in Bonny Rivers sediment in the present study were 318.375, 165.525, 31.22, 0.86, 11.535, 21.58, 10.03, 8.27, 1.39 and 0.11

ppm respectively; while in New Calabar River sediment samples the concentrations were 401.11, 245.53, 58.255, 1.285, 6.02, 14.54, 5.965, 4.72, 0.635 0.045 and 0.10881 ppm respectively. The concentrations of the physicochemical parameters were significantly different ($p<0.05$) across locations. The difference in physicochemical parameter between both locations may be as a result of contaminants such as discharge of untreated or partially treated effluent by various industries at the New Calabar River [10], domestic sewage from several households, runoff water from agricultural lands near the banks and solid waste disposed into the river, as the river transverses the city of Port Harcourt, as against the remote Bonny River.

The mean concentrations of sulphate, nitrate and phosphate (165.525, 46.865 and 0.75 ppm) in the Bonny Rivers water samples were within WHO 200, 50 and 5 ppm limits respectively. However, the concentrations of sulphate, nitrate and phosphate (62.675 and 1.28 ppm) in New Calabar River water samples were above WHO limits of 10 and 1 mg/l respectively [11]. The Cd values (0.045-8.27 mg/l) at both locations exceeded WHO 0.003 mg/l limit [11]. Likewise Mn concentration (6.02-15.5 mg/l) exceeded WHO 5.5 mg/l [11]. Mercury (0.075-1.39 mg/l) was the lowest occurring heavy metal in the water samples but the concentration was still high enough for concern, as the possibility for bioaccumulation in fish species in the river was high. Chloride levels (318.375-423.045 mg/l) in the water samples exceeded the WHO limit of 250 mg/l for drinking water. The samples also had high iron content (0.635-16.19 mg/l) which could be attributed to high organic matter and low dissolved oxygen content traceable to industrial and household waste in the area. The water is generally considered unsafe for drinking purpose.

PAHs in water, sediment and fish

The mean PAHs concentration in Bonny River water samples was 252.0155 ppm whereas in New Calabar River water samples, the concentration was 3533.138 ppm (significant, $p<0.05$). Ten of the sixteen PAH except Acenaphtene, Benzo(a)pyrene, Indeno(1,2,3-cd) pyrene, Dibenz (a,h) anthracene and Benzo (g,h,i) perylene, were detected in water samples from both locations. Levels of PAHs in the water samples far exceeded the safe level of 10 mg/l for drinking water standard [12]. Ogbonna and Origbe [13] reported lower PAH (2.06-2.729 mg/l) in Bonny River, within the same study location. The difference might be due to sampling time and pollution activity in the water as at time of sampling. However, the alarming increase in PAH concentrations in the study area should be a source of concern to environmental and public health scientists.

The mean PAHs concentration in sediment from New Calabar River which was 3533.14 ppm, was higher than the concentration in Bonny River which was 2798.47 ppm (significant, $p<0.05$). However, sediment samples from Bonny River had all PAHs monitored except Benz(a)anthracene whereas sediment from New Calabar River had fewer PAHs present,which were identified as Naphthalene, Acenaphthylene, Acenaphtene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Chrysene, Benzo(b)flouranthene, Benzo(k)flouranthene, Benzo(a)pyrene, Indeno(1,2,3-cd) pyrene and Benzo (g,h,i) perylene. This could be as the results of the different anthropogenic activities taking place in both locations. The concentrations of PAH in the sediments from both Bonny River and New Calabar River were higher than in the fish and water samples (significant, $p<0.05$). Levels of PAH detected in this study were higher than 3.7-5.84 mg/kg reported by Allison and Paul [14] for sediment samples from New Calabar River. Sediments act as sinks and are especially characterized by their ability to accumulate pollutants and give them longer residence times before biodegradation and/or bioaccumulation compared to water [15]. Sediment harbours benthic organisms comprising filter feeders that can take up microplastic and possibly transmit to organisms at higher trophic levels [1].

Fish from Bonny River had mean PAH concentration of 14.88603 ppm. Nine PAH including Chrysene, were detected in the fish samples. Fish samples from New Calabar River had mean PAH concentration of 20.30418 ppp. Five PAHs including Chrysene were detected in the fish samples. Levels of PAHs in fish samples were higher than WHO limit of 0.001 mg/kg for fish [12]. Therefore the fish are not safe for consumption. The mean PAHs levels in fish obtained in this study was higher than 2.626 μg/kg and 2.061 μg/kg detected in catfish and tilapia fish samples from Rivers Niger and Benue Confluence at Lokoja, in a study by Ekere *et al*. [16], as well as in catfish samples from New Calabar River River, having mean concentration of 0.01±0.01 ppm, in an earlier study by Bekibele *et al*. [17]. Ogbonna and Origbe [13] reported much lower PAH (0.002-0.004 mg/kg) in Bonny River, within the same study location. Again, the concentrations were also far higher than the range (0.0459–0.1719 mg/kg) reported in seafood from Niger Delta coastal waters [13]. The high concentration of PAH in the fish samples might be related to the presence of microplastics in the gut of the fish. This perhaps suggest that micoplastic pollution increases the concentration of PAHs in the fish samples.

Pseudotolithus elongatus is a common croaker fish species consumed widely in coastal states of Nigeria. The implication for high level of PAHs contamination of this fish species is the likelihood of transfer to humans that feed on them. PAHs may cause DNA modification in fish that could be associated with carcinogenesis [18]. The concentrations of sixteen priority PAH in water and sediment samples at Bonny River and New Calabar River are reflective of high pollution of the area with hydrocarbons. This by implication, means that aquatic species like fish in this area will take up this pollutant via bioaccumulation. The results of PAH in the fish samples clearly support this. Again, the high concentration of PAH in *Pseudotolithus elongatus* might be explained by the fact that they are bottom feeders that obtain their food by foraging on contaminated sediment.

PCBs in microplastics from water, sediment and fish

Twenty-six (26) PCBs were detected at various concentrations in water, sediment and fish samples. All twenty-six (26) PCBs were detected in water, sediment and fish samples from both Bonny River and New Calabar River. The mean concentrations of PCBs in the water, sediment and fish samples from Bonny River were 83.08 ppm, 78.90 ppm and 21.56 ppm respectively. The mean concentrations of PCBs in the water, sediment and fish samples from New Calabar River were 32.2595 ppm, 112.15 ppm and 23.53 ppm respectively. The mean concentrations of PCBs in the sediment and water samples were higher than in the fish samples. The PCBs levels in all fish samples exceeded the WHO maximum limit of 0.2 mg/kg [19].

The concentration of PCBs in fish ranging from 21.55±3.21 and 23.53±4.22 ppm for Bonny River and New Calabar River respectively, exceeded the average reported in other studies. Concentrations of PCBs in fish ranging from 10.14 mg/kg - 108.752 mg/kg have been reported in Europe [20,21]. That is, the concentrations recorded in this study is within this range. The mean concentrations of PCBs in this study were higher than values reported by Osuala *et al*. [22], who screened for the presence of PCBs in fish species collected from the Lagos Lagoon and reported a mean PCBs level of 8.97 ± 5.62 mg/kg wet weight of *Pseudotolithus elongatus*, with the highest PCBs of 16.28 ± 5.05 mg/kg detected in *Chrysichthys nigrodigitatus*. However, Unyimadu *et al*. [23] in their study reported very high presence of PCBs in brackish water fish in Delta area of River Niger including *Pseudotolithus elongatus*. The PCBs concentrations in *Pseudotolithus elongatus* ranged from

16.2±1.8-144±12.3 µg/kg, with the highest concentration of 1830.0±484.0 µg/kg detected in *Vomer septapinis*, and the lowest in *Pseudotolithus senegalensis*, with a mean concentration of 795±169.3 µg/kg for all samples.

Pseudotolithus elongatus feed on shrimps which have been reported to accumulate PCBs [24]. Jaward *et al*. [24] reported a correlation between the amount of PCBs in fish and the concentrations in the water and sediment samples. Consuming food high in PCBs can lead to developmental and reproductive anomalies [25]; cardiovascular disorder [26]; increases the risk high blood cholesterol, blood pressure [27] and diabetes mellitus [28].

5. CONCLUSION

The present study determined the physicochemical characteristics of selected water bodies receiving solid waste in Rivers State, Nigeria. Surface water, sediment and fish sampled contained objectionable concentrations of heavy metals, polychlorinated bisphenols (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

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