



Monitoring and Assessment of Physico-chemical Parameters in the Surface Water of some selected River in the Niger Delta

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Abstract

A study was conducted on the water bodies of some selected communities in Niger Delta. Standard methods were used to determine the physicochemical levels of the water bodies at four selected sites; Otamiri-Oche River (S1), Nkesir River (S2), Ofuoma River (S3), and Ihimiri-Ama (S4). The results obtained indicated that the Physico-chemical parameters of the water bodies in the selected communities varied significantly ($P < 0.05$). Parameters such as pH, Temperature, Electrical Conductivity and TDS were all below permissible limit (WHO) while Turbidity, and BOD were above permissible limit in all stations except DO which was above permissible limit only in the wet season in Ofuoma River (S3). Heavy metals such as Cd, Ni and Pb were all above permissible limit except Cu which was below permissible limit and Cr which was below Detectable limit in the Dry season in all station and only in Ihimiri-Ama (Control) (S4) in the wet season. These study established that the surface water extracted from these rivers for domestic and agricultural purposes should be discouraged.

Keywords: Niger Delta, Heavy Metals, Water bodies, Anthropogenic

1.1 Background to the Study

Heavy metals are persistent and non-biodegradable, have long biological half-lives and can be bioaccumulated through the biologic chains, soil-plant-food chains, seawater-marine organism-food chains and ultimately leads to undesirable side effect (Singh *et al.*, 2010). Plants take up heavy metals by absorbing them from air

borne deposits on the parts of the plants exposed to the air from the polluted environment as well as from contaminated soils through root system (Elbagermi *et al.*, 2013). The presence of heavy metals in the atmosphere, soil and water, even in trace amount can cause serious problems to organism (Singh *et al.*, 2010). The accumulation of heavy metals in soils is of concern in agriculture due to the adverse effects on food

quality. They are among the major contaminants of food supply and may be considered as one of the most important problems to our environment (Osuji and Onojake, 2013).

2.0 Materials and Methods

2.1 Description of the study area

The study area (figure 1) is made of four locations namely Otamiri-Oche, Nkesir and Ihimiri-Ama in Rivers State, Ufuoma in Delta State, all in Niger Delta.

The rivers in the study areas are the distributaries of the Niger River located in the Niger Delta. These rivers are the Otamiri-Oche River in Umuechem, Nkesir River in Ebocha, Ofuoma River in Delta State and Ihimiri-Ama in Ndashi and serves as a source of economic well-being, for domestic and recreational activities. They are wetland areas where hydrocarbon exploration and production activities are on-going and these may impact on the quality of the rivers.

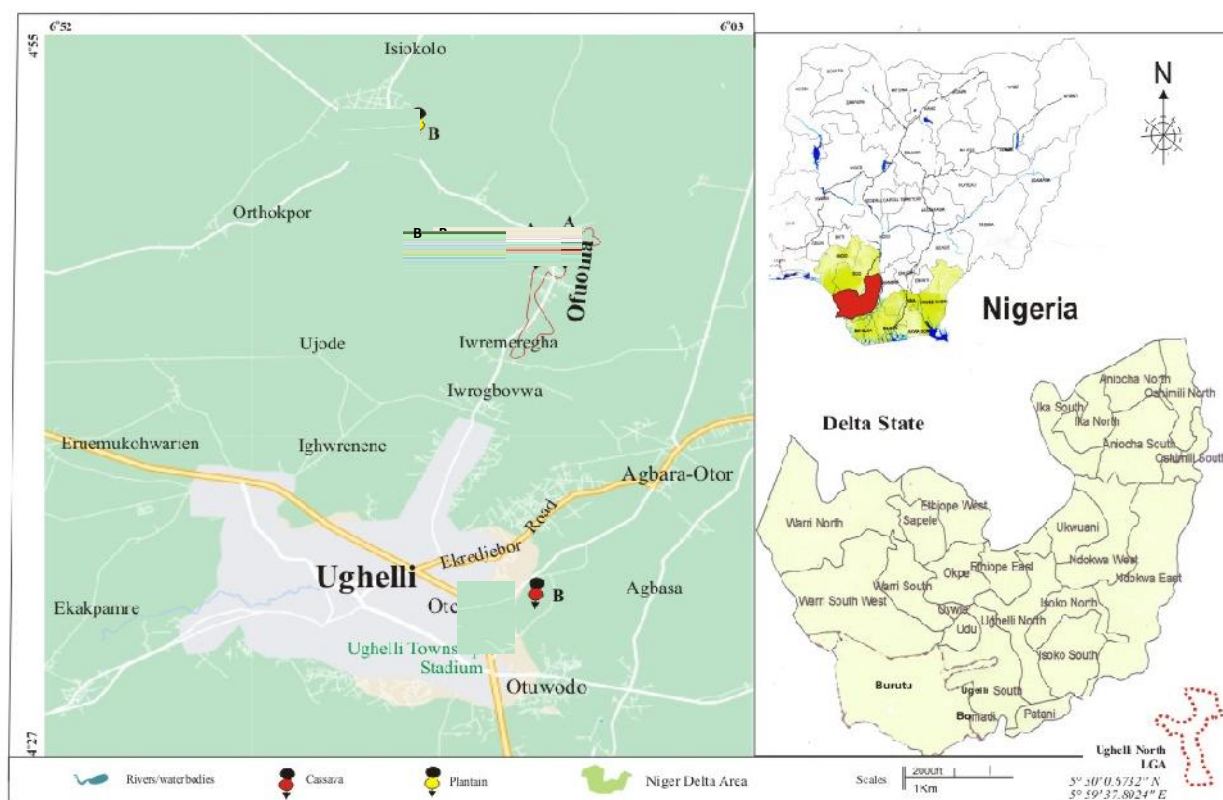


Fig. 1 Map of Rivers and Delta State Showing the Study Areas.

Niger Delta is the delta of the Niger River sitting directly on the Gulf of Guinea on the Atlantic Ocean in Nigeria. The Niger Delta extends over about 70,000 km² (27,000 sq mi) and makes up 7.5% of Nigeria's land mass, (Frank, 2013). It is the largest wetland and maintains the third-largest drainage basin in Africa. The Delta's environment can be broken down into four ecological zones: coastal barriers islands,

mangrove swamp forests, freshwater swamps and lowland rainforests. The region has an estimated regional population of nearly 30 million people (Frank, 2013) and comprise of 9 States including Rivers, Bayelsa, Akwa Ibom, Delta, Imo, Abia, Ondo, Cross River and Edo (Frank, 2013). However, majority of the oil pollution and gas flaring occur in the core Niger Delta states of Bayelsa, Rivers, Delta,

and Akwa-Ibom states respectively. It is also the region of Nigeria where majority of the oil exploration activities are carried out. The area host a number of International Oil Companies (IOC'S) including Shell whose activities is more prominent in the region.

Niger Delta is linked to all parts of the world through its international air and sea ports. Niger Delta climate falls within the sub equatorial climate belt. Temperature and humidity are high throughout the year. The area is marked by two distinct seasons the wet and the dry seasons –with 70 percent of the annual rains falling between April and August, while 22 percent is spread in the two months of September to October. The driest months are from November to March (Ayotamuno et al., 2000; Gobo). The soil type consists mainly of poorly-drained silt clays mixed with sand, which is geologically classified under the Benin formation.

This study was carried out in Umuechem land in Etche Local Government of Rivers State, Ebocha in Ogba/Egbema/Ndoni Local Government of Rivers State, Ofuoma, Ughelli North Local Government Area of Delta State and a control site in Ndashi in Etche Local Government of Rivers State. The three communities under study have petroleum flow stations apart from Ndashi community which serves as control site has none. Therefore, the study determined to monitor and access the levels of Physico-chemical parameters in the surface water of the selected water bodies.

2.2 Water sample collection and Method

The water samples were collected from four different sites in wet and dry seasons in Otamiri-Oche, Ihimiri-Ama, Nkesir and Ufuoma. Samples were collected from two sites (upstream and downstream). The water was collected with white plastic bottles which were washed with distilled water and dried, then were used to collect water from the sampling sites according to standard procedure (DWAF, 1992;

DWAE, 1996) and was taken to the Laboratory for analysis (Afullo, 2009).

2.2.1 Physicochemical Parameters

In-situ measurements of water parameters were carried out for Total Dissolved Solutes (TDS), Temperature, Salinity, Dissolved Oxygen (DO) and pH.

2.2.2 Analysis of Heavy Metals in Surface Water Samples (mg/l)

Digestion of the sample is one of the storage steps taken to preserve the samples from bacterial activities and to release metals into the analytical solution (Afullo, 2009). From each sample, 5cm³ of concentrated HNO₃ was added to 7mls of water samples. The samples were digested for about 30 minutes block in fume cupboard until the solution reduced to 5mls with a characteristic colour, indicating complete digestion. Each digest was allowed to cool and transferred to a 50cm³ acid washed volumetric flask and the volume was brought to the 50cm³ mark with deionized water. Diluted digest was filtered and kept in sample bottles ready for analysis. The level of each metal in the four samples were determined using Bulk 205 model AAS.

2.2.3 Statistical Analysis

Metal data were subjected to analysis of variance (ANOVA), Turkeys multiple comparison was used to compare the significance difference of the mean values amongst the sampled station. Probability less than 0.05 was considered statistically significant. All statistical analysis were carried out with the SPSS 20 software program.

3.0 Results

3.1 Mean concentration of Surface Water in Wet and Dry Seasons

The mean concentration of surface water of Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-ama are presented in Table 1 below.

Table 1: Mean Concentrations of Physico-Chemical Parameter in Surface Water from Rivers in Petroleum and Non-Petroleum Sites in Wet and Dry Seasons in the Study Area.

Parameters	Otamiri-Oche River (S1)	Nkesir River(S2)	Ofuoma River (S3)	Ihimiri-Ama River (S4)	Maximum Acceptable Level (WHO)
pH					6.5-8.5
Wet season	6.83±0.29 ^a	6.91±0.33 ^a	6.51±0.33 ^a	6.6±0.39 ^a	
Dry season	6.81±0.06 ^a	6.81±0.16 ^a	6.86±0.12 ^a	6.58±0.34 ^a	
Temp. (°C)					30(°C)
Wet season	29.07±0.26^a	29.3±0.51^a	29.1±0.29^a	28.1±29.05^a	
Dry season	29.88±0.25^a	29.85±0.1^a	29.80±0.2^a	29.53±0.22^a	
Electrical Cond. (µS/cm)					400(µS/cm)
Wet season	86.6±8.14 ^a	30.9±0.73 ^b	28.1±5.31 ^b	30.13±4.58 ^b	
Dry season	79.80±0.69 ^a	24±0.4 ^b	25±1.51 ^b	24.3±0.95 ^b	
Salinity (%)					N/A
Wet season	0.04±0 ^a	0.01±0 ^b	0.01±0 ^b	0.01±0 ^b	
Dry season	0.04±0	0.01±0	0.01±0	0.01±0	
Turbidity (NTU)					0.01(NTU)
Wet	7.95±4.9^a	0.90±0.79^a	77.30±39.5^a	1.05±0.37^a	
Dry	27.1±0.51^a	3.7±0.12^b	3.6±0^b	3.75±0.06^b	
Total Dissolved Solids (mg/l)					500 mg/l (WHO)
Wet					
Dry	60.8±5.68 ^a	22±0 ^b	20.3±3.77 ^b	21.25±2.87 ^b	
	56.00±0.82 ^a	18.5±2.38 ^b	20.33±2.28 ^b	18.25±0 ^b	
Dissolved Oxygen (mg/l)					5-9.5 mg/l (WHO)
Wet	5.63±0.62 ^a	6.2±0.09 ^a	3.7±0.17 ^b	5.93±0.43 ^a	
Dry	6.45±0.83 ^a	5.75±0.85 ^a	6.58±0.59 ^a	6.55±0.01 ^a	
Biological Oxygen Demand (mg/l)					10 mg/l (WHO)
Wet	5.63±1.14 ^a	6.18±0.32 ^a	3.73±0.67 ^b	5.92±0.42 ^a	
Dry	0.90±0.35 ^b	1.75±0.57 ^a	0.88±0.35 ^b	2.05±0.05 ^a	

The pH (potential hydrogen) of a solution refers to its hydrogen ion activity and is expressed as the logarithm of the reciprocal of the hydrogen ion activity at a given temperature. pH of the water samples in wet season ranged from 6.47 to 7.08 in Otamiri-Oche, 6.44 to 7.15 in Nkesir, 6.18 to 6.84 in Ofuoma and 6.22 to 7.04 in Ihimiri-Ama. The lowest came from Ofuoma (6.18) while the highest came from Nkesir (7.25). The mean and standard deviation are as follows: 6.81 ± 0.29 , 6.91 ± 0.33 , 6.51 ± 0.33 and 6.6 ± 0.39 in Otamiri-oche, Nkesir, Ofuoma and Ihimiri-Ama respectively. The pH in dry season ranged from 6.78 to 6.91 in Otamiri-Oche, 6.67 to 6.95 in Nkesir, 6.68 to 6.92 in Ofuoma and 6.01 to 6.70 in Ihimiri-Ama. The lowest came from Ihimiri-Ama (6.01) while the highest came from Otamiri-Oche (6.95). Comparing the wet and dry season, the lowest pH came from Ihimiri-Ama (6.01) in dry season while the highest came from Nkesir (7.25) in wet season. The mean and standard deviation are as follows: 6.81 ± 0.07 , 6.81 ± 0.16 , 6.86 ± 0.42 and 6.52 ± 0.34 in Otamiri-oche, Nkesir, Ofuoma and Ihimiri-Ama respectively in wet season while in dry season Otamiri-Oche (6.81 ± 0.07), Nkesir (6.81 ± 0.16), Ofuoma (6.86 ± 0.12) and Ihimiri-Ama (6.52 ± 0.34) Nkesir was the highest in wet season while in the dry season Ofuoma was the highest (Table 1).

The Temperature in wet season ranged from 28.8 to 29.3°C in Otamiri-Oche, 28.7 to 29.4°C in Nkesir, 28.9 to 29.5°C in Ofuoma and 28.9 to 29.2°C in Ihimiri-Ama (control site). The lowest came from Nkesir (28.7°C) while the highest came from Ofuoma (29.5°C). The temperature in dry season ranged from 29.5 to 30.0°C in Otamiri-Oche, 29.7 to 29.9°C in Nkesir, 29.5-29.9°C in Ofuoma and 29.2 to 29.7°C in Ihimiri-Ama (control site). The lowest came from Ihimiri-Ama (29.2°C) while the highest came from Otamiri-Oche (30.0°C). Comparing the wet and dry season, the lowest came from Nkesir (28.7) in wet season while the highest came from Otamiri-Oche (30.0) in dry season. The mean and standard deviation are as follows: 29.1 ± 0.26 °C, 29.3 ± 0.51 °C, 29.1 ± 0.29 °C and 28.1 ± 0.15 °C in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama (wet season) while in dry season, Otamiri-Oche

(29.88 ± 0.25 °C), Nkesir (29.85 ± 0.1 °C), Ofuoma (29.8 ± 0.2 °C) and Ihimiri-Ama (29.53 ± 0.22 °C) (Table 1).

The Electrical Conductivity in wet season ranged from 78.1 to 95.1 in Otamiri-Oche, 30.1 to 31.8 in Nkesir, 21.3 to 32.8 in Ofuoma and 23.4 to 33.3 in Ihimiri-Ama. The lowest came from Ofuoma (21.3) while the highest came from Otamiri-Oche (95.1). The electrical conductivity in dry season ranged from 79.2 to 80.4 in Otamiri-Oche, 23.4 to 24.3 in Nkesir, 23.4 to 27.0 in Ofuoma and 23.5 to 25.2 in Ihimiri-Ama. The lowest came from Nkesir (23.4) while the highest came from Otamiri-Oche (80.4). Comparing the two seasons (wet and dry seasons) the lowest came from Ofuoma (21.3) in wet while the highest came from Otamiri-Oche (wet season). The mean and standard deviation of electrical conductivity are 86.6 ± 8.14 , 30.9 ± 0.73 , 28.1 ± 5.31 and 30.13 ± 4.58 in wet season and in dry season, 70.78 ± 0.72 , 24 ± 0.4 , 25 ± 1.51 and 24.3 ± 0.95 in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama respectively (Table 1). Electrical conductivity was higher in Otamiri-Oche than other stations.

Salinity in wet season ranged from 0.04-0.04mg/l in Otamiri-Oche, 0.01 to 0.01mg/l in Nkesir, 0.01 to 0.01mg/l in Ofuoma and 0.01 to 0.01mg/l in Ihimiri-Ama. The lowest came Otamiri-Oche (0.04mg/l) while the highest came Nkesir, Ofuoma and Ihimiri-Ama (0.01mg/l) in wet season. Salinity in dry season ranged from 0.04-0.04mg/l in Otamiri-Oche, 0.01 to 0.01mg/l in Nkesir, 0.01 to 0.01mg/l in Ofuoma and 0.01 to 0.01mg/l in Ihimiri-Ama. The lowest came Otamiri-Oche (0.04mg/l) while the highest came Nkesir, Ofuoma and Ihimiri-Ama (0.01mg/l) in wet season. The three sites (Nkesir, Ofuoma and Ihimiri-Ama) have the lowest (0.01) both in wet and dry seasons while the highest came from Otamiri-Oche (0.04mg/l) in both wet and dry seasons. The salinity is as follows: 0.04 ± 0 mg/l, 0.01 ± 0 mg/l, 0.01 ± 0 mg/l and 0.01 ± 0 mg/l in wet season and in dry season, 0.04 ± 0 mg/l, 0.01 ± 0 mg/l, 0.01 ± 0 mg/l and 0.01 ± 0 mg/l in Unmuechem, Nkesir, Ofuoma and Ihimiri-Ama correspondingly indicating stability in the fresh water ecosystem. Otamiri-Oche had a high salinity than Nkesir, Ofuoma and Ihimiri-Ama.

The Turbidity in wet season ranged from 3.8 to 15.1NTU in Otamiri-Oche, 0.2-0.9NTU in Nkesir, 1.2 to 187.0NTU in Ofuoma and 0.7 to 1.5NTU in Ihimiri-Ama (control site). The lowest came from Nkesir (0.2) and the highest came from Ofuoma (187.0). The Turbidity in dry season ranged from 18 to 36.2NTU in Otamiri-Oche, 3.6 to 3.8NTU in Nkesir, 3.5 to 3.6 in Ofuoma and 3.7 to 3.8NTU in Ihimiri-Ama (control site). The lowest came from Nkesir (3.5) and the highest came from Otamiri-Oche (36.2NTU). Comparing the the two sites, the lowest came from Nkesir (0.2) in wet season while the highest came from Ofuoma (187.0NTU) in wet season too. The mean and standard deviation of turbidity are 7.9 ± 4.9 NTU, 0.9 ± 0.70 NTU, 77.3 ± 39.3 NTU and 1.05 ± 0.37 NTU in wet season and in the dry season, 36 ± 1 , 36 ± 1.41 NTU, 36 ± 1.41 and 36 ± 1.41 NTU in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama respectively. The turbidity in Ofuoma in wet season was high compared to other stations.

The Total Dissolved Solid (TDS) in wet season ranged from 55mg/l to 67mg/l in Otamiri-Oche, 22mg/l to 22mg/l in Nkesir, 15mg/l to 23mg/l in Ofuoma and 17mg/l to 23mg/l in Ihimiri-Ama (control site). The lowest came from Ofuoma (15mg/l) while the highest came from Otamiri-Oche (67mg/l).

The Total Dissolved Solid (TDS) in dry season ranged from 55mg/l to 57mg/l in Otamiri-Oche, 16mg/l to 20mg/l in Nkesir, 9.1mg/l to 23.2mg/l in Ofuoma and 16mg/l to 21mg/l in Ihimiri-Ama (control site). The lowest came from Ofuoma (9.1mg/l) while the highest came from Otamiri-Oche (57mg/l). Comparing the season (wet and dry), the lowest came from Ofuoma (9.1mg/l) in dry season while the highest came from Otamiri-Oche (67mg/l) in wet season. In Table 1, The mean and standard deviation of TDS are 60.8 ± 5.68 , $22 \pm$, 20.3 ± 3.77 and 21.3 ± 2.87 in wet season and 56 ± 0.82 , 18.5 ± 2.38 , 20.33 ± 2.28 and 18 ± 0 in dry season in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama. Otamiri-Oche had the highest TDS in both wet and dry seasons.

Organic pollution as indexed by the Dissolved oxygen measurement which ranged from 5.1mg/l to 6.3mg/l in Otamiri-Oche, 61mg/l to 63mg/l in Nkesir, 3.5 to 3.9mg/l in Ofuoma and 54mg/l to 64mg/l in Ihimiri-Ama the control site in wet season. The lowest came from Nkesir (3.5mg/l) while the highest came from Ihimiri-Ama, the control site (64mg/l).

Dissolved oxygen in dry season ranged from 6.1mg/l to 6.8mg/l in Otamiri-Oche, 4.9mg/l to 6.6mg/l in Nkesir, 6.5 to 6.6mg/l in Ofuoma and 6.5mg/l to 6.6mg/l in Ihimiri-Ama the control site. The lowest came from Nkesir (4.9mg/l) while the highest came from Otamiri-Oche (6.8mg/l). Comparing the two seasons (wet and dry) the lowest came from Nkesir (3.7mg/l) in wet season while the highest came from Ihimiri-Ama (64mg/l). The mean and standard deviation are 5.63 ± 0.62 , 6.2 ± 0.09 , 3.7 ± 0.17 and 5.93 ± 0.43 in wet season and in dry season, 1.7 ± 0.83 , 1.75 ± 0.85 , 1.58 ± 0.59 and 2.09 ± 0.01 . DO was highest in wet season at all stations and very low values in dry season.

The Biological Oxygen Demand (BOD) in wet season ranged from 0.7 mg/l to 2.9mg/l in Otamiri-Oche, 2.1 mg/l to 2.9mg/l in Nkesir, 0.6 mg/l to 1.9mg/l in Ofuoma and 1.5 mg/l to 2.4 mg/l in Ihimiri-Ama. The lowest came from Ofuoma (0.6mg/l) while the highest came from Otamiri-Oche (2.9mg/l).

The Biological Oxygen Demand (BOD) in dry season ranged from 0.6 mg/l to 1.2mg/l in Otamiri-Oche, 0.6 mg/l to 1.9mg/l in Nkesir, 0.7 mg/l to 1.4mg/l in Ofuoma and 2.0 mg/l to 2.1 mg/l in Ihimiri-Ama. The lowest came from Otamiri-Oche and Nkesir (0.6mg/l) while the highest came from Ihimiri-Ama (2.0mg/l). Comparing the two seasons (wet and dry), the lowest came from Ofuoma in dry season, Otamiri-Oche and Nkesir in dry season (0.6mg/l) and the highest came from Otamiri-Oche (2.9mg/l) in wet season.

3.2 Mean Heavy Metal Concentrations in Surface Water in Wet and Dry Seasons

Table 2 shows the mean concentrations of heavy metals in surface water in both wet and dry seasons. Cadmium in wet season ranged from 0.030mg/l to 0.065mg/l in Otamiri-Oche, 0.044mg/l to 0.060mg/l in Nkesir, 0.035 to 0.050 in Ofuoma and <0.001 to 0.08. The lowest came from Ihimiri-Ama (<0.001) the control site while the highest came from Otamiri-Oche (0.065mg/l).

Cadmium in dry season ranged from 0.054mg/l to 0.098mg/l in Otamiri-Oche, 0.042mg/l to 0.076mg/l in Nkesir, 0.058mg/l to 0.070mg/l in Ofuoma and 0.011mg/l to 0.019mg/l. The lowest came from Ihimiri-Ama (0.011mg/l) the control site while the highest came from Otamiri-Oche (0.076mg/l). Comparing the two seasons (dry and wet) the lowest came from Ihimiri-Ama (<0.001) in wet season while the highest came from Otamiri-Oche (0.076mg/l) in dry season. The mean and standard deviation of Cd in Table 2 are 0.05 ± 0.01 , 0.05 ± 0.01 , 0.04 ± 0.00 and 0.03 ± 0.04 in wet season and in the dry season, 0.07 ± 0.02 , 0.05 ± 0.01 , 0.06 ± 0.01 and 0.01 ± 0.00 in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama correspond. Cd was low in dry season compare to other sampled stations and low at the control site (Ihimiri-Ama) both in wet and dry seasons respectively.

Chromium in wet season ranged from 3.369mg/l to 5.865mg/l in Otamiri-Oche, <0.003 to 6.201mg/l in Nkesir, <0.003 to 5.409mg/l in Ofuoma and below dictation limits in Ihimiri-Ama. The lowest came from Nkesir and Ihimiri-Ama (BDL), the control site while the highest came from Nkesir (6.201mg/l).

Chromium in all the sites was below dictectable limit (<0.003) in dry season. The lowest came from all the sites in dry season (BDL) while the highest came from Otamiri-Oche (5.865mg/l). Comparing the wet and dry seasons, the lowest came from all the sites in dry season while the highest came from Nkesir (6.201mg/l) from wet season. The mean and standard deviation of Cr in Table 2 are 4.42 ± 1.21 , 3.43 ± 1.41 , 2.14 ± 1.60 and

BDL in wet season in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama respectively. In the dry season, all stations were below dictation limit (BDL).

Cu in wet season ranged from <0.001 to 0.050mg/l in Otamiri-Oche, <0.001 to 0.019mg/l in Nkesir, BDL in Ofuoma and <0.001 to 0.002mg/l in Ihimiri-Ama. The lowest came from Otamiri-Oche, Nkesir, Ufuoma and Ihimiri-Ama (BDL) while the highest came from Otamiri-Oche (0.050).

Copper in dry season ranged from <0.001 to 27.80mg/l in Otamiri-Oche, 0.028mg/l to 3.20mg/l in Nkesir, 0.030mg/l to 3.70mg/l in Ofuoma and 0.030mg/l to 0.025mg/l in Ihimiri-Ama. The lowest came from Otamiri-Oche (0.001mg/l) while the highest came from Ofuoma (3.70mg/l). Comparing wet dry season, the lowest came from all the sites in wet season while the highest came from Ufuoma (3.70mg/l) in dry season. The mean and standard deviation of Cu in Table 2 are 0.20 ± 0.01 , 0.01 ± 0.00 , $<0.001 \pm 0.00$ and 0.001 ± 0.00 in wet season and in the dry season, 0.01 ± 0 , 0.03 ± 0.00 , 0.03 ± 0.00 and 0.03 ± 0.00 in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama respectively. Cu was higher in Otamiri-Oche in wet season compare to the other three stations.

Ni in wet season ranged from 0.086mg/l to 0.560mg/l in Otamiri-Oche, 0.342mg/l to 0.608mg/l in Nkesir, 0.356mg/l to 0.539mg/l in Ofuoma and 0.113mg/l to 0.129mg/l Ihimiri-Ama (control site). The lowest came from Otamiri-Oche (0.086mg/l) while the highest came from Nkesir (0.608mg/l).

Nickel in dry season ranged from 0.045mg/l to 3.00mg/l in Otamiri-Oche, 0.050mg/l to 13.50mg/l in Nkesir, 0.050 to 15.30 in Ofuoma and 0.015mg/l to 0.023mg/l. The lowest came from Ihimiri-Ama (0.015mg/l) while the highest came from Ofuoma (15.30mg/l). Comparing the two seasons the lowest came from Ihimiri-Ama (0.015mg/l) the control site and the highest came from Ofuoma (15.30mg/l). The mean and standard deviation of Ni in Table 4.2 are 0.30 ± 0.21 , 0.44 ± 0.14 , 0.43 ± 0.00 and 0.12 ± 0.00 in

wet season and in the dry season, 0.04 ± 0.08 , 0.05 ± 0.01 , 0.05 ± 0.02 and 0.02 ± 0.04 in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama respectively. Ni was higher in the wet season than in the dry season.

Pd in wet season ranged from 0.115mg/l to 0.413mg/l in Otamiri-Oche, 0.113mg/l to 0.834mg/l in Nkesir, <0.022 to 0.759 in Ofuoma and 0.02mg/l to 0.552mg/l in Ihimiri-Ama, the control site. The lowest came from Ofuoma (<0.022) and the highest came from Nkesir (0.834mg/l).

Pb in dry season ranged from 0.142 to 25.200mg/l in Otamiri-Oche, 0.029mg/l to 054.90mg/l in

Nkesir, 0.236mg/l to 36.50mg/l in Ofuoma and 0.016mg/l to 0.050mg/l in Ihimiri-Ama, the control site. The lowest came from Ihimiri-Ama (0.016mg/l) and the highest came from Ofuoma (36.50mg/l). Comparing the two seasons, the lowest came from Ihimiri-Ama (0.016mg/l) the control site while the highest came from Ofuoma (36.50mg/l). The mean and standard deviation of Pb in Table 2 are 0.24 ± 0.13 , 0.32 ± 0.34 , 0.34 ± 0.38 and 0.25 ± 0.25 in wet season and in the dry season, 0.15 ± 0.12 , 0.12 ± 0.01 , 0.19 ± 0.05 and 0.026 ± 0.02 in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama respectively. Pb concentrations were high in both wet and dry season in all stations including control.

Table 2: Mean Heavy Metal Concentrations in Surface Water in Wet and Dry Seasons and Recommended Drinking Water Standards

Heavy Metal	Otamiri-Oche River (S1)	Nkesir River (S2)	Ofuoma River (S3)	Ihimiri-Ama(control) (S4)	Maximum Permissible Levels (WHO)	Health Implication
Cd					0.003	Toxic to the kidney
Wet season	0.05 ± 0.01^a	0.05 ± 0.01^a	0.04 ± 0.00^a	0.03 ± 0.04^a		
Dry season	0.07 ± 0.02^a	0.05 ± 0.01^a	0.06 ± 0.01^a	0.01 ± 0.00^b		
Cr					0.05	Cancer
Wet season	4.42 ± 1.21^a	3.43 ± 1.41^{ab}	2.14 ± 1.60^{ab}	BDL		
Dry Season	BDL ^a	BDL ^a	BDL ^a	BDL ^a		
Cu					1	Gastrointestinal disorder
Wet Season	0.02 ± 0.01^a	0.01 ± 0.00^a	$<0.001 \pm 0.00^b$	$<0.003 \pm 0.00^b$		
Dry Season	0.01 ± 0^a	0.03 ± 0.00^a	0.03 ± 0^a	0.03 ± 0.00^a		
Ni					0.02	Possible carcinogenic
Wet Season	0.30 ± 0.21^{ab}	0.44 ± 0.14^a	0.43 ± 0.09^a	0.12 ± 0.00^b		
Dry Season	0.04 ± 0.08^a	0.05 ± 0.01^a	0.05 ± 0.02^a	0.02 ± 0.04^a		
Pb					0.01	toxic to Central/PNS
Wet Season	0.24 ± 0.13^a	0.32 ± 0.34^a	0.34 ± 0.38^a	0.25 ± 0.25^a		
Dry Season	15 ± 0.12^a	0.12 ± 0.01^a	0.19 ± 0.05^a	0.026 ± 0.02^a		

4.0 Discussion

4.1 Physico-chemical Parameters of Surface water

The physico-chemical parameters of Otamiri-Oche, Nkesir, Ufuoma and Ihimiri-Ama across the four stations in relation to the seasons were investigated in the Niger Delta River from April 2021 to February 2022. The mean result of the pH are from 6.81 ± 0.29 , 6.81 ± 0.07 (Otamiri-Oche), Nkesir (6.91 ± 0.33 , 6.81 ± 0.16), Ofuoma (6.51 ± 0.33 , 6.86 ± 0.12) and Ihimiri-Ama (6.6 ± 0.39 , 6.52 ± 0.34) in both wet and dry seasons respectively indicating, the alkaline composition of the surface water and complying with the (WHO, 2004) specification. The WHO (2004) acceptable levels of pH is from 6.5-8.5 while that of EU sets protection limits is from 6 to 9 for fisheries and aquatic life. This study is in line with the study conducted by Andem et al. (2012) in Ona River. Abija et al. (2018) also carried out a similar work in Farcados River, Western Niger Delta, Nigeria, and found out pH values ranging from 7.66-8.31mg/l and 6.2-6.3mg/l in the wet and dry season respectively indicating the alkaline composition of surface water. Statistically, there was no significant difference between the mean values in rivers in petroleum and non- petroleum site in wet and dry seasons of selected river water.

Temperature ($^{\circ}\text{C}$) is basically important for its effect on other properties of water. Temperature values are presented in Table 1, and the values were below WHO (2004) permissible limit of 30°C in fresh water. These values still fall within the water fishery criteria of 29.9°C . Abija et al. (2018) also carried out a similar work in Farcados River, Western Niger Delta, Nigeria, and found that the Temperature varies from 26.27-27.77 in wet season and 30-31 during the dry season. Statistically the values were not significantly different.

Electrical Conductivity were recorded in Table 1 for all the water samples and were all below accepted limit for Nigerian drinking water (SON, 2007) and WHO permissible limit in both oil polluted and non oil polluted waters. Conductivity

in this study is below the recommended limit of $500 \mu\text{S}/\text{cm}$ (WHO, 2004). Mean conductivity value in this study is lower than $3752 \mu\text{S}/\text{cm}$ recorded in New Calabar River by Agbugui and Deekae (2014). Abija et al. (2018) also carried out a similar work in Farcados River, Western Niger Delta, Nigeria and found out that Electrical conductivity varies from 17.0-26.0 $\mu\text{S}/\text{cm}$ with a mean of 21 $\mu\text{S}/\text{cm}$ in the wet season and $68.5 \mu\text{S}/\text{cm}$ in the dry season. Statistically the values showed that there is no homogeneity of variance in petroleum and Non- petroleum sites in wet and dry seasons of selected water bodies.

Turbidity is the determination of the muddiness or opaqueness of water and it is usually influenced by the total number of materials that are present in the water (Oboh and Agbala, 2017). The turbidity of the rivers are presented in Table 1, in Otamiri-Oche (wet and dry seasons), Nkesir (dry season), and Ofuoma (wet and dry seasons) were generally Turbid as the turbidity values obtained in all the stations in exemption of the control site (Ihimiri-Ama) were higher than 5NTU recommendation limit (WHO, 2004). This may have been influenced by petroleum pollution in open surface water (Chinedu et al., 2011). This could be due to the influx of petroleum particulate matter into the aquatic system that made it to exceed 5NTU allowable limit for fresh water aquatic culture and WHO (2004) permissible limit of 0.01. The result of oneway ANOVA shows that the probability in wet season is 0.099 while that of dry season is <0.001 of the water bodies which are greater than 0.05 and 0.01 in wet season and less than 0.05 in dry season. Therefore, there is significance difference between the means of the communities.

The mean values of the Total Dissolved Solids obtained in this study are presented in Table 1: The TDS in this study was lower than the permissible limit $500 \text{mg}/\text{l}$ (WHO, 2004). Solid in water are undesirable, they degrade the quality of water, inhibit the photosynthetic process and reduce the utility of water (Ogbeibu and Anagbaso, 2004). The result obtained from this study is contrary to the study conducted by Ofonmbuk et al. (2014) in Ediena stream. The results of ANOVA, revealed that there is no

significant difference between the mean values in Otamiri-Oche, Nkesir, Ofuoma and Ihimiri-Ama in wet and dry seasons. The result of oneway ANOVA shows that the probability in wet season is 0.099 while that of dry season is <0.001 probabilities are greater than 0.05 in wet season and less than 0.05 in dry season. Therefore, there is significance difference between the means of the river water.

The mean values for Dissolved Oxygen are presented in Table 1, in both wet and dry season. The least mean DO in wet season was observed in Ofuoma which was low in wet season, the mean values were within acceptable limit in all other sampled stations. Otamiri-Oche, Nkesir and the control site (wet season) were within WHO (2004) 5-9.5mg/l limit. The DO values recorded in this study is similar to 0.58-10.00mg/l recorded by Ikongbeh et al. (2014) in Lake Akata. The result revealed that there is a significantly difference between the mean concentrations in the sampled stations.

Biological Oxygen Demand (BOD) is a measure of the amount of oxygen required by micro-organism to break down organic matter in 1liter of water (Clair *et al.*, 2003). It is used to determine the pollution strength of water. BOD in this study recorded in Otamiri-Oche (1.73 ± 1.14), Nkesir (2.63 ± 0.22), Ofuoma (1.2 ± 0.67) and Ihimiri-Ama (1.95 ± 0.42). BOD which had the least mean (Ofuoma) and the highest mean (Nkesir) in the stations was lower than the permissible limit 5mg/l (WHO, 2004). The mean BOD values recorded in this study is lower than 405.57 mg/l recorded in Ona River by Andem *et al.* (2012). Abija et al. (2018) carried out a research in Farcados River, Western Niger Delta, Nigeria and found out Biological Oxygen Demand which is greather than this study, 19.20-28.40mg/l with a mean of 32mg/l in the wet season and <1.0mg/l below detection limit in all sampling stations in the dry season.

4.2 Heavy Metals in Surface Water

The mean values in Cd are presented in Table 2. The values are 0.05 ± 0.01 , 0.07 ± 0.02 mg/l in

Otamiri-Oche River, Nkesir River (0.05 ± 0.01 , 0.05 ± 0.01 mg/l), Ofuoma (0.04 ± 0.00 , 0.06 ± 0.01) and Ihimiri-Ama River (0.03 ± 0.04 , 0.01 ± 0.00 mg/l) in wet and dry season respectively. The least mean came from the control station (Ihimiri-Ama River) dry season while the highest came from Otamiri-Oche River in dry season. Cd in this study is above WHO (2004) permissible limit of 0.003mg/l both in the control site. However, a study by Owamah which evaluated the concentration of Cd in surface water from the River Ijana, Warri showed that the concentrations of heavy metals were higher than the WHO recommended limits, with Cd having 42mg/l. In addition, studies by Emuedo et al. (2014), assessed the concentration of heavy metals of Cd in Okrika and Okpare communities revealed that they were present in concentrations above the WHO (2004) recommended limits for surface water. High levels of Cd have also been recorded in surface waters of Aguobiri community, in South Ijaw Local Government, Bayelsa State, Nigeria by Nun River (Ogaga, 2018). These higher values in oil polluted waters could be as a result of oil company discharge. In view of the fact that the major use of water in the study areas is fishing and domestic purposes, the concentration levels of cadmium recorded exceeded the permissible limit by WHO for aquatic ecosystem, therefore, it is of great concern since cadmium is extremely toxic and the consumption of water high in cadmium could lead to toxicity to the kidney and can cause adverse health effect to end users cadmium has been also found to be toxic to fishes and other aquatic organisms.

The mean values of Cr are presented in Table 2. The least Cr came from the control station and the three other stations in dry season while the highest came from Otamiri-Oche River in wet season. Cr in this study is above WHO (2004) permissible limits of 0.05mg/l. This study is in line with the studies of Emuedo *et al.* (2005) which assessed the concentration of heavy metals (Cr) in surface water from Nembe, Okrika and okpare communities and found out high Cr concentrations (0.60, 0.90 and 0.67 mg/l). The high concentration of chromium in this study

could be attributed to oil company wastes. Cr can lead to cancer when it exceeds the permissible limits.

The values of Cu is presented in Table 2 and the least value came from Ofuoma wet season while the highest came from Otamiri-Oche River. The result of this study shows is below the WHO (2004) permissible limits of 1mg/l for fresh water. Cu is an essential metal and when it is low it can lead to gastroin-intestinal disorder in human (WHO, 2004). The level of Cu analyzed in this study was in agreement with report from Abonnema River by Ideriah (2012) with mean concentration (0.01mg/l).

The values of Nickel are presented in Table 2, the least value was revealed in the control station (Ihimiri-Ama) in dry season while the highest came from Nkesir wet season. The result of Ni in this study was above WHO (2004) permissible limits of 0.02 and this could be attributed the discharge of oil waste into the fresh water and Ni can lead to carcinogen. High level of Ni have also been recorded in surface waters of Aguobiri community, in South Ijaw Local Government, Bayelsa State, Nigeria and Num River by Ogaga et al. (2018), Imasuen and Egai (2013).

The Pb concentrations are presented in Table 2. The least Pb was revealed in Ihimiri-Ama (control site) in dry season while the highest came from Ofuoma wet season. Pb and Ni are distributed in surface waters due to weathering of minerals and atmospheric deposition (Merian, 1991; Robinson, 1996). Also, Pb and Ni presence at high concentration could be as result of drilling of petroleum. Similar results were reported for the Choba section of New-Calabar River, in Eastern Niger-Delta, Lagos Lagoon and for Tombia and Gbarantoru axis of Num River in Bayelsa State (Nwankwoala and Angaya, 2017). The high concentration of Pb may be attributed to the oil and gas pipelines, the degeneration of pipes from oil jetties. This study emphasized that due to continuous exposure of the study area to industrial and anthropogenic activities into the water bodies, over time will constitute a health risk problem to the individuals in the area and organisms.

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