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Characterization of surface water in Robertkiri, Idama and Jokka Creek of the Niger Delta area of Nigeria

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Abstract
The oil industry has been a growth engine to the economy of Nigeria; however, its activities such as oil exploration, exploitation, spillage, refining and distribution have caused several environmental defects to its receptors of which surface water is at risk. This research examined the characteristics of surface water in oil-producing areas in the Niger Delta during the wet and dry seasons. The pH values ranged from 6.10- 6.80 during the wet season and 6.25 - 6.92 for the dry season. This was an optimum value for the aquatic lives inhabiting these waters. However, the electrical conductivity and TDS values were relatively high for the dry season and low for the wet season, where rain could have diluted the salt content. The TDS values ranged from 2176 - 4036 mg/L. Polycyclic aromatic hydrocarbons concentrations varied between 0.003 - 0.034 mg/L for wet season and ranged from 0.008-0.0054 mg/L for the dry season. Due to the natural conditions for degradation of petroleum hydrocarbons, it is favourable with high temperatures and relatively high rainfall. In respect to this, a lower concentration was recorded for the wet season and much higher during the dry season. Value as high as 0.00 - 8.05 mg/l were observed for zinc which could be detrimental to human health. The continuous oil exploration and anthropogenic activities if not properly monitored, could pose serious threat to human and aquatic lives.

Keywords: surface water, Niger Delta, oil exploration, oil-producing areas

1. Introduction
Surface waters in oil-producing areas have adversely been impaired over the last few decades. Oil-producing areas in Nigeria are areas where intensive and extensive crude oil exploration, exploitation and production, including industrial installations like pipeline materials, flow stations, gas clusters and gas flaring sites, are carried out; all of which have adverse impact on the environment (Yakubu, 2017) [19]. The Niger Delta is an area where these environmental hazards are experienced ranging from oil spillage to soil and water contamination. Getting underground water in these areas is not so tedious because the aquifers are a few feet from the surface. In areas where there is a spill, there is groundwater and surface water contamination.
In local communities where crude oil activities are carried out, its inhabitant suffer surface water and even possible groundwater contamination. This is because oil contamination originates from anthropogenic activities such as drilling operations and transportation, which is a well-known and well-studied environmental pollution problem. However, due to their visibility and dramatic appearance, oil spills constantly attract the attention of the media and consequently the politicians and public, as in the case of the Deep-water Horizon blowout in the Gulf of Mexico in 2010 (Romero *et al*., 2015) [14]. However, the oil spills happening in the Niger Delta have received less attention in global media, despite significantly higher impacts on human health and the local ecology (UNEP 2011) [18]. Statistics indicate that between 1976 and 2001, 6,817 oil spills has occurred in the Niger delta which resulted in the loss of approximately 500,000m^3 of oil to the sea and soil (UNDP, 2016) [16]. About 1.4 and 2.1 million m^3 of oil had been leaking out into the ecosystem of Niger Delta over the past 50 years (UNEP, 2011) [18]. The oil spills in Niger Delta are under-reported. The government and oil company's operators in the Niger Delta maintain their own data on leakages; their data are sometimes unreliable and conflicting as both the government and operators seek to limit their legal liability for commensurate claims and compensations from oil spills damages. In extreme cases, the spills are never reported or branded as minor without post-spill containment, recovery and remediation activities.

About half of the surface water pollution in the Niger delta comes from natural seepage of oil into the sea and coastal environments from oil deposits on the continental shelf, when a drilling accident occurs by blowouts of liquid and gaseous hydrocarbons from the oil well and long term leakages from pipelines into oceans (NRC 2003). Due to the influence of the tides and at times floods in connection with rains, spilt oil is gradually and rapidly distributed over large areas and remobilized with rising tides. The oil spills sometimes originate from leaking wellheads, pipelines, and flow stations, from spills in connection with transport of mostly stolen oil; from illegal tapping of the wells; and from artisanal refining under very primitive conditions (Mmom and Arokoyu 2010) [8]. As a result of the contamination of oil in mangroves and wetlands as well as on land, oil has penetrated deep into soils down to several meters and has contaminated ground waters over large areas. This has led to the contamination of water wells as a particularly serious concern from a human health perspective (Moffat and Linden 1995; Ana *et al*. 2009) [9].

This study elaborates on the physicochemical characteristics of surface water in these areas as they are vital in determining its water quality which may directly or indirectly have impact on the sustainability of fish and other aquatic lives. Also, the level of heavy metal toxicity on estuarine organisms tend to affect the physicochemical composition of the ecosystem (Frank and Boisa, 2018) [4]. Hence, the essence is to compare the present results to the baseline data and deduce possible solutions on how this can be curtailed.

2. Materials and Methods

2.1 Study area

Surface water samples were taken at different points from rivers in Robertkiri, Idama and Jokka Creeks of Akuku-Toru local government Area in Rivers State, Nigeria. Akuku-Toru is an oil-producing area of Rivers State which has its headquarters in the town of Abonnema. It has a landmass area of 1,443 km^2 and a population of 156,006 conducted at the 2006 census. Their major occupations includes: farming, palm oil milling, local gin making, fishing and trading. The Map of Study Area and sampling points are presented in figure 1, while the geographic coordinates of the sampling points are shown in Table 1.

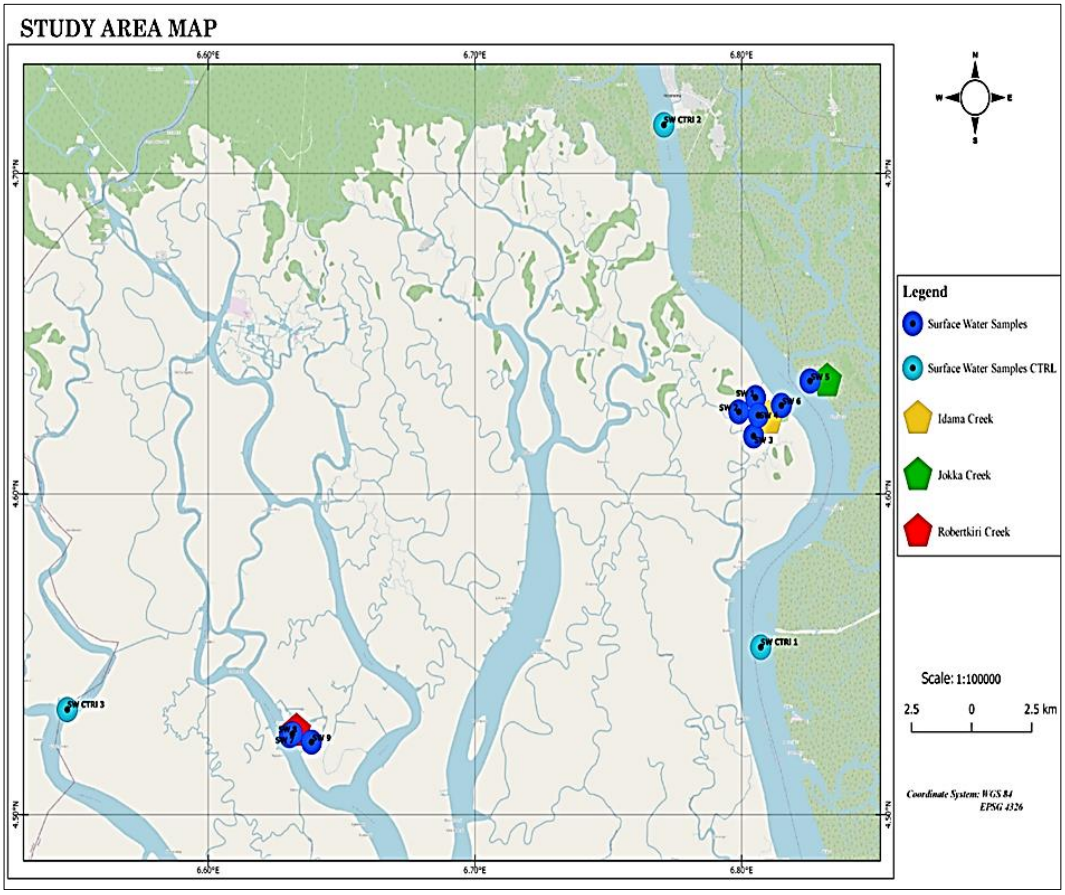

Fig 1: Sampling map of study area

2.2 Surface water sampling

The field work was conducted during the Wet and Dry Season. The areas where the water samples are collected were close to oil and gas operational fields. However, three control samples were taken from pristine areas where oil and gas operations are currently infinitesimal. Water samples were collected at approximately 500m depth (downstream) from the water bodies within the study areas. Samples were collected using a two-litre plastic container which has been pre-treated by washing in dilute hydrochloric acid and rinsed with distilled water. At the point of sampling, the plastic container was rinsed with the relevant sample to be collected. Water samples were taken by submerging the container below the surface and allowing it to overflow. Samples were collected in replicates and analyzed for some physicochemical and metal parameters. Water quality parameters determined on-site (*in-situ*) include pH, Conductivity, Dissolved oxygen, Total Dissolved Solids (TDS), Turbidity and Temperature. The Samples were preserved by cooling at (<4oC) for the physicochemical parameters, while samples for metals and organics were held in 1-2ml of 1:1 nitric and sulphuric acid, respectively. All ex-situ analysis was carried out in Dukoria Laboratory Ltd, Effurun, Delta State.

Table 1: Geographic coordinates of the sampling locations

Water samples in onshore/swamp				
Sample ID	**Sample type**	**Eastings**	**Northings**	**Location**
SW 1	Surface Water	E 006˚ 48' 18.62"	N 04˚ 37' 48.27"	Idama creek
SW 2	Surface Water	E 006˚ 47' 56.12"	N 04˚ 37' 32.31"	Idama creek
SW 3	Surface Water	E 006˚ 48' 16.01"	N 04˚ 37' 5.15"	Idama creek
SW 4	Surface Water	E 006˚ 48' 22.44"	N 04˚ 37' 28.38"	Idama creek
SW 5	Surface Water	E 006˚ 49' 32.22"	N 04˚ 38' 6.87"	Jokka creek
SW 6	Surface Water	E 006˚ 48' 53.62"	N 04˚ 37' 39.47"	Idama creek
SW 7	Surface Water	E 006˚ 37' 49.54"	N 04˚ 31' 28.69"	Robertkiri creek
SW 8	Surface Water	E 006˚ 37' 53.45"	N 04˚ 31' 30.57"	Robertkiri creek
SW 9	Surface Water	E 006˚ 38' 19.35"	N 04˚ 31' 21.50"	Robertkiri creek
SW CTRL 1	Surface Water	E 006˚ 48' 25.76"	N 04˚ 33' 8.00"	Idama control
SW CTRL 2	Surface Water	E 006˚ 46' 15.05"	N 04˚ 42' 54.41"	Jokka control
SW CTRL 3	Surface Water	E 006˚ 54' 11.87"	N 04˚ 53' 27.36"	Robertkiri control

2.3 Methods

The parameters listed in Table 2 were analyzed to characterize the surface waters in the oil-producing areas.

Table 2: Analytical methods for parameters analyzed in this study

Parameters	Analytical methods
Physico-chemical	
pH	Electronic method (APHA - 4500-H+)
Temperature, ^{0}C	Thermometer (APHA, 2550-B)
Conductivity, µS/cm	APHA 2510 B
Total dissolved solids (TDS), mg/L	APHA 2540-C
Total Suspended Solids (TSS), mg/L	Gravimetric method (APHA-209-D)
Turbidity, NTU	Nephelometric method (APHA - 2130-B)
Anions	
Salinity (Cl-), mg/L	Mohr's Argentometric method (APHA 4500 Cl-B)
Nitrate, mg/L	Cadmium Reduction method (ASTM, 2016 -D3867)
Phosphate. mg/L	Ascorbic Acid method (APHA-4500 PO43-)
Sulphate, mg/L	Turbidity method (APHA-426C SO42-E)
Gross organics	
BOD, mg/L	5 day method (APHA 5210B)
DO, mg/L	APHA - 4500-O C
COD, mg/L	Dichromate method (Reflux) (APHA - 5300 B)
Inorganics	
Calcium, mg/L	APHA3500
Magnesium, mg/L	APHA3500
Metals	Atomic Absorption Spectrophotometer (AAS), (APHA 3000)
PAH	Polynuclear Aromatic Hydrocarbons (APHA 6440)

Source: APHA, (2012)

2.4 Statistical analysis

Statistical analysis was carried out for basic descriptive statistics to determine the significance of difference between the controls and sampling points at a probability level of 5% using the Data Analysis package of Microsoft Excel 2016 (Office 365).

2.5 Laboratory analysis

The physicochemical parameters were carried out in the laboratory by validated standard operating methods adapted from APHA standards methods listed in table 2 above. However, heavy metals were determined as follows: Two hundred and fifty (250) mL of the water sample was measured and transferred into a beaker. Five (5) mL of concentrated nitric acid (HNO_3) was measured and added to the beaker containing the water sample. The sample was heated on a hot plate at a temperature between 90 and 95^{o}C until the volume reduced to approximately 15-20 mL. The beaker was removed from the heater and allowed to cool; afterwards it was filtered. The filtrate was poured into a 25 mL volumetric flask, and the final volume adjusted to the mark with distilled water. The metals in the samples were analyzed using the atomic absorption spectrophotometer (AAS), Varian Spectra AA 100.

2.5.1 Polynuclear aromatic hydrocarbon

The samples were collected in a 1-litre amber glass bottle with Teflon-lined screw cap, 5 mL of 1:1 HCl acid was added and cooled to 4^{0}C before it was taken to the Laboratory prior to analysis (APHA, 2012). They were always extracted within 14 days and extracts analyzed within 40 days. The samples were extracted using methylene chloride, and solvent-exchanged into hexane. A litre of the water sample was transferred into a separatory funnel. The sample bottle was rinsed with 120 mL of methylene chloride and also transferred to the separatory funnel. After shaking the sealed separatory funnel vigorously by hand for 1-2 minutes, it was placed on a mechanical shaker and shaken for 5 minutes. The separated methylene chloride was drained into a 500 mL Erlenmeyer flask, and 120 mL of methylene chloride was added to the separatory funnel for a repetition of the extraction procedure. After measuring and reading the volume of the extracted sample in a 1 litre graduated cylinder, the extract was dried by adding 75g of Sodium Sulphate. The

sulphate was allowed to contact the extract by swirling for 30 minutes.

Thereafter, the extract was concentrated by using the Rotary evaporator. The extract was rinsed with 15 mL of methylene chloride into the 500 mL evaporation flask attached to the concentrator tube. The concentration was done until the sample volume was between 5 mL and 10 mL. The extract from the concentrator tube was transferred to a 25 - 40 mL vial. The extract was then taken for clean-up and fractionation using silica gel permeation chromatography to separate the aromatic fractions in preparation for GC analysis. After setting the GC column conditions, the final extracts were injected into the Gas Chromatograph (Agilent 5890) with Flame Ionization Detector.

3. Results

The surface water quality of the study areas is expressed in Table 3-6 and Figures 1-2 for wet and dry seasons and from control stations.

3.1 Mean physicochemical and metal characteristics of the surface water

The pH of the surface water samples ranged from 6.10 - 6.80 across all the sampling locations in the wet season, and in the dry season, pH values ranged from 6.25 - 6.92. These values are considered optimum and favourable for the existence of aquatic life. Turbidity, which is the measure of the cloudiness of water, was low in all sampling locations as it ranged from 1.00 - 3.50 NTU during the wet season and 1.5 - 3.00 NTU in the dry season. The TDS levels of the surface water bodies ranged from 2176 - 4036 mg/L across all the sampling stations in the wet season and in the dry season. The DO levels of the surface water bodies ranged from 4.90 - 5.80 mg/L across all the sampling stations in the wet season, and in the dry season, DO values ranged from 5.80 - 6.40 mg/L. The BOD levels of the surface water bodies varied between 3.40 - 3.75 mg/L in the wet season and 3.69 - 4.36 mg/L in the dry season. The COD levels ranged from 5.96 - 7.10 mg/L in the wet season and in the dry season, COD values ranged from 7.4 - 8.05 mg/L. The concentrations of nitrate, phosphate and sulphate in surface water were 0.016 - 2.441 mg/L; 0.028 - 5.436mg/L and 41.44 - 124.56 mg/L in the wet season while the dry season levels ranged between 0.093 - 0.963 mg/L; 0.037 - 5.638 mg/L and 194.43 - 262.35 mg/L respectively. The recorded concentrations, however, suggest optimum conditions for survival of aquatic life (RPI, 1995). The total hydrocarbon (THC) concentration of the surface water bodies ranged from 0.01 - 15.68 mg/L across all the sampling stations in the wet season and in the dry season; THC concentration was below detection limit (<0.001 mg/L). The concentrations of heavy metals in surface water whose levels were above detection limit in the study area are: Cr (0.00 - 0.23 mg/L), Fe (0.081 - 1.577 mg/L), Cd (0.09 - 0.056 mg/L), Pb (0.00 - 0.019 mg/L) and Zn (0.00 - 4.04 mg/L) in the wet season while the concentrations of heavy metals in the surface water in the dry season are: Fe (0.114 - 2.053mg/L), Cd (0.01 - 0.234 mg/L); Pb (0.00 - 0.02 mg/L) and Zn (0.08 - 8.05 mg/L).

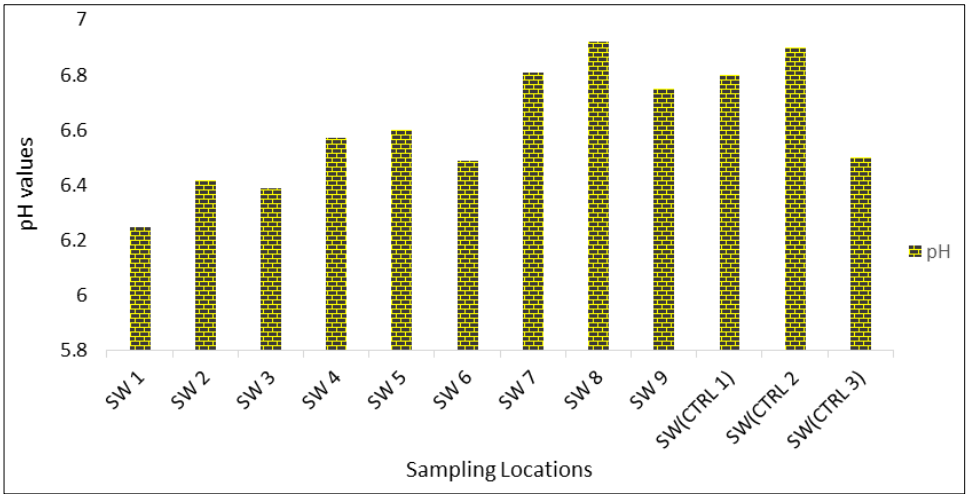

Fig 1(A): Variations of pH for surface water in all sampling locations during dry season

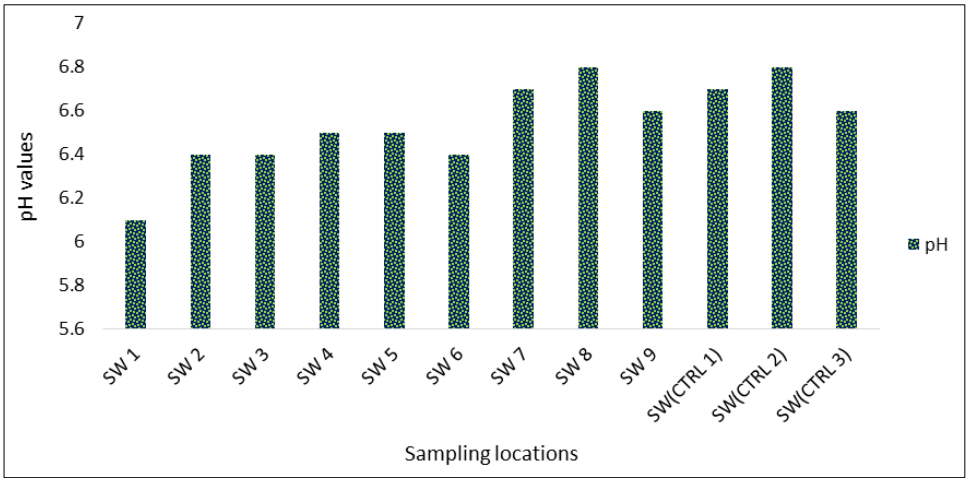

Fig 1(B): Variations of pH for surface water in all sampling locations during wet season

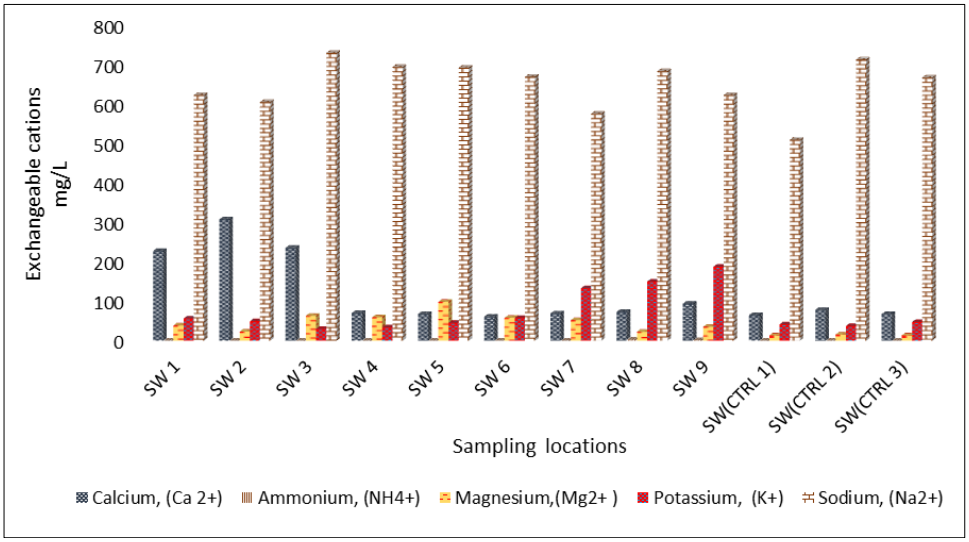

Fig 2: Variations of exchangeable cations for surface water in all sampling locations during wet season

Table 3: Mean result for the physico-chemical properties of surface water in the various sampling locations during the wet season

Parameters	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW CTRL 1	SW CTRL 2	SW CTRL 3
Physico-chemical												
Ph	6.10	6.40	6.40	6.50	6.50	6.40	6.70	6.80	6.60	6.70	6.80	6.60
Electrical Conductivity, µS/cm	2500.00	2400.00	3100.00	3900.00	3890.00	3760.00	3400.00	3840.30	3500.00	3990.00	4005.00	3750.00
Total Suspended Solids (TSS), mg/l	3.50	4.00	2.90	1.00	1.51	0.50	0.50	1.50	0.50	1.00	2.50	2.00
Total Dissolved Solids (TDS), mg/l	2240.00	2176.00	2624.00	2496.00	2489.60	2406.40	2176.00	2457.60	2240.00	2553.60	2563.20	2400.00
Dissolved Oxygen (DO), mg/l	5.00	5.20	5.10	4.95	5.30	5.00	5.20	5.10	5.20	5.80	5.50	5.30
Color, Pt-Co	1.00	2.00	0.50	0.00	1.00	1.50	2.00	0.50	1.00	0.00	1.00	0.50
Alkalinity, mg/l	340.00	400.00	320.00	370.00	154.00	280.00	580.00	290.00	175.00	90.00	60.00	80.00
Biochemical Oxygen Demand (BOD), mg/l	3.50	3.60	3.50	3.40	3.60	3.45	3.50	3.50	3.55	3.75	3.70	3.60
Chemical Oxygen Demand (COD), mg/l	6.40	6.37	6.22	5.96	6.45	6.31	6.40	6.63	6.37	7.10	6.92	6.74
Turbidity, NTU	2.00	2.50	3.00	3.50	2.00	1.50	1.00	1.50	2.00	2.00	1.00	1.00
Organics, mg/l												
Oil & Grease	0.18	0.12	0.06	0.05	0.17	0.22	0.04	0.21	0.12	<0.01	0.03	0.03
Total Hydrocarbon Content (THC)	0.01	0.09	0.14	0.36	1.53	15.68	3.69	4.75	5.51	<0.01	<0.01	0.05
PAH	0.009	0.006	0.003	0.005	0.008	0.012	0.016	0.034	0.008	0.005	0.004	0.005
Anions (ppm)												
Sulphate, (SO_4^{2-})	115.60	104.52	124.56	62.24	61.82	56.42	41.44	59.74	64.51	65.98	61.66	56.00
Phosphate, (PO43-)	0.310	0.296	2.410	2.362	1.748	2.396	4.551	5.436	1.374	0.028	0.020	0.022
Nitrite, (NO2-)	1.904	1.851	2.223	2.122	2.116	2.045	1.850	2.089	1.915	1.041	1.763	2.040
Nitrate, (NO_3^-)	0.472	1.623	0.047	0.059	1.258	2.441	0.563	0.148	1.250	0.016	0.012	0.003
Cations (ppm)												
Calcium, (Ca^{2+})	226.71	306.92	234.77	69.89	67.38	60.93	68.81	72.62	93.60	65	77.85	67.20
Manganese, (Mn2+)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Ammonium, (NH4+)	0.123	0.147	0.135	0.245	0.239	0.127	0.119	2.741	1.352	0.079	0.063	0.115
Magnesium, (Mg^{2+})	38.56	22.96	63.05	59.36	98.11	57.82	52.14	22.69	35.41	13.62	15.74	13.57
Potassium, (K^+)	56.35	49.05	29.86	33.68	45.28	57.41	132.65	149.66	187.23	41.52	36.95	47.50
Sodium, (Na^{2+})	621.38	603.62	727.90	692.39	690.62	667.54	574.26	681.74	621.38	708.37	711.03	665.76

Table 4: Mean result for heavy metals of Surface Water in the various sampling locations during the Wet Season.

Heavy metals (mg/l)	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW CTRL 1	SW CTRL 2	SW CTRL 3
Iron, (Fe)	0.493	0.285	0.136	0.247	1.263	1.577	0.861	0.592	0.437	0.081	0.056	0.077
Zinc, (Zn)	4.04	0.027	0.056	0.024	0.075	0.019	0.007	3.02	<0.001	0.003	<0.001	<0.001
Chromium, (Cr)	0.002	0.011	0.009	0.041	0.017	0.230	0.004	0.001	0.017	<0.001	<0.001	<0.001
Lead, (Pb)	0.001	<0.001	<0.001	0.003	0.007	0.019	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
Cadmium, (Cd)	0.023	0.019	0.027	0.033	0.013	0.009	0.056	0.042	0.019	<0.006	<0.006	<0.006
Mercury, (Hg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 5: Mean result for the physico-chemical properties of surface water in the various sampling locations during the dry season

Parameters	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW CTRL 1	SW CTRL 2	SW CTRL 3
Physico-chemical												
pH	6.25	6.42	6.39	6.57	6.60	6.49	6.81	6.92	6.75	6.80	6.90	6.50
Electrical Conductivity, µS/cm	6400.04	6218.10	7265.08	6924.35	6729.60	6425.22	6382.09	5384.10	6642.37	6144.55	7251.38	6928.14
Total Suspended Solids (TSS), mg/l	1.00	0.50	2.50	1.50	1.00	1.50	0.50	0.50	1.00	0.50	1.00	0.50
Total Dissolved Solids (TDS), mg/l	3555.58	3454.50	4036.11	3846.86	3738.67	3569.57	3545.61	2991.17	3690.21	3413.64	4028.54	3848.97
Dissolved Oxygen (DO), mg/l	6.10	5.90	6.00	6.25	6.40	6.30	5.80	6.06	6.20	5.90	6.04	6.30
Color, Pt-Co	1.50	1.50	3.00	2.00	2.50	3.00	1.50	1.00	1.50	1.00	1.50	1.00
Alkalinity, mg/l	260.00	200.00	380.00	220.00	320.00	140.00	160.00	190.00	280.00	100.00	75.00	80.00
Biochemical Oxygen Demand (BOD), mg/l	3.98	4.36	3.88	4.19	4.57	3.69	3.78	4.26	3.77	3.81	3.74	4.20
Chemical Oxygen Demand (COD), mg/l	7.95	7.40	7.83	7.92	8.05	7.60	7.93	7.67	7.85	7.45	7.00	7.80
Turbidity, NTU	1.78	1.50	2.50	3.00	2.70	2.60	2.50	2.00	1.50	2.15	2.00	1.50
Organics, mg/l												
Oil & Grease	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Total Hydrocarbon Content (THC)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
PAH	0.008	0.038	0.009	0.06	0.054	0.021	0.026	0.045	0.023	0.008	0.005	0.005
Anions (ppm)												
Sulphate, (SO_4^{2-})	231.11	224.54	262.35	250.05	243.01	232.02	230.46	194.43	239.86	221.89	261.86	250.18
Phosphate, (PO43-)	0.345	0.321	2.456	2.715	1.963	2.558	4.921	5.638	1.665	0.037	0.029	0.036
Nitrite, (NO2-)	2.063	1.635	1.257	1.063	2.185	2.369	1.411	0.784	2.103	1.085	1.359	1.871
Nitrate, (NO_3^-)	0.536	0.783	0.158	0.187	0.963	1.041	0.325	0.156	0.741	0.093	0.102	0.089
Cations (ppm)												
Calcium, (Ca^{2+})	99.56	96.73	113.01	107.71	104.68	99.95	99.28	83.75	103.33	95.58	112.80	107.77
Manganese, (Mn2+)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Ammonium, (NH4+)	0.11	0.24	0.28	0.27	0.26	0.25	0.25	2.39	0.41	0.10	0.12	0.12
Magnesium,($Mg2^+$)	103.11	114.00	133.19	126.95	123.38	117.80	117.01	98.71	121.78	99.34	117.23	111.62
Potassium, (K^+)	252.45	245.27	286.56	273.13	265.45	253.44	251.74	248.27	306.29	119.48	141.00	273.28
Sodium, (Na^{2+})	986.32	958.28	1119.62	1067.12	1037.11	990.20	983.55	829.75	1023.66	946.94	1117.52	1067.70

Table 6: Mean result for heavy metals of surface water in the various sampling locations during the dry season

Heavy metals (mg/l)	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW CTRL 1	SW CTRL 2	SW CTRL 3
Iron, (Fe)	0.452	0.269	0.314	0.285	0.471	1.362	1.427	2.053	1.423	0.114	0.209	0.237
Zinc, (Zn)	8.05	0.15	0.17	0.25	0.17	0.15	6.07	5.26	0.19	0.08	0.06	0.06
Chromium, (Cr)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead, (Pb)	0.009	0.017	0.020	0.003	0.010	<0.002	<0.002	<0.002	0.003	<0.002	<0.002	0.007
Cadmium, (Cd)	0.031	0.010	0.152	0.114	0.069	0.027	0.234	0.057	0.132	<0.002	0.013	0.027
Mercury, (Hg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

4. Discussion

Since the 1960s, crude oil has generated an estimate of US$600 billion to the Nigerian government. Despite this, majority of the Niger Deltas population lives in poverty with substandard social infrastructure and increasing levels of oil contamination of their natural resource. The poor oil spill management regime is clearly demonstrated by the oil spills in Bodo creek area and Ogoniland in the eastern Niger Delta, which occurred as a result of a 600mm diameter pipeline fault on august 28, 2008. The post-spill report indicated a significant increase in heavy metal concentration and TPH, which lasted till 8 years after. Currently, over 65% of Bodo creek features a network of brackish water creeks and mangrove swamps (Scheren, *et al.*, 2002) [15]. The impact of the presence of crude oil contamination is found to be more toxic to the marine life than the water itself.

In this study, the analysis of the physico-chemical parameters showed results considering the different conditions during the wet and dry season. The pH values were within normal ranges of 6.5-8.0 which appears favourable for a large variety of aquatic species as reported by KWW (2001) [7]. pH outside this range stresses the physiological systems of most organisms and can reduce reproduction. Low pH can also allow toxic elements and compounds to become mobile and available for uptake by aquatic plants and animals. Most times, cases of low pH are often recorded during rainy season caused by atmospheric deposition (acid rain). The turbidity, which influences the values of BOD and DO of all surface waters were low and optimum. Using the BOD values as an index of pollution, the water bodies may be described as moderately polluted. This implies that the concentrations of dissolved oxygen and biochemical oxygen demand were favorable to aquatic lives. Otherwise, high concentration of BOD and DO means that these locations have been densely polluted either by domestic or industrial waste or oil spills. Salinity, Total hardness, and alkalinity were relatively low for all locations as similar in a research by Mogborukor (2014) [10] were he examined the impact of oil exploration on water quality.

In Nigeria, the dominant types of crude oil (Sweet crude and bonny light) contain high concentrations of heavy metals, so rivers surrounding these oil-producing areas are likely to have some heavy metals present in them. In this study, surface water 1 (SW1) and Surface Water 8 (SW8) of Idama and Robertkiri Creek respectively had high concentrations of zinc during the dry season and optimal concentration of iron and cadmium. The presence of trace or heavy metals in the environment has the potential for bio-accumulation and bio-

concentration in aquatic organisms and food crops. Cadmium is considered a cumulative toxin due to the ability of the human body to excrete just 0.01% of the amount ingested daily (Genchi *et al*., 2020) [5]. Zinc as essential to life can be a threat in excess amount. Severe effects of heavy metal contamination include reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. Exposure to some metals, such as mercury and lead, may also cause development of autoimmunity, in which a person's immune system attacks its own cells.

Although result from this study indicated that PAH was relatively low however if persistent in the environment, PAH can have acute toxic effects. Some PAH are identified as carcinogens, mutagens or teratogens. Human exposure to PAH could cause nausea, vomiting with skin and eye irritation. The THC of the locations in this study was below detection limit during the dry season and minimal in the wet season except in (SW6) of the Idama creek which implies the presence of trace amount of crude oil in this river. The presence of oil in surface water prevents oxygen from dissolving in water leading to the death of fish, shellfish and other aquatic lives. Surface water contaminated with oil, when used for irrigation purposes, is toxic to plants. It stops photosynthesis, disrupts the food chain and wipes out large areas of vegetation as occurred in Ogoniland; when a spill happened close to the drainage basin, the force of the river and tides forced crude oil to move up into the areas of vegetation (Olof and Jonas, 2012) [11].

As a rough estimation, freshwater may be considered to have TDS of 1500 mg/l; brackish water, 5000 mg/l and saline water, above 5000 mg/l and seawater TDS values lie between 30,000 and 34,000 mg/L. The recommended maximum value for surface inland water bodies is 2,000 mg/l and for brackish/marine waters 5,000 mg/L (EGASPIN, 2002). In this study, during the dry season the concentration of electrical conductivity and TDS was relatively higher than the wet season were rains would have diluted the salt content; this in turn has an effect on the concentration of some metals (Holdway, 2002) [6].

The major impact of nutrients on freshwater bodies is that of enrichment or fertilization, which may lead to eutrophication (Rim-Rukeh *et al*, 2009) [12]. Excess nitrogen can cause over-production of plankton and as they die and decompose they use up the oxygen, which causes other oxygen-dependent organism to die. The recorded concentrations, however, suggest optimum conditions for survival of aquatic life (RPI, 1985) [13].

5. Conclusion

This study characterized surface water in three creeks: Rokertkiri; Idama; Jokka of oil producing areas in the Niger Delta. Some locations recorded high concentration of metals, TDS, electrical conductivity and traces of THC. It can therefore be established that the oil exploration and refining, as well as other industrial-related activities, could affect the quality of surface water around these regions. However, efforts by the government and oil industries that poses their oil mining fields around these areas should be channelled towards improving asset integrity management such as replacing faulty pipelines and flow lines, upgrade flow station, stop illegal bunkering, proper industrial waste management and mitigate the impact of crude oil spill.

6. References

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