ISSN No:-2456-2165

Physicochemical Characteristics Assessment of Surface water in Okrika Local Government Area, Rivers State, Nigeria

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Abstract:- Pollution of aquatic ecosystem poses a serious threat to aquatic organisms and gradually the entire ecosystem. The polluted water often makes its way into the water tables and water systems, which means it is in the drinking water we access. The physiochemical characteristics of surface water in Okrika LGA. Rivers State, Nigeria were assessed during the dry season (February) and wet season (July, November), 2020. Water samples were obtained randomly from six surface waters in different communities in Okrika, namely, Ogan-Ama, Kalio-Ama, George-Ama, Edeme-biri, Okari-Ama, Isaka Town and analyzed according to standard international methods to determine the physicochemical parameters of collected samples. Parameters analyzed include among others; pH, EC, TDS, DO, BOD, TPH, PAH, Salinity and heavy metals. The Surface waters contained high Electrical Conductivity values which ranged from 30400us/cm to 65400us/cm with highest during the dry season. In comparing values of Total Dissolved Solids (TDS)of 18645mg/l to 50200mg/l with World Health Organization (WHO) limits, these values are above WHO limits of 600mg/l. This is not acceptable due to disruption of fish spawning and rearing in the marine environment. Salinity value of 15840mg/l was recorded in Isaka which is higher than WHO's limit of 200mg/l and can cause acute and chronic effects on aquatic organisms. Most samples recorded low DO, of less than 6mg/l(WHO/National Environmental Standards Regulations Enforcement Agency -NESREA), High BOD above WHO limit of 0.002mg/l but within NESREA limit of 3.0mg/l. There were traces of TPH, PAHs, also, contamination with Cadmium, Lead and Zinc metals. These can cause histopathological alterations in tissues of aquatic organisms and threatens survival of fishes. This calls for proper management of the marine environment by appropriate authorities in order to safe guard the ecosystem and human lives.

Keywords: *- Contaminant concentration, Assessment, Aquatic degradation, Endangered species, Okrika.*

I. INTRODUCTION

Human activities have noticeably changed the water quality of rivers in the past decades (USGS, 2021). It is of note that water, once contaminated, is very difficult, costly and almost impossible to treat. Still, today, 80 percent of global wastes containing everything from human waste to highly toxic industrial discharges are released into the water bodies (UN, 2019).

Measurable residues of persistent organics have been reported from fish and aquatic mammals from all corners of the earth. Also, heavy metals have been widespread and has caused human health problems due to bioaccumulation of metals by fishes and shellfish used as human food resources. The inshore estuarine ecosystem is another area of particular concern with the effects of toxic substances on aquatic life. The estuary serves a vital function in the life history of most commercially important shellfish and many fish species (AFS,2020)

A number of studies have been conducted all over the world to assess the physiochemical characteristics of surface water (Mottalib et al., 2016; Hague et al., 2019 and Tripathi et al., 2016.) In Nigeria today, studies indicate that majority of the water bodies are polluted. The pollution of the aquatic ecosystem in Nigeria is fast increasing in scope and magnitude (Ali et al., 2005). This is as a result of rapid population, industrialization and non-enforcement of existing environmental laws. However, Edosen (2006) observed that the uncontrolled release of these wastes effluent into the water bodies has negatively affected both water quality and aquatic life.

In Okrika, studies have shown that refinery effluent discharged in the Okrika arm of the Bonny River estuary resulted in the presence of high concentrations of pollutant in the water and sediment (Otokunefor and Obiukwe, 2005). More so, an extremely adverse impact on the physiochemical and bacteriological water quality characteristics of Okrika creek was as a result of the discharge of poor quality effluent from the fertilizer company (Obire, et al., 2008). Investigations also revealed that various pollutants are released into the water bodies surrounding Okrika communities which has affected the littoral zone and shallow waters along the shore and the

ISSN No:-2456-2165

livelihood of the people of the area (John and Chimka, 2017).

Though the study area had developed as a result of the siting of the refinery, more industries which has caused the influx of people seeking employment and the activities of these companies had caused serious water pollution in the area. These industries discharge their wastes directly into the water bodies, adversely affecting the livelihood of the people of the area. This has over the years affected the main occupation of the people which is fishing. The people had reported that fish and shellfish were scarce in nearby creeks, thereby forcing them to move further towards the ocean. Also, there were reports of fishes having pungent smell and bitter taste which make them sometimes unmarketable and difficult to eat. These had few years ago led to agitations by youths and women and subsequently resulted to finding new source of income through illegal crude oil bunkering.

Meanwhile, the problem of mismanagement of solid house-hold waste and open defecation into the water bodies is another area that deserves the attention of the local government authority. New techniques on how to manage these wastes are available. It is left for the government to brace up and take up the responsibility to save the health of the people and the environment.

The main objective of this study is to assess the physicochemical properties of surface water in Okrika Local Government Area, Southern Nigeria. Though the refinery has been shut down for maintenance for two years, this study will provide benchmark information on the extent of pollution brought about by the industries, illegal bunkering/ *kpofire* activities, transportation of oil and gas products and direct sewage in the water bodies of the study area.

II. MATERIALS AND METHODS

2.1 Study Area

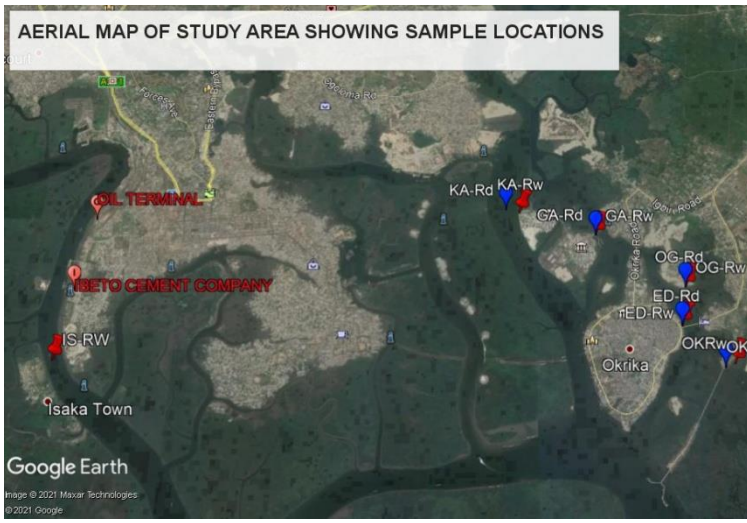

Fig. 1 Aerial map of study area

The study was conducted in Ogan-Ama,Kalio-Ama,Okari-Ama,George-Ama, Edeme-biri (Okrika Island) and Isaka Town all in Okrika Local Government Area, Rivers State, Nigeria.

Okrika surface water is an arm of the Bonny River estuary, surrounded by numerous creeks and canals, one of which is the Ekerekana creek, effluent discharge point of the Port Harcourt Refinery Company and its subsidiaries. Also, the Okochiri creek effluent discharge point of former National Fertiliser Company of Nigeria (NAFCON), now taken over by Notore Fertilizer Company. The Okrika Jetty, loading and unloading point of petroleum and gas products situated at Okari-Ama is a major area of serious pollution. Other similar industries have been operational in the area over the years due to the establishment of the refinery.

2.1 Sampling Locations and Sampling Collection

Table 1 Surface Water (Dry Season)

S/No.	LOCATION CODES	LATITUDE	LONGITUDE	Town
1.	OG-Rd	4°44'57.14"N	7° 5'29.43"E	Ogan-Ama
2.	KA-Rd	4°45'42.57"N	7° 3'57.51"E	Kalio-Ama
3.	GA-Rd	4°45'26.98"N	7° 4'44.35"E	Geoge-Ama
4.	ED-Rd	4°44'36.33"N	7° 5'26.35"E	Edeme-biri
5.	OK-Rd	4°44'14.27"N	7° 5'46.53"E	Okari-Ama

Table 2 Surface Water (Wet Season)

S/No.	LOCATION CODES	LATITUDE	LONGITUDE	Town
1.	OG-Rw	4°44'57.14"N	7° 5'29.43"E	Ogan-Ama
2.	KA-Rw	4°45'40.72"N	7° 4'4.52"E	Kalio-Ama
3.	GA-Rw	4°45'26.98"N	7° 4'44.35"E	Geoge-Ama
4.	ED-Rw	4°44'37.10"N	7° 5'26.15"E	Edeme-biri
5.	OK-Rw	4°44'16.42"N	7° 5'51.42"E	Okari-Ama
6.	IS-Rw	4°44'28.48"N	7° 0'8.70"E	Isaka Town

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All samples were collected during the dry and wet seasons. The water samples for physicochemical analysis were collected randomly from river banks/mid-river in different communities in Okrika. Samples were collected with clean bottles, rinsed several times and dried. Sample bottles were rinsed several times at the point of collection. Caution was taken not to keep any air bubbles inside the bottles. Samples were transported in ice packed coolers for analysis.

Physicochemical analysis

The water samples were analyzed for physical and chemical parameters using standard analytical methods.

Statistical analysis

The data obtained from the samples were analyzed using the software Microsoft Excel 2010. Tables and charts were used for the presentation of the result

III. RESULTS AND DISCUSSION

pH

pH values for surface water ranged from 6.0 to 7.8 with a mean value of 7.18 . KA-R recorded the highest pH value of 7.8 while GA-R recorded the lowest pH of 6.0. For wet season, pH values ranged from 6.47 to 7.15 with a mean value of 6.79.

Water Temperature

Water temperature values for surface water samples in dry season ranged from 30°Cto 31°C with the highest temperature value of 31°C recorded at OG-R.

For wet season, temperature values for surface water ranged from 26.4°C to 28.7°c with a mean value of 27.2°C. GA-R recorded the lowest value of 26.4°C while IS - R recorded the highest temperature value of 28.7°C.

Electrical Conductivity

Electrical Conductivity values for surface water samples in dry season ranged from 30400 µs/cm to 65 400 µS/cm with a mean value of 54880 µS/cm. GA-R had the highest conductivity value of 65 400 µS/cm and the lowest conductivity value of 30 400 recorded in OK-R.

For wet season, electrical conductivity values for surface water ranged from 33900 µS/cmto 45440 µS/cm with a mean value of 38923 µS/cm. The highest conductivity value of 45440 µS/cm was recorded at IS.R while the lowest conductivity value of 33900 µs/cm was recorded at KA-R .

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Table 3: Water Sample Results for Surface Water of Okrika LGA Rivers State (Dry Season) Physicochemical Properties

S/n	PARAMETERS	Unit	OG-R	ED-R	OK-R	GA-R	KA-R	Mean	Std.	Min	Max	WHO(2017)	NESREA(2011)
1	pH		7.2	7.6	7.3	6.0	7.8	7.18	0.70	6.0	7.8	6.5 – 8.5	6.5 – 8.5
2	Temperature	˚C	31	30	30	30	30	30.2	0.45	30	31		
3	Electrical Conductivity	us/cm	59700	62800	30400	65400	56100	54880	14119.03	30400	65400	-	
4	Total Dissolved Solids(TDS)	mg/l	49100	48100	50200	39000	42700	45820	4779.85	42700	50200	600	
5	Salinity	mg/l	2	15	9	32	9	13.4	11.37	2	32	200	
6	Turbidity	NTU	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	5	
7	Chlorine	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	5	
8	Bromine	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.05	
9	Dissolved Oxygen (DO)	mg/l	1.6	1.6	1.7	1.2	1.6	1.54	0.17	1.2	1.7	6	6
10	Biochemical Oxygen Demand (BOD)	mg/l	0.8	1.0	0.4	0.2	0.5	0.58	0.32	0.2	1.0	0.002	3.0
11	Nitrate	mg/l	0.338	0.967	1.338	0.775	0.251	0.73	0.45	0.251	1.338	50	9.1
12	Phosphate	mg/l	0.196	0.581	0.173	0.334	0.063	0.27	0.20	0.063	0.581	0.5	3.5
13	Total Petroleum Hydrocarbon	mg/l	ND	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01		
14	Polycyclic Aromatic Hydrocarbon (PAH)	mg/l	ND	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01		

ND: Not Determined

Table 4: Water Sample Results for Surface Water of Okrika LGA Rivers State (Wet Season) Physicochemical Properties

S/N	PARAMETERS	Unit	OG-R	ED-R	OK-R	GA-R	KA-R	IS-RW	Mean	Std.	Min	Max	WHO(2017)	NESREA (2011)
1	pH		6.47	6.7	6.77	6.47	7.04	7.15	6.8	0.24	6.47	7.15	6.5 – 8.5	6.5 – 8.5
2	Temperature	˚C	27.1	27.7	26.7	26.4	27.1	28.7	27.3	0.82	26.7	28.7		
3	Electrical Conductivity	us/cm	34800	40000	34700	44700	33900	45440	40423.33	5105.85	33900	45440	-	
4	Total Dissolved Solids(TDS)	mg/l	19140	22000	19085	24585	18645	24990	21407.5	2879.20	18645	24990	600	
5	Salinity	mg/l	2.332	2.68	2.325	2.995	2.271	15840	2642.10	6465.62	2.271	15840	200	
6	Turbidity	NTU	0.226	0.400	0.29	0.137	0.28	1	0.39	0.31	0.137	1	5	
7	Chlorine	mg/l	0.01	0.01	0.01	0.01	0.01	4.798	1.02	1.85	0.01	4.798	5	
8	Bromine	mg/l	0.01	0.01	0.01	0.01	0.01	ND	0.01	0.01	0.01	0.01	0.05	
9	Dissolved Oxygen (DO)	mg/l	0.5	1.2	1.1	0.5	0.7	8.3	1.39	3.38	0.5	8.3	6	6
10	Biochemical Oxygen Demand (BOD)	mg/l	0.4	1.1	0.9	0.3	0.5	3.17	1.20	1.01	0.3	3.17	0.002	3.0
11	Nitrate	mg/l	3.426	4.216	4.121	4.958	4.461	2.4	3.93	0.78	2.4	4.958	50	9.1
12	Phosphate	mg/l	0.5	1.189	0.248	0.125	0.616	1.56	0.71	1.20	0.125	1.56	0.5	3.5

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13	Total Petroleum Hydrocarbon	mg/l	ND	0.22	0.95	0.73	ND	4.64	1.23	1.71	0.22	4.64		
14	Polycyclic Aromatic Hydrocarbon (PAH)	mg/l	ND	0.001	0.003	0.003	ND	0.24	0.06	0.12	0.001	0.24		

ND: Not Determined

Table 5: Heavy Metals Results for Surface Water of Okrika (Dry Season)

S/N	PARAMETERS	OG-R	ED-R	OK-R	GA-R	KA-R	Mean	Std.	Min	Max	WHO (2017)	NESREA (2011)
1	Cadmium (mg/l)	0.055	0.127	0.074	0.001	0.001	0.0516	0.05	0.001	0.127	0.003	0.005
2	Lead (mg/l)	0.002	0.002	0.002	0.002	0.002	0.002	0.00	0.002	0.002	0.003	0.01
3	Zinc (mg/l)	0.005	0.005	0.005	0.005	0.005	0.005	0.00	0.005	0.005	3.0	0.01

Table 6: Heavy Metals Results for Surface Water of Okrika (Wet Season)

S/N	PARAMETERS	OG-R	ED-R	OK-R	GA-R	KA-R	IS-RW	Mean	Std.	Min	Max	WHO (2017)	NESREA
1	Cadmium (mg/l)	0.044	0.079	0.063	0.052	0.049	0.05	0.056	0.01	0.044	0.079	0.003	0.005
2	Lead (mg/l)	0.001	0.206	0.117	0.001	0.001	0.001	0.055	0.09	0.001	0.206	0.003	0.01
3	Zinc (mg/l)	0.036	0.069	0.047	0.029	0.022	0.037	0.040	0.02	0.022	0.069	3.0	0.01

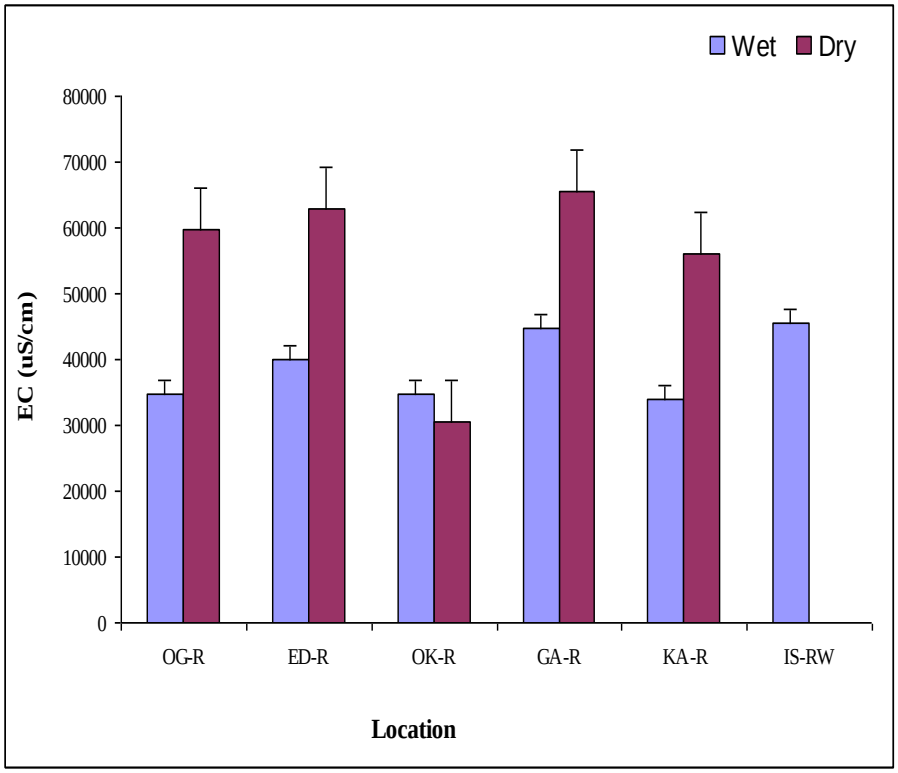

Fig. 2: Spatial Distribution of Electrical Conductivity in Surface Water at Okrika LGA

ISSN No:-2456-2165

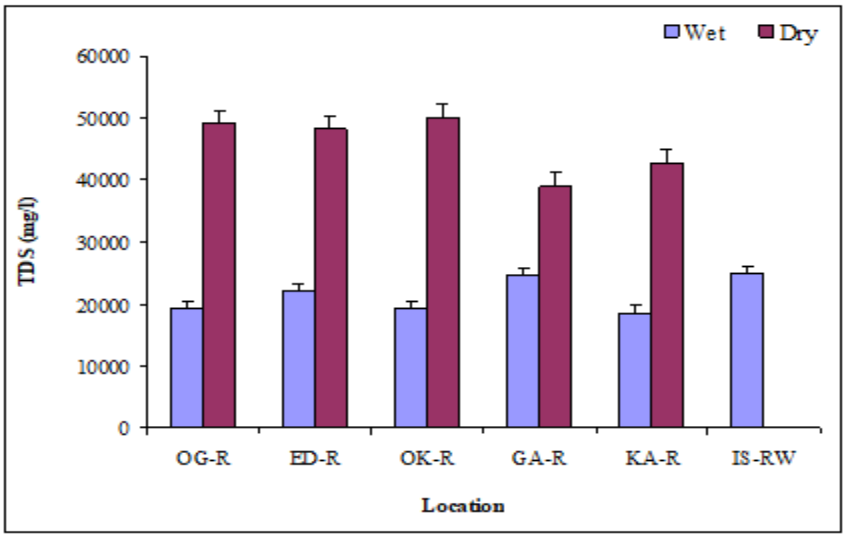

Fig. 3: Spatial Distribution of Total Dissolved Solids in Surface Water at Okrika LGA

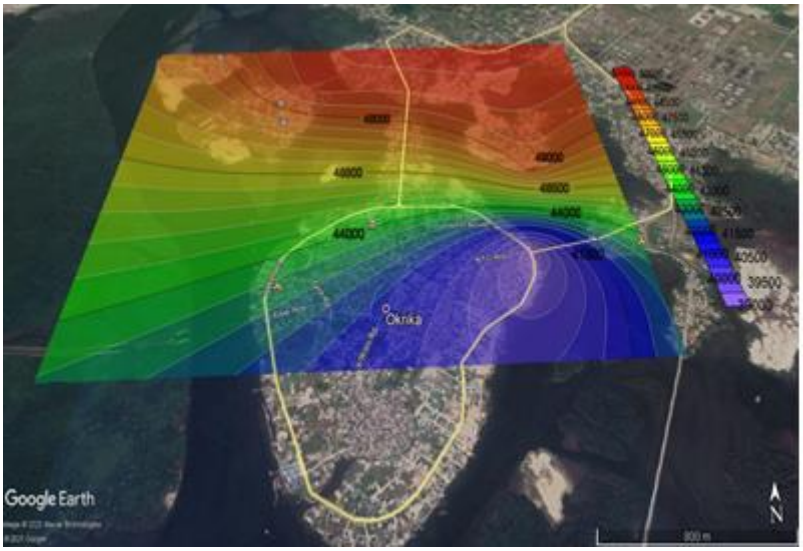

Fig. 4: Distribution of Concentration of Total Dissolved Solids in Surface Water at Okrika LGA

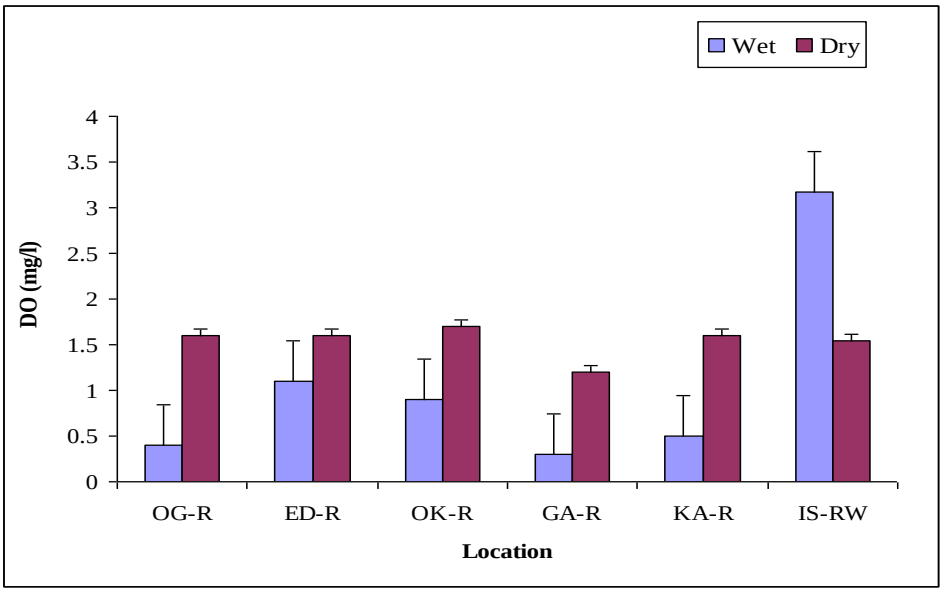

Fig. 5: Spatial Distribution of Dissolved Oxygen in Surface Water at Okrika LGA

Total Dissolved Solids (TDS)

The values of Total Dissolved Solids (TDS) in dry season ranged from 39000mg/l to 654000mg/l with a mean value of 458.20mg/l. For wet season, the values of Total Dissolved Solids (TDS) ranged from 18645 mg/l - 24990mg/l with a mean value of 21399.5mg/l .

Salinity

Surface Water

Salinity values during the dry season ranged from 2.0 to 32.0 mg/L with a mean value of 13.4mg/l. For the wet season, salinity values ranged from 2.271mg/l to 14840.0mg/l. The highest value of 15840mg/l was recorded in IS.W while the lowest value of 2.271mg/l was recorded in KA-R .

Turbidity

Turbidity values for surface water samples in dry season recorded 0.01NTU respectively for all the samples. For wet season, Turbidity values ranged from 0.137 to 1.0 NTU.

Chlorine

Chlorine values in surface water samples during dry season recorded 0.01mg/l in all the surface water samples. In wet season, chlorine values ranged from 0.01mg/l to 9.567mg/l with a mean value of 1.607mg/l

Bromine

Bromine values for surface water samples in the dry and wet season recorded 0.01 mg/l respectively in all the samples.

DO

Dissolved Oxygen values for surface water samples in dry season ranged from 1.2 to 1.7 mg/l with a mean value of 1.54 mg/l. For wet season, Dissolved Oxygen values ranged from 0.5mg/l to 8.3 mg/l with mean values at 2.05 mg/l. The highest value of 8.3mg/l was recorded in IS - R while the lowest value of 0.5mg/l was recorded in OG-R and GA - R respectively.

Biochemical Oxygen Demand

Biochemical Oxygen Demand values in dry season ranged from 0.2mg/l to 1.0mg/l with mean values of 0.58mg/l. For wet season, Biochemical Oxygen Demand values ranged from 0.3mg/l to 3.17mg/l with mean values of 1.061mg/l. The highest value of 3.17mg/l was recorded in IS-R.

Nitrate

Nitrate values in dry season ranged from 0.251mg/l to 1.338mg/l with a mean value of 0.733mg/l. For wet season, Nitrate values ranged from 2.4 mg/l to 4.958mg/l with a mean value of 3.93 mg/l. The lowest concentration of 2.4 mg/l was recorded in IS - R while the highest concentration of 4.958 mg/l was recorded in GA-R.

Phosphate

Phosphate values in dry season ranged from 0.063mg/l to 0.581mg/l with a mean values of.269mg/l. For wet season, phosphate values ranged from 0.125mg/l to 1.56 mg/l with a mean value of 0.706mg/l.

Total Petroleum Hydrocarbon

Total Petroleum Hydrocarbon value of 0.01mg/l was recorded in all surface water samples in the dry season except OG-R. In wet season, Total Petroleum Hydrocarbon value of 0.22mg/l, 0.95mg/l, 0.73mg/l and 4.64mg/l was recorded in ED-R, OK-R, GA-R, and IS-R respectively.

PAH

PAH value of 0.01mg/l in dry season in ED-R, OK-R, GA-R and KA-R was recorded respectively. For wet season, PAH value of 0.001mg/l, 0.003mg/l, 0.003mg/l and 024mg/l in ED-R, OK-R, GA-R and IS-R respectively

Heavy Metal Parameters

Cadmium

Cadmium in dry season ranged from 0.001mg/l to 0.127mg/l with a mean value of 0.0516mg/l. The highest concentration of 0.127mg/l was recorded in ED-R (Edeme-biri) while the lowest concentration of 0.001mg/l was recorded in GA-R and KA-R respectively.

For wet season, Cadmium values ranged from 0.044mg/l to 0.056mg/l with a mean value of 0.056mg/l.

Lead

Lead values in dry season for surface water recorded 0.002mg/l.

For wet season, lead values ranged from 0.001mg/l to 0.206mg/l with a mean value of 0.054mg/l. The highest concentration of 0.206mg/l was recorded in ED-R (Edeme-biri)

Zinc

Zinc values in dry season was 0.005mg/l in all samples.

For wet season, zinc values ranged from 0.022mg/l to 0.069mg/l with a mean value of 0.04mg/l. The highest concentration of 0.069 was recorded in ED-R (Edeme-biri), while the lowest concentration of 0.022mg/l was recorded in KA-R (Kalio).

IV. DISCUSSION

pH

Pollution can change a water's pH which in turn can harm animals and plants living in water. pH in water is important because if the pH of water is too high or low, the aquatic organisms living within it will die. pH range of 6.5 - 9.0, though some can live in water with pH levels outside this range.

The values for pH were maximum (7.8) at Kalio Ama and lowest (6.0) at George Ama for surface water samples during the dry and wet seasons respectively. These recorded values are within the guideline limit of 6.5- 8.5 except

ISSN No:-2456-2165

George Ama surface water which is below WHO and NESREA limit, this could be due to the acidic materials from the shipping repair company at the location.

As pH levels move away from the normal range for surface water it can stress aquatic animals and reduce hatching and survival rates.

From the recommended pH levels for aquatic life, salmon and crayfish will find it difficult to thrive in the surface waters sampled because these survive well in pH level of 8.0-9.0. Alberta guideline limit is 6.5-9.0. However, Ling et al.,(2017), recorded pH value of 4.93-8.06 during the wet season.

Temperature

The effect of temperature on living organisms can be critical. Steep temperature gradients can have harmful effect on fish (EPA Ireland, 2001). Also, the rate of chemical reactions increases at higher temperature. Warm water holds less dissolved oxygen than cool water and may not contain enough dissolved oxygen for the survival of the different species of aquatic life. According to Canadian guidelines for surface water, algal growth in surface water becomes noticeable at temperatures above 15°c

The recorded maximum temperature (T) values surface water in dry season was 31°c (Ogan Ama) while the lowest was 30°c. For the wet season, maximum temperature was 28.7 (IsakaTown) and the lowest was 26.4°C (George Ama). Guideline limit for surface water of 26°c to 28°c is ideal for health benefits, during swimming. Nienie and Pote` (2017) had Temperature values of river, 24.8°c(wet season) and 29.2°c(dry season)

Electrical Conductivity (us/cm).

In sea, Electrical Conductivity can indicate pollution of water body. This could be due to additional chloride, phosphate and nitrate ions from agricultural runoff, industrial discharges and sewage leakages. However, fresh and saltwater fish may need different levels of water to survive. Electrical Conductivity values of 65400us/cm (George Ama) was recorded as highest and 300400us/cm(Okari Ama) in both dry and wet season. The United States Environmental Protection Agency guideline limit range is between 50 to 1500us/cm. Studies indicate that water that support good mixed fisheries have a range between 150 and 500us/cm. Conductivity outside this could mean that the water is not suitable for certain species of fish. However, Electrical Conductivity (2712us/cm) was recorded, (Amoo, et.al, 2017). Silas et al., (2018) recorded a lower value of 56.2,us/cm. Anaero-Nweke et al (2016), also had value of 2877.66us/cm in Okrika.

Total Dissolved Solids (TDS)

The recorded Total Dissolved Solids were high. The highest recorded value (50.200mg/1)- Okari Ama river during dry season. Higher values of TDS was recorded during the dry season than the wet season with the highest value of 24900mg/1 at Isaka Town river. The TDS concentration in water is the total of all the substances, organic and inorganic dissolved in water (USGS, 2021), Silas et al., (2018) recorded a lower value of 47.7mg/l Anaero-Nweke et al., (2016) had value of 2058.00mg/l in Okrika.

Salinity

Small amounts of dissolved salts in natural waters are vital for the life of aquatic plants and animals, higher concentrations of salinity change the way the water can be used. Increased salinity and flow in streams and wetlands can be a problem to vegetation, many plants tolerate higher salinities for short time but cannot survive long periods (Barrett, 2003). Salinity values in surface water samples were higher during dry season with the highest value of 32.0mg/1(George-Ama River) with also the lowest of 2.0mg/1 (Ogan-Ama River). With the recommended limit of less than 500 according to guideline limit by Western Australia Environment Protection Authority (2017), the salinity values are within limit. Jaya thunga et al., (2016), recorded salinity average range of 10.4ppn-28.4ppn. Anaero-Nweke et al., (2016) had 28.13mg/l in Okrika, which was a bit lower.

Turbidity

Turbidity values of all sampled surface water during the dry season recorded (0.01NTU) which is low but had a little higher values of 0.226, 0.400, 0.290, 0.137, 0.28 and 1.0 NTU respectively in the wet season.

This could be as a result of runoff after rainstorm, where particles are washed into the river. This could affect ecological productivity, recreational values and habitat quality, like negative effect on fish and other aquatic life. Particles from runoff can aid pollutants like metals and bacteria. Jaya thunga et al., (2016) Turbidity average was 27.4NTU, which is higher.

Chlorine

Chlorine values for all sampled surface water during the dry season recorded 0.0mg/1 while in the wet season, there was increased values of chlorine. This could be as a result of runoff of waste water from industries, oil well wastes and effluent waste water treatment plants (Kumar and Puri 2012). Chloride values of 16.4mgll-80.1mgll were recorded by Agwo and Ogu, (2014).

Bromine

Bromine values for all sampled surface water recorded 0.01mg/1 during the dry and wet season. However, the guideline value for Bromide in seawater is 65mgi/ to 80mg/l (WHO, 2017).

Dissolved Oxygen (DO)

Dissolved oxygen values for sampled surface water recorded 1.2mg/1 to 1.7mg/l during the dry season. For wet season, samples recorded 0.5mg/l to 8.3mg/l. Isaka Town recorded the highest (8.3mg/1). According to guideline limits of 6mg/1 (WHO,2017) for surface waters by standards for Japan (2015), NESREA (6mg/l) and Alberta (6.5mg/l), only Isaka Town River met the limit while the other rivers were not within the range. From Oram(2020), warm water fish need (D.O-5.0mg/l) cold water fish (D.O-

6.0mg/l), spawning season (D.O-7.0mg/l) and Estuarine biota (D.O-5.0mg/l). The result of excess organic matter can result in depletion of oxygen from an aquatic system through chemical or biological oxygen consumption or demand. Where DO concentration is low, algal blooms can occur under such condition. However, Amoo et al., (2017) had high D.O. value of 45.5mg/l, Agwo and Ogu, (2014) recorded DO values 2.4-3.8mg/l.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand values for all sampled surface water recorded during the dry and wet seasons were all below 2.0mg/1, except Isaka Town river that recorded 3.17mg/1. For WHO (0.002mg/l), all sampled water had high BOD and above it's limit. With the recommended limit of 3mg/l (NESREA) and 2-3mg/1 of Japan Standard, only Isaka Town river was more than the limit (3.17mg/1) while the other rivers, during the dry season were within the standard of 1-2mg/1(clean water) and during the wet season, Edeme-biri and Okari river were within 1-2mg/1(Oram 2020). BOD directly affects the amount of oxygen in rivers. It generally represent how much oxygen needed to break down organic matter in waters by bacteria and other microorganisms if out of limit is moving towards pollution. However, Anacro-Nweke et al., (2016) had higher values of 66mg/l and 81.33mg/l. Agwo and Ogu, (2014) recorded 20mg/l-81mg/l.

Nitrates

Contamination of water by nitrates is a problem. This could be from sewage system, solid waste, waste water treatment effluent and fertilizers.

Nitrate values of sampled water recorded o.251mg/l to 1.338mg/l in dry season and 2.4mg/l to 4.958mg/l in wet season which were within limit of 9.1mg/l(NESREA) and 50mg/l (WHO), but in wet season, OG-R, ED-R, OK-R, GA-R and KA-R were not within the Alberta guidelines limit of 2.0mg/l. However, Agwo and Ogu (2014) had values of 55.0mg/l to 6.1mg/l.

Phosphate (mg/1)

Continuous phosphate loading in surface water can lead to build up in such waters, accelerate the aging process of the surface water, also lead to nutrient in balance and then reduce the stability of the ecosystem. Phosphates may spread over large distances in surface waters, causing algae and duckweed, these use large amounts of oxygen and prevent sunlight from entering the water, thereby making it fairly inhabitable for other organisms. The phosphate values were lowest during the dry season with the highest value of 0.581mg/1 (Edeme-biri river). There were increase in the phosphate values in the wet season with the highest value of 1.56mg/1(Isaka river). This could be due to anthropogenic activities, which are major sources of phosphate and nitrate pollution in aquatic ecosystems in rivers.

This cause algal blooms, hypoxia, fish deaths, loss of bio diversity aquatic plant beds and coral reefs, including other problems.

Agwo and Ogu, (2014) also had phosphate values of 1.06mg/l to 2.10mg/l

Total Petroleum Hydrocarbon (TPH)

Hydrocarbons include large class of hydrogen and carbon containing compounds. These include petroleum and natural gas deposits, also consension of organic molecules in the environment through chemical and biological processes (Neff, 2003)

Total Petroleum hydrocarbon (TPH) values during the dry season recorded 0.01mg/l while during the wet season, TPH values for sampled surface water recorded 0.22mg/1 (Edeme-biri) to 4.64mg/1 (IsakaTown).

PAH

PAHs enter the environment from a variety of combustion processes. It has been detected in fish from contaminated waters (WHO, 2017). Surface water recommended limit for EPA, Ireland is 0.002mg/l. PAHs are environmental contaminants that pose significant risk to health of fish. PAHs have toxic mutagenic and /or carcinogenic functions. They are highly lipid soluble which lead to a fast absorption by gastrointestinal tract of marine mammals.

Zinc (Zn)

Zinc in surface waters, the toxic action is more important and very much lower limits have been imposed by World Health Organization (WHO, 2017). The recommended limit is 3.0mg/l. However, a lower limit of 0.01mg/l was imposed by NESREA. The toxicity of Zinc to aquatic life is independent on the hardness of the water. The recommended limit for Zinc for surface water by Japan Environmental Authority is 0.03mg/l in order to conserve aquatic life. For EPA, Zinc limit for surface water is 3.0mg/l. Zinc values of 0.005mg/l was recorded for all sampled waters during the dry season, while during the wet season, all sampled water values were within the allowable limit of 3.0mg/l of WHO but not within the limit for NESREA (0.01mg/l) and Japan waters to conserve aquatic life (0.03mg/l). Extreme discharge of Zinc can contaminate the surface water and subsurface environment and contribute to groundwater pollution. However, Agwo and Ogu (2014) recorded Zinc values of 0.02mg/l to 0.10mg/l.

Lead (Pb)

Lead is highly toxic and has extensive environmental damage with health problems worldwide. Surface waters and groundwaters can become polluted with lead through industrial wastewater runoff, mineral fertilizers, fall out of atmosphere dust, lead based paints, wastes from metals, chemicals and petrochemical industries (USEPA, 2021).

Lead is s cumulative toxicant that affects the body system and is particularly harmful to young children.

Lead values for sampled surface water during the dry season all recorded 0.002mg/l, During the wet season, lead values recorded was 0.001mg/l for Ogan, George, Kalio, and Isaka. However, Okari and Edeme-biri recorded 0.206mg/l

and 0.117mg/l respectively. This could be due to bunkering activities at Edemebiri. Okari is host to the Okrika Jetty where crude oil and other petroleum products are transported from the refinery into vessels. From the recommended limit of 0.01mg/l for NESREA and 0.05mg/l for surface water by the EPA, Ireland, Edeme-biri and Okari, are not within permissible standard.

Cadmium (Cd)

Cadmium is a toxic element, concentrates of this element is crucial to human health and the environment. High Toxicity of Cadmium in surface water poses a threat to the development of flora and fauna. Anthropogenic sources account for more than 90% of the total cadmium in surface water (Jared *et al.*, 2019).

Cadmium is easily absorbed and accumulated in tissues. Its main sources in our diet are fish and cereal products (Olmedi *et al.*, 2013). Cadmium exposure is associated to glucose metabolism disorders, breast and lung cancer, cerebral infarction and cardiac failure (Khan *et al.*, 2017).

Cadmium values of sampled surface water recorded highest values during the dry season. The highest value of 0.127mg/l was recorded at Edeme-biri. Permissible limit for Cadmium in surface waters according to NESREA and EPA, Ireland, is 0.005mg/l. All surface water samples were polluted with Cadmium metal during the dry and wet season. The aquatic wetland plants are capable of up taking higher concentration of Cadmium as compared with terrestrial land plants, and that is a problem (Singh *et al.*, 2017).

V. CONCLUSION

The results obtained from this study show that PH values for G. A - R in dry and wet seasons were below WHO and NESREA limits of 6.5. This could be as a result of pollution from the ship-yard situated in the study area. The levels of Electrical Conductivity and Total Dissolved Solids were higher that WHO limits. This could be as a result of industrial wastes. Salinity values were within limit except Isaka river. Which could be as a of industrial wastes. Turbidity, Chlorine and Bromine were within limits. However all DO values except Isaka were low and not within limits which can suffocate fishes. BOD values were higher than WHO limits but within NESREA limits . Nitrates and Phosphate were within limits. However,Nitrates during the wet season was not within Alberta guideline limits of 3.0mgIL. This can stunt the growth of fishes and comprise their immune systems . There were traces of TPH,PAHs and heavy metals. Some of the levels were more than the limits set by WHO and NESREA.

RECOMMENDATION

The results obtained from the study have indicated that most of the parameters assessed did not meet the recommended standards by regulatory bodies. It is therefore recommended that there should be frequent monitoring and surveillance of the waters bodies. Further research into the effects of toxic substances on aquatic life in the area should be top priority in order to safeguard human lives. Also, enforcement of existing environmental laws should be carried out on the industries and households in the area.

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