Tidal Influence in the Distribution of Discharged Effluents from Port Harcourt Refinery Company in Okrika Creek, Rivers State, Nigeria.

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ABSTRACT: Background: Okrika Creek in Rivers State Nigeria has over the years served as the recipient water body for the discharge of refinery effluents. A study was conducted on the creek and its adjoining river to determine the role of tide in the distribution of discharged effluents from Port Harcourt Refinery Company. Methods: Standard methods were used to determine the physico-chemical parameters of the discharged effluents and the receiving water bodies at four selected sites; Refinery effluent (S1), Point of Discharge (S2), Upstream of the river (S3), and Downstream river (S4). Results: The results obtained indicated that the physicochemical parameters of the refinery effluent and the receiving water bodies varied significantly ($P<0.05$). Parameters such as turbidity, Biochemical Oxygen Demand, Chemical Oxygen Demand, phosphate, ammonia, phenol, lead, cyanide, and nickel were all above maximum permissible limit as specified by Environmental Standards and Guidance for the Petroleum Industries in Nigeria (EGASPIN) in all the sampled stations. Also, total suspended solids, total dissolved solids, and total chromium were above permissible limit in the river water than in the refinery effluent. The other parameters such as pH, temperature, sulphide, vanadium, copper and zinc were all below permissible limit in all the stations. However, the concentration of heavy metals analysed in sediment samples in the water bodies were higher than those of the surface water samples, Conclusion: This study established that the refinery effluent discharged had negative impact on the creek and its adjoining river water qualities. The absence of significant differences in the concentrations of the physico-chemical parameters within the sampled water bodies could be attributed to the tidal water movements which disperses the pollutants along the sampled stations. Hence, surface water extracted from these rivers for domestic and agricultural purposes should be discouraged without some form of treatment.

Keywords: Okrika Creek, Refinery Effluents, Tidal Influence, Distribution, Port Harcourt Refinery

1.1 Introduction

Advancement in industrial technology / activity as a means of addressing human social needs has always been one of the major reasons for the global environmental problems. The obvious reduction of water quality as a process of neutralization of pollutants and run offs make most creeks a choice for industrial operations [12]. However, indiscriminate discharge of untreated hazardous industrial effluents, (run off and waste water); domestic / organic wastes, coupled with the attitude of humans in throwing solid wastes into running water bodies have largely contributed to marine and estuarine pollution [10]. The petrochemical industries and oil refining activities generate different kinds of wastes, which are released to the environment in the form of gaseous emissions, particulates, sludge, and liquid effluent, all these pose serious threat to marine ecosystems and human health [8,15], especially close to petroleum handling facilities such as harbours and refineries. The industrial emission of obnoxious gases into the atmosphere also constitute environmental hazard as they also find their way into the water body as the final recipient of waste [15].

Some specific industrial activities within the marine and estuarine environments include Oil and Gas Resources Development, Manufacturing Industrial Activities, operations of different treatment and process plants; marine transport and other related activities; all these introduce pollutants into the water [13]. The ability of the specific industrial operators to treat their waste and manage / reduce the hazardous risk to a tolerable level before discharge has always been the peculiar challenge facing the operations [15]. This study considers the role of tide in the distribution of discharged effluent from Port Harcourt Refinery Company (PHRC) into Okrika Creek in Nigeria. The level of chemical contaminants in the Refinery treated effluent discharged into the creek has constantly been the source of controversy. This perceived pollution effect even when there were no discharges are seen to be generating constant conflict. It is the main objective of this study to consider the role of tide in the dilution and distribution of the pollutants and also to establish the expected level of impact of the pollutants on the physico-chemical properties of the water.

2.0 MATERIALS AND METHODS

2.1 Description of the study area

The sampling stations were established along Okrika Creek in Okrika Local Government Area, of Rivers State, Nigeria. The creek is brackish as it is tidal and also evidenced in the presence of mangrove vegetation, which consists mostly of *Rhizophora racemosa* that lined the shores of these stations and *Avicennia nitida* at the inner shoreline. Anthropogenic activities along the creek include sand mining or dredging, fishing, navigation, washing, bathing and other recreational activities. A major industrial outfit which is situated in station 2 (Ekerikana) is the Port Harcourt Refinery Company (PHRC) [a subsidiary of the Nigerian National Petroleum Corporation (NNPC)], which generates several volumes of effluents that are channelled into the creek via a drainage system.

Four (4) main sampling stations were selected and established for this study as indicated in figure 1 and are described below:

1. The refinery effluent area: In this location 3 sampling points were taken namely;
   - Untreated effluent (E_1)
   - Treated effluent from treatment plant (E_2)
   - Observation Pond waste water (OP): The combination of both untreated and treated effluent
2. Ekerekana Creek which served as the Point of Discharge into the river (S.2)
3. Okochiri Creek as site 3 (S.3), that represented the Upstream of the River
4. Okari-ama Creek as site 4 (S.4): Representing the Downstream of the River

2.2 Sample Collection and Method

Samples from each of the four (4) stations were collected on a monthly basis for nine (9) months. Surface water samples were collected at each of the stations at about 20cm surface level with a 2 litre 'Hydrobios' sampling bottle by lowering and allowing water to overflow before it was withdrawn and transferred to a clean 2 litre water storage container (for physicochemical parameter analysis), 250ml capacity borosilicate glass bottles (for oil and grease determination) and samples for heavy metal analysis were preserved by acidification with 2 drops of concentrated nitric acid. The collected samples were stored in an ice box at 4^oC before they were taken to the laboratory within six (6) hours for analysis. All analyses were completed within two weeks (14 days) of sampling and analytical methods followed standard procedures for analyses of water and waste water [2].

3.0 RESULTS and DISCUSSION

3.1 Physical composition and concentration of refinery effluent and river water

The results of the mean concentrations of analysed physical parameters of refinery effluents and surface water samples are presented in Table 1.

Figure 1: Map Showing Nigeria, Niger Delta, Rivers State and Okrika the Study Area

Table 1: Mean concentration of Physical parameters and EGASPIN compliance limit

Parameters	Untreated	Treated	Observation	Point of	Upstream	Downstream	EGASPIN

	Effluent (E1)	Effluent (E2)	Pond (OP)	discharge (POD) station 2	river station 3	river (station 4)	Compliance limit
Ph	7.27 ±0.15	7.13 ±0.11	6.24 ±1.31	6.91 ±0.18	6.83 ±0.32	7.14 3±0.25	6.5-8.5
Temp ^{o}C	25.00 ±2.04	25.36 ±1.87	25.43 ±1.66	25.66 ±1.56	25.26 ±2.01	26.70 ±3.20	30
Cond (µS/cm)	2403.33 ± 366.10	341.00 ±21.51	986.00 ±204.97	1145.33 ±19.29	2563.00 ±427.07	2877.66 ±177.45	1400
TDS(mg/l)	760.00 ± 60.00	181.00 ±51.50	338.66 ±29.48	250.33 ±87.29	2256.33 ±264.87	2058.00 ±320.95	<2000
TSS(mg/l)	36.33 ±8.08	28.33 ±8.14	20.33 ±9.29	207.33 ±170.73	99.66 ±6.42	52.00 ±8.88	30
Turbidity (NTU)	22.89 ±5.29	62.50 ±3.96	48.26 ±4.10	45.14 ±6.85	24.85 ±6.19	19.83 ±8.46	5
Salinity (mg/l)	173.26 ±92.56	3.60 ±0.78	35.66 ±9.12	22.33 ±3.44	26.56 ±5.80	28.13 ±15.24	N/A
TOC(mg/l)	177.43 ±27.77	138.66 ±68.53	129.73 ±78.21	176.00 ±58.92	202.33 ±101.86	239.50 ±183.30	N/A

EGASPIN: Environmental Guidelines and Standards for Petroleum Industries in Nigeria (2002)

3.2 Chemical composition and concentration of the refinery effluent and river water

The results of analysed chemical parameters of the effluents and surface water from all the sampling stations are shown in Table 2.

Table 2: Mean concentration of chemical parameters and EGASPIN (2002) compliance limit

Parameter	Untreated effluent (E1)	Treated effluent (E2)	Observation pond (OP)	Point of Discharge (POD) STN 2	Upstream river STN 3	Downstream river STN 4	EGASPIN Compliance limit
Oil & grease (mg/l)	160.14±29.81	6.81±4.09	21.5±1.36	4.41±4.15	6.39±1.45	1.66±1.15	10
BOD(mg/l)	113.00±45.57	40.00±18.02	63.00±20.66	30.66±10.06	66.00±12.16	81.33±20.13	10
COD(mg/l)	183.50±51.10	65.00±24.36	106.03±16.31	83.56±6.44	102.33±31.10	93.83±23.25	40
HCO_3^- (mg/l)	166.00±24.020	40.26±6.100	117.10±41.983	105.86±27.630	143.86±22.948	135.70±64.89	N/A
PO_4^{3-}(mg/l)	2.20±1.10	1.25±0.42	3.68±0.98	1.29±0.28	0.32±0.12	0.21±0.17	0.2
SO_4^{2-}(mg/l)	3.75±1.11	8.07±1.88	7.64±2.16	5.67±2.03	134.09±57.08	351.33±88.75	250
NH_4^+(mg/l)	1.21±0.16	0.90±0.49	0.35±0.26	0.25±0.14	2.24±0.39	0.67±0.35	0.2
Total P (mg/l)	2.94±0.59	1.74±0.58	4.16±1.43	1.68±0.56	0.38±0.07	0.39±0.07	1
Cyanide (mg/l)	0.01±0.109	0.01±0.00	0.01±0.10	0.01±0.00	0.01±0.00	0.01±0.00	0.01
SO_3^-(mg/l)	0.01±0.005	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.01
Phenol (mg/l)	0.39±0.015	0.14±0.05	0.25±0.01	0.28±0.02	0.27±0.03	0.24±0.02	0.2
Pb(mg/l)	0.16±0.06	0.34±0.17	0.32±0.21	0.13±0.10	0.14±0.09	0.13±0.10	0.05

Zn(mg/l)	0.71±0.52	0.05±0.01	0.40±0.30	0.16±0.04	0.03±0.02	0.04±0.01	1.0
Cu(mg/l)	0.04±0.00	0.03±0.02	0.03±0.02	0.03±0.15	0.23±0.16	0.05±0.01	1.5
Cr (mg/l)	0.07±0.04	0.09±0.01	0.07±0.04	0.08±0.02	0.09±0.03	0.13±0.05	0.3
Ni/l)	0.07±0.05	0.11±0.01	0.10±0.00	0.23±0.051	0.38±0.07	0.43±0.15	0.05
V (mg/l)	0.13±0.10	0.17±0.05	0.17±0.05	0.13±0.10	0.14±0.04	0.17±0.05	0.33

3.3 Some physico-chemical profile of the Sediment

The levels of physico-chemical parameters of sediments from the sampled stations are shown in Table 3.

Table 3: Physico-chemical properties of the indicated sediment sampling points

Parameters	Point of Discharge (POD) (station 2)	Upstream (station 3)	Downstream (station 4)
pH	7.60	7.17	6.56
Temperature ^{o}C	28.9	28.3	28.6
Conductivity(µS/cm)	5140	7920	4670
Salinity (mg/l)	2.7	4.3	2.4
Sulphate(mg/kg)	95.7	30.3	185.5
Phosphate(mg/ kg)	<0.05	<0.05	<0.05
Phenol (mg/ kg)	BDL	BDL	BDL
Lead (mg/ kg)	<0.001	8.27	3.66
Zinc (mg/ kg)	53.27	11.59	23.02
Copper (mg/ kg)	2.35	2.46	0.87
Nickel (mg/ kg)	6.41	0.42	4.87
Chromium (mg/ kg)	<0.001	<0.001	<0.001
THC(mg/ kg)	2328.82	126.47	964.12

The tidal nature of the creek distributes industrial pollutants back and front thereby localizing pollution within the axis. The statistical analysis of the result using turkey's multiple comparison ($P<0.05$) indicated that the discharge of untreated effluent into the observation pond was the major cause of pollution in the creek though the treatment plant was not very efficient to reduce pollutants to appreciable levels.

4.1 Physical Parameters

Results from this study showed that pH values at all stations were all below the permissible limit as specified by EGASPIN except those of the Observation Pond effluent which had pH of 6.24±1.31. Turkey's multiple comparison at ($P<0.05$) showed that the mean values were not statistically significant. In effect, continuous discharge could result in acid deposition in the recipient water body.

The Temperature of all the sampling stations (Table 1) was within permissible limit as specified by EGASPIN. Turkeys multiple comparison at ($P<0.05$) showed that the temperature of all sampling stations were not significantly different from each other.

Total suspended solid levels (Table 1) were above the permissible limit at all stations except in the Treated effluent and Observation pond which might have been due to dilution by rain water. The higher levels recorded in the river water could also be due to frequent discharging of effluent into the water and its accumulation. Turkey's multiple comparison ($P<0.05$) revealed that mean values of refinery effluent and the river water were significantly different which could have been due to higher levels recorded in the river water. Conductivity values recorded at all sampling stations were above the permissible limit except at the Treated effluent, Observation pond effluent and POD surface water (Table 1). Statistically the mean values were significantly different from each other due to higher values recorded in the untreated effluent, Upstream and Downstream points. The significant increases in the conductivity of water Upstream and Downstream were indicative that pollutants might have entered the water which could adversely affect the survival of aquatic animals and increased level of other measured parameters.

Total Dissolved Solid levels measured inside the refinery showed that the effluent discharged out of the refinery were below permissible limits (Table 1). The river water had lower concentration at the POD but higher concentrations above permissible limit were recorded at the Upstream, and Downstream points. The higher TDS levels recorded within the creeks compared to the effluents and POD are expected based on the influence of the tidal water on the creeks. Turkey's comparison at ($P<0.05$) showed that the values recorded were significantly different.

The observed turbidity in all the sampled stations was above the permissible limits (Table 1). Turkey's multiple comparison ($P<0.05$) revealed that there was a significant change which could be attributed to high turbidity of the refinery effluent discharged into the creek. Increase in turbidity of water can cause problems in the treatment plant and also result in the death of aquatic organisms (plants and animals) in the river. The high level of turbidity recorded could be attributed to the movement of the tidal creek.

4.2 Chemical Parameters

The levels of phenol, phosphate, and ammonia, were above EGASPIN permissible limit at all the stations. Turkey's multiple comparison (at $P<0.05$) showed that the differences were significant. The observed high concentration may be traced to very high levels in the untreated effluent which is channeled into the Observation pond without treatment and the slow dilution by the creek.

Natural sources of water typically contain little ammonia, usually in concentrations below 0.1mg/l, with the recommended maximum permissible limits in refinery effluents as 0.2mg/l [6]. The concentration of ammonia in the effluent and river water was above permissible limit which was due to higher concentration from the untreated effluent, inefficient effluent treatment plant and accumulation in the Observation pond and river water.

The concentration of phosphate was also above the permissible limit at all the stations, statistically the values were significant using turkeys multiple comparison at ($P<0.05$).These recorded high concentrations could also be attributed to the outflow of Untreated effluent and the inefficiency of effluent treatment plant resulting to slow dilution and bioaccumulation in the Observation pond and river water.

The mean levels of total phosphorus in all sampled stations were all above permissible limit as shown in Table 2 except Upstream and Downstream of the river. Turkeys multiple comparison showed that the mean values were significant ($P<0.05$). This showed the inefficiency of the treatment plant and high concentration in the untreated effluent discharged into the Observation pond which is released to the recipient environment. Reduction below permissible limit in the Upstream and Downstream of the creek could be attributed to dilution within the creek due to tidal influence. In effect, high levels of total phosphorus and other nutrients have been reported to encourage eutrophication which could further deplete the dissolved oxygen levels of the surface water and adversely affect aquatic lives [4].

Oil and grease concentration in the untreated effluent was responsible for the increased concentration of oil and grease in the Observation pond which was above permissible limit [6] (Table 2). The effluent-receiving water body had low concentration of oil and grease which could be attributed to proper dilution of the effluent following tidal flushing in the creek.

Total hydrocarbon content in sediment at the Point of Discharge, was 2328.82(mg/kg) but lower at the Upstream sediment (126.47 mg/kg) and Downstream sediment (964.12 mg/kg). These concentrations were found to be higher than the Target level of 50mg/kg stipulated by DPR [6]. These high levels are comparable to the 900 -1000mg/kg recorded in chronically polluted areas of Bonny Estuary [5]. The high total hydrocarbon content recorded in the sediment of the effluent-receiving water body in this study and in combination with other pollutants could to a large extent be responsible for the depletion of fishes and other aquatic life at the Point of impact of the effluent as evidenced from the interview with local fishermen which indicated that the area around the point of discharge of the effluent is devoid of fishes and hence no fishing activity is carried out there anymore.

The concentration of sulphate was above permissible limit only in the Downstream side of the creek as shown in Table 2. Sulphide and cyanide concentrations however were not significant and below the permissible limit at all the sampled stations. Salinity, Total organic carbon and bicarbonate concentrations indicated significant differences in all the stations sampled.

The levels of Biological Oxygen Demand were high in all the sampled stations and above the permissible limit of 10mg/l [6] (Table 2); comparison of the mean values were also significant ($P<0.05$) using turkey's multiple comparison. This could be attributed to the input of organic matter from the biological treatment plant, and the untreated effluent which flowed into the Observation pond (OP), coupled with input of faecal wastes by the surrounding communities.

The Chemical Oxygen Demand values recorded at all stations were also above EGASPIN permissible limits (Table 2). Statistically the results were significant using turkey's multiple comparison at ($P<0.05$). Earlier studies had indicated that refinery effluent discharged into Okrika Creek resulted in the presence of high concentrations of pollutant in the water and sediment, which were toxic to different aquatic organisms [11].

The results in this study indicated that the water bodies sampled had suffered deterioration and degradation due to continuous discharge of partially treated and untreated effluent into the recipient water body.

4.3 Heavy metal concentration

Heavy metal concentration such as zinc, copper, total chromium and vanadium in the effluent and river water were below the permissible limit as shown in Table 2. Metals such as lead and nickel recorded levels were above permissible limit of 0.05mg/l at all the stations. Higher concentration of nickel and lead in the river water could be attributed to slow dilution due to accumulation of the metals.

Sediment concentration in Table 3 showed that all the heavy metals (zinc, copper, nickel) were above permissible limit apart from total chromium which was not detected at all the stations and lead that was not detected in the Upstream river sediment. It is very interesting to know that zinc and copper which were not present in the effluent and river water but were present in high concentration in the sediment. This confirmed the earlier indication in previous study that sediment is usually the sink of pollutants (both THC and heavy metals) [1]. Heavy metals are strongly particle associated due to their hydrophobic properties and tend to accumulate in sediments [9]. If the loading of these contaminants into the waterways is large enough, the sediments may accumulate excessive quantities of contaminants that directly or indirectly disrupt the ecosystem and cause significant contamination and loss of desirable species [3], particularly macrophytes, benthic organism and demersal fish and marine birds. The accumulation of heavy metals in the sediments has been shown to affect benthic organisms physiologically as well as change their feeding and reproduction behaviours [7, 12]. The sinking of heavy metals into the sediments particularly at the POD accounted for the lower levels recorded at the other stations.

5.0 Conclusion

This study showed that some of the physico-chemical parameters observed from refinery effluent were above permissible limit, indicating the partial/inefficiency of the treatment plant. Higher levels of total hydrocarbon contents and heavy metals in sediment at the POD showed the sediments were the ultimate sink for pollutants as the metals adsorbed to particulate matters and consistently accumulate in the sediment. The concentration of these pollutants at the various stations sampled which did not show any significant difference confirmed the influence of the tidal actions in their dispersal and distribution.

5.1 Recommendations

Careless disposal of untreated effluent into the observation pond should be discouraged.

The treatment plant should be upgraded to be more efficient and enable the reduction of pollutants to appreciable level before discharge into the recipient water body.

Regulatory agencies in Nigeria should effect the regulations on industrial effluents, as well as their continuous monitoring and surveillance in order to ensure the protection of water resources from further degradation.

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