Evaluation of the Impact of Kaduna Refinery Effluent on River Romi

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Abstract.

The continuous global quest for management of the scarce water resources to make available to the human populace, portable water for drinking has necessitated this study. River Romi is the effluent discharge point of Kaduna Refining and Petrochemical Company Limited where the refinery waste water is disposed after treatment. This study investigates the impact of Kaduna refinery effluent on River Romi. The physicochemical properties of Kaduna River, Kaduna refinery effluent, Romi River (upstream and downstream) were analyzed from dry and wet seasons. The results obtained were compared with standard set by regulatory bodies and it was discovered that Kaduna refinery effluent has the highest number of pollutants. The body of River Romi upstream was found to contain low level of contaminants which are generally within the standard limits. Comparing the results of both upstream and downstream of River Romi shows that the concentration of pollutants increased after the introduction of effluent.

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Introduction.

Kaduna refining and petrochemical company (KRPC) Limited, is one of the strategic business units (SBUs) of the Nigerian National Petroleum Corporation (NNPC). The company is engaged in crude oil refining into valuable petroleum products, petrochemicals and manufacturing of tins and drums for sales to customers. In carrying out these tasks, various compounds both organic and inorganic are generated from the refining activities. These compounds include: Arsenic, Mercury, Cadmium, Chromium, Sulphates, Ammonia, Phenols, Cyanide, Iron, Lead, Copper, Hydrogen Sulphides, Mercaptan, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) (Odigure and Adeniyi 2002; Yusuf and Osinbanjo, 2006). The inorganic compounds created in water effluent are caused by the chemicals used for production and the organic pollutants are due to reactions arising from production. Most of these compounds could be toxic and fatal if they come in contact with human beings. Also aquatic life suffers damage if the water is discharged to the river untreated or partially treated. However, water remains an important utility in the crude oil refinery and its importance cannot be overemphasized. Its forms of usage include as dried steam, cooling water, drinking water, service water and fire

River Kaduna serves as the only source of water to Kaduna refinery. It is located 14 kilometers away from the refinery. The refinery has three lift pumps charged with the responsibility of lifting water from the river to the surface for pretreatment (Odigure *et al.*, 2002; Akpan *et. al.*, 2008). After the water is treated and used, the waste water from the refinery is treated in waste water treatment plant and the effluent is conveniently discharged to Romi River. Rivers passing through industrial and mining areas are prone to hazards and it remains one of the major causes of environmental pollution around the globe. Romi River is not an exception since it remains the final destination of KRPC effluent. Thus, the communities around the river can be said to be in danger of water-related diseases. River Romi discharges into the Kaduna River system and like other rivers in Nigeria, it has two distinct seasons which are the wet and dry season (Ahmad, 2014). This paper is focused at investigating the seasonal variation of physicochemical properties of water and concentration of heavy metals in river Kaduna, KRPC effluent and river Romi (upstream and downstream).

Materials and Methods.

Water samples were collected monthly over a period of one year. The water sources were from Kaduna River, Kaduna refinery effluent

Romi River upstream and Romi River downstream. The water samples for Kaduna River were taken from Kaduna refinery water intake unit while effluent samples were taken from Kaduna refinery waste water treatment plant. Samples of river Romi upstream were taken 100 meters before the point of discharge and downstream samples were taken 100 meters away from the discharge point. Samples were collected in two-litre plastic bottles that have been previously soaked in 10% nitric acid and rinsed with de-ionized water before sampling.. During sampling, the sample bottles were rinsed thrice with the water to be sampled before sampling and then the samples were collected by careful immersion of the sampling bottles in the water body. The samples were well-labeled; stating the source and date of collection. The labeled water samples were then taken to KRPC laboratory for analyses. The collected samples were analyzed for temperature T(^{0}C), pH, electrical conductivity EC (ms/cm), biochemical oxygen demand BOD (mg/l), chemical oxygen demand COD (mg/l), dissolve oxygen DO (mg/l), total hardness TH (mg/l), alkalinity ALK (mg/l), total dissolve solid TDS (mg/l), sulphate SO_4^{2-} (mg/l), chloride Cl^- (mg/l), iron $Fe^{2+/3+}$ (mg/l), cadmium Cd^{2+} (mg/l), lead Pb^{2+} (mg/l), zinc Zn^{2+} (mg/l), copper Cu^{2+} (mg/l), vanadium V (mg/l), nickel Ni^{2+} (mg/l)

Evaluation of the Effect of Weather Variation on the Physicochemical Properties of Water Samples Analyzed.

Table 1 gives a summary of some marked variation in the physicochemical parameters measured for the four sampling points and the seasons. The temperature results recorded shows that there were little variation in the four stations and seasons. It was observed that the temperatures recorded in the month of January were the lowest compared with the other months. The lower temperature observed could be attributed to dry season, in which the temperature in the atmosphere is relatively higher than those of the wet seasons due to rainfall. Emeaso (2011) also reported a similar observation in his study on pollution and self-purification of river Romi. It was observed that the temperature started reducing in the month of April and the temperature drops further from April to June. This drop in temperature could be as a result of rainfall and storm. The mean values of water characteristics during dry (January-March) and wet (April-June) seasons of the different water samples taken from Kaduna River, Kaduna refinery effluent, Romi River upstream and downstream were evaluated and compared with United Nation Environmental Programme (UNEP) standard and Nigerian Drinking Water Standard (NDWS).

Results.

Table 1: Seasonal Variations of Physicochemical Parameters of Kaduna River, KRPC Effluent, Romi River Upstream and Romi River Downstream

Parameters	Kaduna river		KRPC effluent		Romi river (upstream)		Romi river (Downstream		UNEP	NDWS
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry		
T (°C)	28.70	30	28.80	29.90	27.80	29.20	28.00	29.20	30	
Ph	7.39	6.88	6.80	6.35	7.9	7.10	7.80	7.05	6.0-9.5	6.5-8.5
EC (ms/cm)	240	280	394	400	180	210	210	250	380	
BOD (mg/l)	158.80	116.20	280	230	105	89	125	100	25	
COD (mg/l)	200.80	130	400	350	190	140	220	180	200	
DO (mg/l)	11.90	10.10	7.32	6.4	13.90	12.10	12.40	11.90	>10	
TH (mg/l)	250	280	100	115	210	275	212	265		150
ALK (mg/l)	92	108	57	60	115	130	116	125	20-60	
TDS (mg/l)	180.90	200.80	230	268	160.90	178.20	180	208	2000	
$S0_4^{2-}$ (mg/l)	42	50	145	250	22	35	48	85	500	
Cl (mg/l)	30	48	94	120	22	35	33	52	20	
Fe (mg/l)	0.06	0.12	1.30	1.92	0.05	0.09	0.30	0.48		0.3
Cd (mg/l)	0.001	0.002	0.008	0.010	0.001	0.001	0.002	0.004	0.1	
Pb (mg/l)	0.02	0.05	0.13	0.16	0.01	0.04	0.04	0.06	0.2	0.01
Zn (mg/l)	0.14	0.25	1.02	1.26	0.14	0.20	0.40	0.6	0.5	3.0
Cu (mg/l)	0.04	0.06	0.70	0.75	0.03	0.04	0.06	0.08	0.01	
V (mg/l)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Ni (mg/l)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		

Values recorded for pH (Figure 1) over the period under investigation shows that the pH decreased with increase in temperature with River Romi having the highest value and KRPC effluent with the lowest. This suggests the presence of acidic substance in the effluent. The values recorded of pH were within the standard set by UNEP. However, this could pose adverse effect on the receiving water body as low pH can allow toxic elements such as heavy metals to become mobile and available for uptake by aquatic organisms (Yusuf and Osinbanjo, 2006; Swammy *et. al.*, 2013; Ahmad, 2014).

Electrical conductivity was higher during the dry season than the wet season (Figure 2). Ibrahim *et. al.* (2009) also observed similar trend for Kontagora reservoir in Niger State. This increase in water levels may dilute the mineral concentration of the water bodies. Thus the mineral ions are more concentrated during the dry season due to the reduced water volume and high water temperature since electrical conductivity increases with temperature (Ibrahim *et. al.*, 2009).

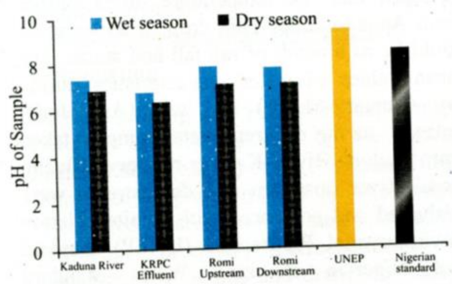

Figure 1: pH of water samples at different sources compared to UNEP standard and NDWS

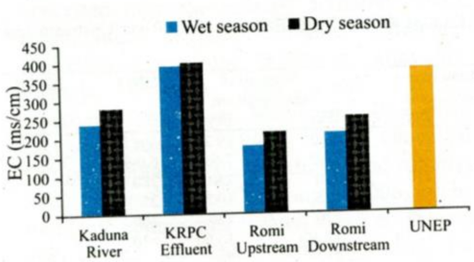

Figure 2: Electrical conductivity of water samples at different sources compared to UNEP

BOD values (Figure 3) recorded shows that it was low in the dry season with the lowest value recorded in the month of March and the highest value recorded in the month of June. The high value in the rainy season could be due to rainfall as a result of washing of organic matter into the water bodies. The high value during the rainy season could affect aquatic organisms present in water by reducing the amount of dissolve oxygen available to them (Ahmad, 2014).

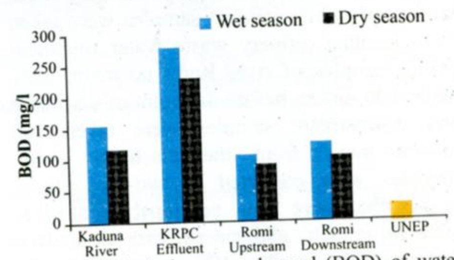

Figure 3: Biological oxygen demand (BOD) of water samples at different sources compared to UNEP Standard

The value of COD (Figure 4) follows the same trend with BOD. The high values recorded between the month of April and June could also be due to the presence of high organic matter in the water bodies. Thus more oxygen will be required to chemically oxidize them to carbon dioxide and water. This would limit the amount of oxygen in water and which otherwise might have negative impact on aquatic organisms.

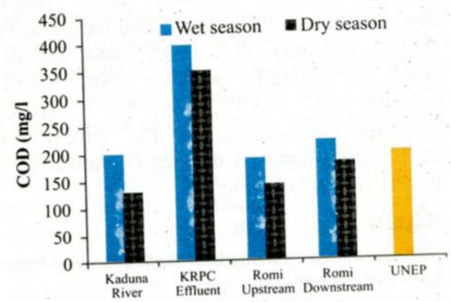

Figure 4: Chemical oxygen demand (COD) of water samples at different sources compared to UNEP standard

Discussions.

The values of Dissolve oxygen were high during the rainy season despite the high value of BOD and COD. This contradicts the report of Emeaso in 2011 on self-purification of river Romi. This may be due to the fact that during rainy season, oxygen in air tends to dissolve in rain water as it falls. Also low temperature could be responsible for higher dissolve oxygen concentration in the wet season because solubility of gas increases with decreasing temperature (Swammy et. al., 2013).

Generally, the values recorded for total hardness, total dissolve solid, Alkalinity, sulphates and chlorides were high during the dry season (Table 1). This observation is probably due to low water level in the dry season with increase in concentration of ions and salts in the water bodies. The result recorded during the rainy season could be attributed to dilution. The high level recorded for alkalinity during dry season agrees with the findings of Ufodike *et. al.* (2001) for Dokowa mine Lake. Kolo and Oladimeji in 2004 made similar observation for Zaria dam. Furthermore, in Kaduna River the concentrations of iron, cadmium, lead, zinc and copper were high between January and March and started decreasing in the month of April. The lower values obtained between the month of April to June could be due to dilution of the water bodies as a result of rainfall. The values recorded for vanadium and nickel were constant throughout the months in the four stations. Thus, rainfall may dilute and reduce the effects of point source pollution like heavy metals but it also increases the effect of non-point pollution such as organic waste by land runoff from farming activities.

Evaluation of Water Quality Parameters and Comparison with Standards.

From Figures 1 to 4 and Table 1 the values obtained for temperature, pH, electrical conductivity, chemical oxygen demand, dissolve oxygen, sulphates, iron and zinc in Kaduna River are within the standard set by UNEP. Also, the values recorded for pH, iron and zinc complies with the value of NDWS. However, the result of Biological oxygen demand is above the standard for UNEP. The high value could be as a result of the indiscriminate domestic waste disposal into the river along its course. Animals such as cattle and birds also feed along the river and their faeces could also increase the biological oxygen demand of the river. The values recorded during dry and wet season for total hardness are above the NDWS of 150 mg/l. This could be as a result of mining activities of limestone near the river. The values of alkalinity obtained for Kaduna River during the dry and wet season were also above the UNEP standard. The presence of inorganic salts could be responsible for the high value of chlorides recorded in both dry and wet season. Lead concentrations in both seasons were high compared with Nigerian Drinking Water Standard of 0.01mg/l (Kolo and Oladimeji, 2004).

Furthermore, the average concentration of water parameters obtained for refinery effluent during the rainy and the dry season were above standard limit of UNEP and NDWS. The mean values recorded for temperature and pH in both seasons were within the acceptable limit of UNEP. However, the average value recorded during the dry season was not within the acceptable standard of drinking water in Nigeria. The low value of pH could be due to the contamination of water with sulphuric and hydrochloric acid in the process plant. Crude oil is a composition of hydrocarbon, water, inorganic salts, water soluble trace metals, organic sediments and other impurities which are often removed prior to the refining of crude oil in other to prevent corrosion, catalyst poisoning, plugging and fouling of equipment (Odigure *et. al.*, 2002).

The desalted water which is rich in organic waste, inorganic salt, trace metals and other waste water generated in the process of refining crude oil are sent to waste water treatment plant for treatment prior to discharge of the effluent into Romi River. This explains the high concentrations recorded for electrical conductivity, BOD, COD, chlorides, iron and copper in both dry and wet season compared with UNEP Standard. Low concentrations of dissolve oxygen and alkalinity were recorded in the effluent. This could be associated with high BOD and COD level. Also the removal of oxygen in boiler feed water could contribute as well to this, since steam is employed in the stripping process to remove impurities from products. After stripping the steam rich in impurities is sent for treatment in waste water treatment plant. The values recorded for alkalinity in both seasons were lower than UNEP. The values recorded in both seasons for total dissolve solid, sulphates, cadmium, lead, and zinc are within the desirable limit of UNEP. The values obtained for total hardness and zinc also agree with Nigerian drinking water standard while the values obtain for lead and iron are above the desirable limit. The high concentration of lead and iron could be associated with the presence of metallic salts and heavy metals in crude oil (Akpan *et al.*, 2008; Odigure *et al.*, 2002).

There is a good agreement between upstream parameters of river Romi with UNEP acceptable limits though the value of biological oxygen demand is higher than the acceptable limit. This could be attributed to agricultural activities such as animal rearing and run off of organic waste into the river. Also the values recorded for chloride is slightly above UNEP standard. Similar trend was observed in the downstream of the river but the value recorded for COD during the rainy season and the value of zinc in the dry season were above UNEP standard. Also the value of iron is above the standard limit in both seasons. This could be as a result of refinery effluent contamination in river Romi downstream.

Conclusions.

The results obtained from the analyzes of some physicochemical properties of River Romi (upstream and downstream) reveals the values recorded for temperature, electrical conductivity, BOD, COD, total dissolve solid, sulphate, chloride, iron, cadmium, lead, zinc and copper are higher in the downstream of the river. Also, the values recorded for pH, dissolve oxygen and alkalinity are higher in the upstream. The values recorded for total hardness vanadium and mercury are almost the same. Thus the concentration of pollutants in the downstream is a bit higher compare to the concentration in the river upstream. Even though it does not constitute an immediate harm when viewed from the value alone, but not when viewed from the longtime of exposure. Thus, the effluent from the refinery is a major source of environmental pollution on River Romi water system. The values recorded for iron, zinc and copper during dry season are above the limit set by regulatory bodies. Though these elements are required in minute quantity for metabolic activities in living tissues but when present in high concentrations it poses a great threat to the environment. Greater care should be taken with the effluent discharge into river Romi by the refinery and other human activities around the vicinity.

Acknowledgements.

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