

EVALUATION OF INDUSTRIAL DISCHARGE POINT SOURCE POLLUTION IN IKEJA INDUSTRIAL ESTATE, IKEJA, LAGOS, NIGERIA

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Abstract

The rate of water pollution resulting from industrial effluents is on the increase in Nigeria. This study assessed the physico-chemical and heavy metal parameters from waste water and sediment samples from drainage discharge point of brewery, textile, paints, confectionary, and fibre-cement roof industries in Ikeja Industrial Estate, Lagos in dry and wet seasons. The samples were evaluated for their quality and the data obtained were compared with local and international regulatory standards. Among the parameters determined were colour, pH, temperature, electrical conductivity, total dissolved solid, biological oxygen demand (BOD), chemical oxygen demand (COD), chloride, sulphate, and phosphates using standard methods and procedures. The levels of heavy metals in the water and sediment samples were determined using atomic absorption spectrophotometer (AAS). The values of pH, temperature, BOD, COD, and orthophosphate –P in the water samples were higher than the NESREA limit. Results of analysis of variance (ANOVA) revealed that there was no seasonal significance difference in water and sediment samples ($p > 0.05$) in all the sampling points. The concentrations of Cd, Cu, Pb, Cr, Zn and Ni in water and sediment samples were higher than the NESREA standards in one or two sampling points along the drainage system. This study revealed that some of these industries still discharge untreated or partially treated waste water into the environment through the drainage system. There is need for regular monitoring and compliance enforcement by appropriate Government Regulatory Agencies on regulatory requirements.

Keywords: Pollution, industrial effluents, sediment, heavy metals, physicochemical parameters, point source.

1. Introduction

Lagos is the economic capital of Nigeria and according to Oresanya (2000) it has over fifty percent (50%) of the total industries in the country. High industrialisation and

urbanisation have led to an increase in the quantity of waste generated, hence, high environmental degradation and increased pollution rate (Adesuyi *et al.*, 2015a). The industrial waste water pollution problems faced by Lagos with over 7,000 medium and large scale manufacturing facilities are directly related to the rapid industrial growth and the haphazard industrialization without proper environmental consideration (Oketola and Osibanjo, 2009). Water production requirements and waste water generation in industries is dependent on the type and size of the industry, the raw materials involved, the end products and the industrial processes involved. Though some industries may require just a small a volume of water in their processes, while some due to the nature of their processes require large volumes of water (for cooling in metal/ore industries, textiles, paints, breweries) (Oketola and Osibanjo, 2009; Adewoye, 2010).

National Environmental Standards and Regulations Enforcement Agency (Establishment) (Effluent Limitations) Regulation 2007 (Official Gazette, Federal Republic of Nigeria, No 25, Vol. 78, July 2007) mandates every industry to install anti-pollution equipment for the detoxification of effluent and chemical discharges emanating from the industry (Regulation 1(1). Such installed anti-pollution equipment shall be based on Best Available Technology (BAT), Best Practicable Technology (BPT) or the Uniform Effluent Standards (UES) (NESREA, 2007). It also stipulates restriction on the release of toxic substances, requirement for pollution monitoring unit, machinery for combating pollution and contingency plan by industries; submission of list and details of chemicals used by industries to Federal Ministry of Environment. It also contains permissible limits of discharge into public drains inland water and land, and protection of workers (NESREA, 2007). However despite all these regulations, available reports in Nigeria cite gross contamination of most major River bodies across the nation due to discharge of industrial effluents, sewage and agricultural wastes among others (World Bank, 1995; Adebayo *et al.*, 2007; Adewoye, 2010; Adeboyejo *et al.*, 2013).

Effluent and waste water discharged into the environment by industries and the various human activities releases different pollutants into the environment, consequently, causing harm to the ecosystems (Adesuyi *et al.*, 2015b; Adesuyi *et al.*, 2016). Aquatic pollution by heavy metals is very prominent in industrialized and mining areas; the occurrence of these metals in excess of natural load has become a problem of increasing concern, not only to environmentalists but also to health practitioners (Adesuyi *et al.*, 2015b; Jolaoso *et al.*, 2016). The concern about heavy metals stems from their persistence in the environment as they are not easily degraded either through biological or chemical means unlike most organic pollutants (Sabo *et al.*, 2013). The discharge of various metal pollutants into aquatic environment as pointed out by Njoku and Keke (2003) and Adesuyi *et al.* (2016) would damage the quality of the ecosystem thereby rendering water body unsuitable for its intended uses posing a serious health threat to the food web and the immediate population (UNESCO-UNEP-WHO, 1996).

Hence, the main objective of this study is to assess the physicochemical parameters of water and sediment samples from drainage discharge points of brewery, textile, paints, confectionary and fibre-cement roof industries in Ikeja Industrial Estate, Lagos so as to evaluate the effluent quality and compare findings with local and international regulatory standards.

2. Materials and Methods

2.1 Study Area

Lagos State is the economic and industrial hub of Nigeria comprising of coastal cities with industrial estates. Ikeja Industrial estate is one of its foremost. Ikeja Industrial Estate has cotton textile plants that are among Nigeria's largest, and there are also wool textile factories. Other factories in Ikeja includes footwear, cosmetics, pharmaceuticals, plastics, paper and cork products, ceramics, paints, matches, and lightbulbs industries. Also, there are various food processing plants and a large brewery in the town. Heavy industries include steel products, trailer-truck tanks, wire aluminum, and rubber products. Several publishers and printers and import-export businesses are also centred there.

2.2 Description of Sampling Points

Six experimental (sampling) points were purposively selected at the various industries discharge points along the drainage course of Oba Akran Avenue, Ikeja (Table 1).

Table 1: Sampling points and their GPS location

S/n	Sampling point	Industry	Description of point	GPS location	
1	Point A	Brewery	Discharge Point	6.61612N	3.33538E
2	Point B	Textile	Discharge Point	6.60828N	3.33616E
3	Point C	Paint	Discharge Point	6.60746N	3.33627E
4	Point D	Confectionery	Discharge Point	6.60705N	3.33505E
5	Point E	Fibre-cement sheets	Discharge Point	6.60356N	3.33735E
6	Point F	Down stream	Drainage downstream	6.60193N	3.33812E

2.2 Sample collections and designs

A two-season field data collection and sampling was carried out at the tail end of the dry season in April and early rainy season in June 2015. Six water samples designated W_1 to W_6 and six sediments samples designated S_1 to S_6 were collected from the sampling locations (discharge points) along drainage course in this Industrial Estate as shown in figure 1.



Figure 1: Sampling points in Ikeja Local Government Area

All water samples (in a particular season) were collected on the same day at noon and kept in two litres sampling bottles, which have been previously washed with 10% HNO₃ and 1:1 HCl for 48 hour. The rubber bottles were labeled and immediately few drops of HNO₃ were added in order to prevent loss of metals. Sediment samples were collected via a polyethylene corer and properly labeled. The water and sediment samples were conveyed in ice pack chamber to the laboratory for chemical analysis using standard procedures.

2.4 Sample Preparation and Analyses

The physicochemical analysis of discharge water (pH, temperature, electrical conductivity and total dissolved solid) was determined on sites using a portable Hanna meter, HI991404-01 Model. Accuracy was $\pm 0.5^{\circ}\text{C}$ for temperature, ± 0.1 for pH and $\pm 2\%$ F.S for EC/TDS. Sulphate, phosphate-phosphorus (PO₄³⁻-P) and Chloride were determined according to APHA (2005) methods in the laboratory. Chemical oxygen demand (COD) and biological oxygen demand (BOD) were also determined following the procedure of De (2006).

Heavy metal determination in water samples was done according to APHA/AWWA/WEF (1985) Standard Methods. Fifteen ml of HNO₃ was added to 250 ml of water samples and then evaporated down to 25 ml. The solution was transferred into 50 ml volumetric flask and made up to the mark with distilled water. Then, heavy metals were detected using Atomic Absorption Spectrophotometer (AAS).

Heavy metal determination in sediment was accomplished by acid extraction method. Before extraction, samples were heated at 60° C for eight hours to obtain dry weight. Then, two grams of dry sample was weighed and placed into a 50 mL beaker. Ten mL of aqua regia (3:1 of HNO₃ and HCl) was added to the beaker, covered by watch glass (to prevent metal vaporization), and heated on water bath for about 4 hours. Then, 3 ml of H₂O₂ was added to the beaker to dissolve any grease and protein. The solution was filtered and transferred into 50 ml volumetric flask and made up to the mark with distilled water. Heavy metals were determined by AAS (EPA Method 2001).

2.5 Statistical Analyses

The data were subjected to descriptive statistical analysis (95% confidence interval) using Graph Pad Prism software package (version 6.0). Analysis of variance (ANOVA), means, standard error and range was also generated to assess whether sampled parameters varied significantly between wet and dry seasons, and also between sampled discharge points.

3. Results and Discussion

The results of the physicochemical qualities of water samples from the different sampling points are as shown in Table 1.

3.1. Physicochemical Parameters

The pH of the collected sample waste water sample ranged from 4.7-7.9 in wet season and 4.6-10.5 in the dry season. All the pH values were within the NESREA (2007) permissible limit of 6-9 except those from the drainage discharge point of the station C during the dry season (4.60) and station E also in the dry season (10.50). Across board from all sampling points, the pH in the dry season is higher than that of wet season except in station C (7.90) and Point D (7.50). Statistical analysis using ANOVA showed that pH regimes vary significantly ($P < 0.05$) in the sample points throughout the study but there was no seasonal significant difference ($P > 0.05$). The pH values recorded is similar to that reported by Al-Farraj *et al.* (2013) in assessment and heavy metal behaviors of industrial wastewater in Riyadh city, Saudi Arabia, which is an indication that the water is slightly polluted. This will ultimately contribute to pH change of the recipient water body, and may affect metabolic activities of aquatic organisms since they are often pH dependent (Adeyemo *et al.*, 2008; Wang *et al.*, 2002). pH value also affects biological and chemical reaction in water bodies and it is a factor that determines water suitability for various purposes including toxicity to animals and plants (Sabae *et al.*, 2014; Adesuyi *et al.*, 2015b).

Table 2: Seasonal variation in physicochemical parameters in water sample from the six sampling sites

Variables	Season	Point A	Point B	Point C	Point D	Point E	Point F	Average	Variance	P-Value	F calc	F crit	WHO limit	NESREA limit
pH	Wet	4.70	7.20	7.90	7.50	7.50	7.10	6.98	1.33	0.65	0.22	4.96	-	6-9
	Dry	5.50	8.50	4.60	6.80	10.50	8.90	7.47	4.97					
Temp (°C)	Wet	28.20	38.40	29.30	27.90	26.50	27.50	29.63	19.27	0.89	0.02	4.96	23	-
	Dry	27.80	30.50	31.70	31.80	29.00	25.30	29.35	6.36					
EC (µS/cm)	Wet	301.90	508.0	596.60	156.9	134.7	134.0	305.35	41285.03	0.37	0.87	4.96	1000	-
	Dry	430.70	722.50	669.1	143.6	396.1	189.1	425.18	56758.67					
DO (mg/L)	Wet	10.50	5.40	9.10	6.90	4.50	8.50	7.48	5.27	0.26	1.44	4.96	-	>10
	Dry	5.90	5.10	8.50	7.90	0.90	6.20	5.75	7.27					
TDS (mg/L)	Wet	246.70	419.0	343.04	187.7	131.4	129.9	242.96	13860.39	0.35	0.97	4.96	-	2000
	Dry	327.80	614.5	535.3	150.2	214.5	170.1	335.40	38830.90					
BOD (mg/L)	Wet	29.0	86.0	50.0	25.0	54.0	19.0	43.83	622.17	0.94	0.01	4.96	-	10-30
	Dry	36.0	19.0	80.0	89.0	32.0	15.0	45.17	997.37					
COD (mg/L)	Wet	290.0	189.0	116.0	118.0	90.0	103.0	151.0	5820.80	0.65	0.21	4.96	-	30-80
	Dry	193.0	78.50	218.0	120.0	87.0	101.0	132.92	3420.84					
Cl (mg/L)	Wet	15.0	50.0	139.0	31.0	38.0	30.0	50.50	2009.90	0.46	0.59	4.96	250	600
	Dry	32.0	152.0	99.0	100.0	32.0	18.0	72.17	2805.77					
SO₄²⁻ (mg/L)	Wet	130.0	229.0	140.0	134.0	45.0	64.0	50.50	4009.1	0.99	0.0001	4.96	-	500
	Dry	190.0	320.0	57.0	30.0	64.0	64.0	72.17	12102.8					
PO₄-P (mg/L)	Wet	3.10	35.0	15.0	1.90	45.30	14.20	19.08	306.38	0.98	0.001	4.96	-	5.0
	Dry	41.0	8.90	1.60	0.70	11.70	49.0	18.82	435.35					

Water sample temperature in the wet season ranged from 26.5 °C to 38.4°C while it ranged from 25.3 °C to 31.8 °C in the dry season. Highest temperatures were recorded in station B (38.40 °C) and station D (31.80 °C) and the two lowest in station F - drainage downstream (25.30 °C) during the dry season and station E (26.5 °C) during the wet season. Significant variation ($p < 0.05$) was observed between the six sampling points but there were no seasonal differences ($p > 0.05$). Temperatures of the six sampling points were relatively high. The high volume water with high temperature from these discharge points may be due to the large quantity (volume) of water involved in their production processes as observed by Oketola and Osibanjo (2009). Water temperature in water bodies like rivers, and streams have direct relationship with dissolved oxygen (Akan *et al.*, 2012), as well as fluctuation and availability of phytoplankton community (Almamoori *et al.*, 2012). Hence, if this is not properly addressed, the receiving water bodies will undergo spatial and temporal changes leading to reduced oxygen, elevated metabolic activity of organisms, and may also cause shift and reduction in phytoplankton distribution and diversity (Almamoori *et al.*, 2012).

The Electrical conductivity ($\mu\text{S}/\text{cm}$) of water samples ranged from 134.0 to 722.5. All EC values were below the WHO permissible limit of 1000 ($\mu\text{S}/\text{cm}$). There was no significance difference ($P > 0.05$) in EC values at all sampling stations across the two seasons. The highest values of EC were recorded in station B (722.50 $\mu\text{S}/\text{cm}$) and station C (669.1 $\mu\text{S}/\text{cm}$) during the dry season while the lowest values of EC were recorded in station F (134.0 $\mu\text{S}/\text{cm}$) and station E (134.70 $\mu\text{S}/\text{cm}$) both during the wet season. These high values of electrical conductivity from textile and paint industries indicate a high level of contaminant in the drainage of these industries. Similar observations were also reported by Ezzat *et al* (2012) and Ghannam *et al.* (2014).

The levels of dissolved oxygen (DO) within the six sampled water were between 4.50 and 10.50 mg/L in the wet season, while it ranged from 0.9 mg/L to 8.5 mg/L during the dry season. In the investigated samples dissolved oxygen concentration are still within the NESREA (2007) permissible limits of >10 mg/L except in sample from station A discharge point (brewery) during the wet season (10.5 mg/L). The DO values obtained from this study are similar to those reported by Fatoki *et al.*, (2001) and, Igbinoso and Okoh (2009). Depletion of dissolved oxygen is an indication of high organic matter and nutrients load which may lead to high rate of microbial decomposition in receiving water body as reported by Sabae *et al.* (2014). Generally in rivers and streams, DO levels less than 3 mg/L are stressful to most aquatic organisms. Most fishes die at 1-2 mg/L. However fish can move away from low DO areas. Water with low DO from 0.2 – 0.5 mg/L are considered hypoxic; waters with less than 0.5 mg/L are considered anoxic. The standard for sustaining aquatic life is stipulated at 5 mg/L, a concentration below 2 mg/L may lead to mass death for most fishes (Chapman, 1993). Statistical analysis showed that there was no seasonal significant difference ($P > 0.05$) in DO but there exist a significant variation from one sampling stations to the other.

Total dissolved solids in water are mainly made up of carbonates, bicarbonates, chlorides, phosphates, nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles (Mahananda, 2010). The TDS values ranged from 129.9 mg/L to 614.5 mg/L, they do not exceed NESREA guidelines (2007) of 2000 mg/L. However, higher values of TDS were recorded during the dry season than in wet season at all the sampling points (dry > wet season) except in station D (150.20 mg/L during the dry < 187.79 mg/L during the wet season). The notable increase of TDS values in dry season is similar to that recorded by Ghannam *et al.* (2014) in a study of seasonal variations in physicochemical parameters and heavy metals in water of El-Bahr El-Pharaony Drain, El-Menoufia Governorate, Egypt. According to Ghannam *et al.* (2014), this may be due to stagnation and concentration of salts along the drainage course. However, there is no seasonal significant ($p > 0.5$) difference in TDS concentration. Excessive TDS from the drainage system into the receiving water body (rivers) can reduce water clarity, hinder photosynthesis and lead to increased water temperatures (Chapman *et al.*, 2000).

Measurement of biological oxygen demand is used to determine the level of organic pollution in water/wastewater. Obtained values from analyses showed values between 19 mg/L and 86 mg/L during the wet season while it was between 15 mg/L and 89 mg/L in the dry season. These values exceeded the NESREA guideline of 10 to 30 mg/L. The highest values of BOD were recorded during the dry season at station D (89.0 mg/L) followed by point C (86.0 mg/L) during the wet season. High BOD values in the entire drainage sample may be due to high level of organic matter load from the discharge points as reported by Chapman *et al.* (2000). Using the BOD values as standard for evaluating water quality, the water along the drainage system may be described as heavily polluted.

Chemical oxygen demand and biological oxygen demand are useful parameters in water quality analyses and they are both a function of DO. The COD values give a measure of the non-biodegradable organic materials present in the samples (Siyanbola *et al.*, 2011). The COD values obtained ranged from 78.50 mg/L to 290 mg/L. Highest values of COD are recorded in station A (290.0 mg/L) during the wet season and in station C (218.0 mg/L) during the dry season. All values obtained exceeded the NESREA (2007) permissible limit of 30 – 80 mg/L. Statistically there was significant variation ($P < 0.05$) in COD value at each sampling station while there was no seasonal significant difference in COD concentration. The high BOD and COD levels indicate that water samples are highly polluted which was similar to findings reported by Igbinsola and Okon in a study of impact of wastewater discharge on the physicochemical qualities of a receiving water shed (2009). It may be attributed to the high demand on dissolved oxygen by the wastes discharged into the water along the drainage system and which may render receiving water body unfit for drinking, irrigation and also decrease the recreation value of water (Reddy and Baghel, 2010).

Chloride values in the waste water samples from all the sampling station ranged from 15 mg/L to 152 mg/L. Highest values were recorded in point B (152.0 mg/L) during the wet season and in point C (139.0 mg/L) during the wet season. All values recorded are all below the NESREA guideline of 600 mg/L. Statistically, there is no significant ($P > 0.05$) seasonal variation in all the sampling points for this parameter except in point B and point D. High chloride concentration in waste water as reported by Hasalam (1991), is in indication of pollution and according to Subin and Husna (2013), can be attributed to discharge of sewage waste and effluents from these industries.

Sulphate content were between 30 mg/L and 320 mg/L. Higher values (229-320 mg/L) are observed in both wet and dry season at point B and lower values (45-64 mg/L) in point E. Sulphate concentrations in all the seasons and at all sampling points were within the NESREA permissible limit of 500 mg/L. Anthropogenic inputs and domestic sewage tend to increase sulphate concentration in the drainage system (Ghannam *et al.*, 2014; Grasby *et al.*, 1997). An excess of sulphate in river water is taken as an index of pollution as reported by Bolawa and Gbenle (2012). The release of sulphate ions from various wastes discharged points might be the reason for the excessive content along the drainage system. Excessive content of sulphate in water has been recorded to have laxative effect in man (Subin and Husna, 2013).

The orthophosphate contents in all waste water samples varied between 1.6 mg/L and 49 mg/L; the orthophosphate level was significantly high during the wet season and there was no statistical seasonal variation ($p > 0.05$) in the phosphate values at all the sampling point. The highest level was recorded in the downstream sample during the dry season. Generally, phosphate level was higher than the NESREA (2007) permissible limit of 5.0 mg/L in 75% of the samples. As observed high level of phosphate can lead to eutrophication and can reduce DO levels in the receiving water bodies, which ultimately will lead to destruction of such rivers ecosystem through nutrient enrichment, productivity, decay and sedimentation as reported by Adeyemo *et al.*, (2008). Eutrophication could adversely affect the use of rivers and dams for recreation purposes as the covering of large areas by macrophytes could prevent access to waterways and could cause unsightly and malodorous scum which could lead to the growth of blue-green algae and the release of toxic substances (cyanotoxins) into the water systems (Igbinosa and Okon, 2009).

3.2 Heavy metal concentration of sediment and water

As shown in table 2, the concentration of cadmium in the water samples ranged from 0.10 mg/L to 0.72 mg/L during the wet season, and during the dry season between 0.11 mg/L and 0.75 mg/L. The sediment Cd concentrations were between 0.25 mg/L and 1.45 mg/L during the wet season; and between 0.59 and 0.91 mg/L during the dry season. Highest Cd value in the water samples was recorded at station E during the dry season while the least was in station C during the dry season too. The highest Cd values in sediment were

recorded at point D during the dry season and least at station E during the wet season. There was statistical significant difference ($p < 0.05$) in the concentration of Cd in sediments and water samples. This might be due to runoff, regular and constant release of pollutants (effluents) into this drainage system, hence, accumulation in the sediment samples (Hutton *et al.*, 1999). Similar report was also recorded by Akan *et al.* (2012). The level of Cd in the water samples from all the sampling points do not exceed NESREA limit of 1.0 mg/L, while that of the sediments do not exceed too except for point D (confectionary) and station F (drainage downstream). Source of cadmium in the water environment can be from domestic waste water, non-ferrous metal smelting and refining, batteries, manufacturing of plastics, chemicals and metals. Cadmium levels of up to 5 mg/kg have been reported in sediments from river and lakes, and from 0.03 - 1 mg/kg in marine sediments. The average cadmium content of seawater is about 5-20 mg/L in open seas, while concentrations of 80 – 250 mg/L had been reported in French and Norwegian coastal zones. Concentrations measured in European rivers roughly vary from 10 to 100 mg/L (OSPAR 2010). High concentration of Cd in receiving water body from this drainage will lead to toxicity in fish tissues and planktons, and it has been observed to be toxic at concentrations between 0.005 mg/L and 0.01 mg/L in fishes (Akan *et al.*, 2012).

Table 3: Seasonal heavy metal pollution in water (mg/L) and sediment samples (mg/kg)

	Point A		Point B		Point C		Point D		Point E		Point F		*NESRE 2011	Average	Variance	F cal	F crit	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry						
Cadmium	Water	ND	0.20	0.72	0.50	0.19	0.11	0.10	ND	ND	0.75	0.35	0.19	<1.0	0.26	0.07	2.75	4.30
	Sediment	0.50	0.91	ND	ND	0.91	0.58	ND	1.15	ND	0.25	ND	1.45	0.59	0.53	0.25		
Copper	Water	3.80	2.70	2.10	1.60	2.50	2.20	1.10	2.10	4.00	1.90	3.50	4.29	<1.0	2.65	1.04	1.81	4.30
	Sediment	2.05	2.85	3.73	2.25	1.90	2.53	1.24	1.54	1.12	1.29	2.80	2.49		2.15	0.61		
Lead	Water	0.50	5.10	0.90	1.20	0.30	1.10	0.45	ND	2.30	1.40	2.90	4.40	<1.0	1.72	2.70	0.04	4.30
	Sediment	1.80	0.90	2.60	2.40	1.11	1.82	0.65	1.82	0.86	1.30	2.11	2.00		1.61	0.41		
Chromium	Water	0.10	0.20	0.50	0.20	ND	ND	0.12	0.14	0.10	0.30	0.10	0.30	<1.0	0.17	0.02	0.05	4.30
	Sediment	ND	1.05	0.10	0.10	ND	ND	0.23	0.10	ND	0.10	ND	0.10		0.15	0.08		
Zinc	Water	0.95	0.90	1.15	0.11	0.10	0.15	0.21	0.56	0.90	0.19	1.70	1.20	<1.0	0.68	0.28	0.06	4.30
	Sediment	0.55	2.92	0.90	1.30	0.31	0.07	0.11	0.32	0.12	0.34	0.24	0.15		0.61	0.66		
Nickel	Water	0.90	ND	1.30	0.80	0.10	ND	0.34	0.07	0.95	0.87	1.60	1.90	<1.0	0.74	0.41	0.52	4.30
	Sediment	0.20	0.60	1.10	0.50	0.48	0.30	0.11	0.20	0.41	0.34	0.10	2.30		0.55	0.38		

*NESREA 2011, Effluent limitation guidelines in Nigeria for all categories of industries: Limit for discharge into surface water.

The levels of copper in the water samples fluctuate between 1.10 mg/L and 4.00 mg/L during the wet season; and between 1.60 mg/L and 4.29 mg/L during the dry season. Cu concentration in sediment samples ranged from 1.12 mg/kg and 3.73 mg/kg during the wet season, while between 1.29 mg/kg and 2.85 mg/kg were recorded in the dry season. The highest value of Cu in water was recorded at station E (4.00 mg/L) while the least was recorded in station D which was 1.10 mg/L for the wet season. Copper is used in the production of electrical wiring, roofing, pigments, cooking utensils, pipes and in chemical industry. Copper compounds are also used as food additives; copper salts are used in water supply systems to control biological growths in reservoirs and distribution piping. Copper compounds form a number of complexes in natural waters with inorganic and organic ligands (WHO, 2004; Abbasi *et al.*, 1998). The copper concentration in the water samples along this industrial drainage was found to be higher than NESREA permissible threshold of 1.0 mg/L. This might be due to influence of untreated or partially treated waste release from these industries. The ability of copper to cycle between an oxidized state, Cu(II), and reduced state, Cu(I), is used by cuproenzymes involved in redox reactions (Stern, 2010). However, it is this property of copper that also makes it potentially toxic because the transitions between Cu(II) and Cu(I) can result in the generation of superoxide and hydroxyl radicals (Tchounwou *et al.*, 2008; Stern, 2010). Also, excessive exposure to copper has been linked to cellular damage leading to Wilson disease in humans (Tchounwou *et al.*, 2008).

The concentration of lead in water samples ranged from 0.30 mg/L to 2.90 mg/L during the wet season, while that for dry season ranged between 1.10 mg/L and 5.10 mg/L. The concentration of Pb in sediment samples during the wet season ranged from 0.65 mg/kg to 2.60 mg/kg, while that of the dry season were between 0.90 mg/kg and 2.40 mg/kg. The highest concentration of Pb in water was recorded at station A, while the least was at station C. The highest Pb value in sediment was recorded at station B and the least at station D. In this study, there was no statistical difference ($p > 0.05$) in Pb at all the sampling points in this drainage system irrespective of the seasons. This is an indication that Pb concentration is solely dependent on the waste waters from these factories. The level of Pb in the samples along the drainage showed that the NESREA permissible threshold of less than 1.0 mg/L was exceeded. This might be attributed to runoff, agrochemicals, and effluents discharged as reported by Banat *et al.*, (1998) and Akan *et al.*, (2012). Bioaccumulation of Pb in man may induce brain damage, kidney damage, and gastrointestinal diseases, while chronic exposure may cause adverse effects on the blood, central nervous system, blood pressure, kidneys, and vitamin D metabolism (Apostoli *et al.*, 1998; USEPA, 2002).

The concentrations of Chromium in the water samples during the wet season were between ND and 0.5 mg/L while that of the dry season were between ND and 0.30 mg/L. Cr level in sediments ranged from 0.10 mg/kg to 0.20 mg/kg in the wet season and between 0.10 mg/kg and 1.05 mg/kg in the dry season. Chromium was not detected in

some of the water and sediment samples; the highest concentration of Cr was recorded in point A (1.05 mg/L). However, the Cr values were all below the NESREA threshold of less than 1.0 mg/L except in Point A during the dry season. Although, chromium is an essential trace nutrients, its compounds are used as pigments, mordents, and dyes in textiles and as tanning agents in leather processing (Akan *et al.*, 2012). Sources of Cr in the drainage might be from waste waters from laundry chemicals, paints, tyre wear, corrosion of bushings, commercial welding, radiators, and erosion runoff as reported by Dixit and Twari (2008). Chromium enters into various environmental matrices (air, water, and soil) from a wide variety of natural and anthropogenic sources (Akan *et al.*, 2012; Adesuyi *et al.*, 2015a).

The levels of Zinc in the water samples were found between 0.10 mg/L and 1.70 mg/L during the wet season, and ranged from 0.11 mg/L to 1.2 mg/L during the dry season. The concentration of Zn in sediment samples were between 0.11 mg/kg and 0.9 mg/kg in the wet season; and between 0.07 mg/kg and 2.92 mg/kg in the dry season. Zinc was present in all the water and sediment samples. Zinc plays a biochemical role in the life processes of all plants and animals. It is an essential trace metal. Zinc is essential for growth in both plants and animals but also toxic at elevated level (WHO, 2004). Zinc is also potentially hazardous in soils because excessive levels lead to phytotoxicity (weed killer). Zinc is used in a number of alloys (brass and bronze), and pigments. All the Zn values were below the NESREA threshold value of less than 1.0 mg/L except at station A and station F. Concentration of Zn in the receiving river from this drainage system might over time become be high which may be toxic to the aquatic organisms as reported by WHO (2004) and Jolaoso *et al.* (2016). However, there was no significant difference ($p > 0.05$) in Zn concentration in water and sediment samples, and also in the two seasons under this investigation.

Nickel concentrations in water samples ranged from 0.10 mg/L to 1.6 mg/L in the wet season; and ranged from ND to 1.90 mg/L in the dry season. Nickel levels in sediment samples were between 0.10 mg/kg and 1.10 mg/kg in wet season; and ranged between 0.20 mg/kg and 0.60 mg/kg in the dry season. The highest Ni value in water was recorded in station E and the least in station D, while in sediment samples the highest and the lowest value were recorded in station F. There is no significant difference ($p > 0.05$) in Ni concentration in water and sediment sample, and also no seasonal difference. The concentrations of Ni were all below the NESREA threshold value of less than 1.0 mg/L except in stations B and F. The high concentration of Ni in these samples from this drainage system will subsequently lead to increased Ni level in receiving water body, hence, accumulation and toxicity in fishes and other aquatic organisms (WHO, 2004). It was reported that Ni contamination in fresh waters is only by anthropogenic pollution, industries being the prime contributor (Jolaoso *et al.*, 2016).

Conclusion

It is evident that the drains and channels in these industrial areas serve as point sources for industrial waste water into the environment. The released wastewaters, whose qualities do not meet acceptable limits in parameters, like pH, Temperature, BOD, COD, zinc, nickel, copper and lead are obvious sources of entrant of contaminants into water bodies or the soil. This is an indication that some of these industries still discharge untreated and or partially treated waste waters through the drainage system. Therefore, there is an urgent need for essential steps to be taken to treat all waste water before they are discharged into drainage system so as to reduce the pollutant loads in receiving water bodies. The findings from this research make it important for Government of Nigeria and other regulatory/compliance bodies to take the following actions: All industries in this industrial Estate should be mandated to install efficient and best available technologies in treatment of their waste waters as outlined in NESREA Act. Government needs to conduct regular on-site monitoring of waste and effluent drains, and assessment of waste water receiving water bodies (streams/rivers) to ensure that concentration of pollutants does not reach harmful level.

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