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Pollution Load of Heavy Metals in Ilupeju, Ikeja and Isolo Industrial Wastewaters and Seasonal Impacts on Quality of Water Downstream and Upstream in Lagos Metropolis

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Abstract: Profiles of heavy metals in Ilupeju, Ikeja and Isolo industrial wastewaters and seasonal impacts on quality of water downstream and upstream in Lagos metropolis were determined. Wastewater samples from industrial estate were collected at the point of discharge of effluents into the streams and at spatial interval of 50 to 200 meters upstream and downstream of the discharge point over a two- year period (2005-2007) .The effluents were analyzed for heavy metals using standard methods. At the point of wastewater discharge into water bodies, during dry and rainy seasons, only Manganese showed significant difference ($p < 0.05$) in the first year in Ikeja. In dry and rainy seasons, the level of iron fluctuated from 8.95 ± 0.18 mg/L upstream to 8.96 ± 0.88 mg/L downstream in Ikeja; 1.40 ± 0.17 mg/L to 15.94 ± 1.56 mg/L in Ilupeju and 9.10 ± 0.64 mg/L to 4.98 ± 0.76 mg/L in Isolo industrial zones. In all the industrial areas considered, all the heavy metals have high accumulation factor at one season or the other except chromium and zinc. Accumulation factor for manganese increases in order of 2.38<4.10<4.70 in Ilupeju, Ikeja, Isolo respectively and in the order of 2.21<3.91<4.04 for copper in Isolo, Ilupeju, Ikeja respectively. However, iron had highest accumulation factor of 11.38 in the rainy season for Ilupeju. The upstream and downstream levels of chromium, manganese, iron and lead were higher than permissible level with traces of cadmium. The upstream and downstream water quality was poor and not suitable for drinking and routine purposes hence control of industrial wastewater is necessary to asswage its impact on proximate river bodies.
Key words: industrial wastewaters, effluents, discharge point, upstream, downstream, accumulation factor, heavy metals, seasonal variation.

INTRODUCTION

Occurrence of heavy metals in waters and biota usually indicate the presence of natural and anthropogenic sources [1]. The major natural sources of metals in waters occurs when rocks and soils are directly exposed to surface water resulting in chemical weathering of minerals and soil leaching [2]. The anthropogenic sources are associated mainly with industrial and domestic effluents, urban storm, water runoff, landfill leachate [3-4].

Heavy metals are found in significant quantities particularly in effluents from printing, pulp and paper, metal manufacturing, paints and pigment and mining industries [2, 5]. The discharge of various treated and untreated liquid wastes from these industries into water bodies account for large amount of metals in the rivers and lakes.

The existence of heavy metals in aquatic environments has led to serious concerns about their influence on plant and animal life. Some metals such as copper, zinc and iron are biochemically classified as essential elements. Their presence in trace amounts play an important role in different physiological processes of living organisms. One the other hand, other elements such as lead and cadmium are non-essential to the body. The exhibit extreme toxicity even at trace levels [6-7]. The need to prevent their accumulation should therefore be given utmost priority.

All heavy metals exist in surface waters in particulate, colloidal and dissolved phases. Rivers are a dominant pathway for metals transport and this was the reason trace metals were regarded as significant pollutants of even some small riverine systems [8-11]. Extent of mixing with water current, dilution factor, direction of water flow, synergistic effect of heavy metals and rapid industrialization are known factors that contributed to high levels of metal in water [12-13].The aggravated levels of metals in industrial wastes

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are often toxic and could persist in the environment for a long time because of slow degradation thus causing hazards to human health, living organisms and ecosystem [14].

In Lagos with teeming population and diverse industrialization, levels of heavy metals in industrial wastewaters can be affected by seasonal changes. This study thus determines the impact of industrial wastewaters on upstream and downstream water quality as season changes. The choice of these three industrial areas was necessary by reason of size and diversity of industries releasing copious wastewaters into proximate streams thus causing changes in water quality. Regular assessment is necessary to check uncontrolled release from the industries and assess the performance of regulatory and supervisory bodies.

STUDY AREAS

The study was conucted in three major industrial areas in Lagos city namely: Ikeja, Ilupeju and Isolo industrial areas (Figures 1-3).

Ikeja is located 30km North of Lagos Island and spans a total area of 325sqkm, bounded on the North, South, West and East by Agege / Ifako Ijaiye; Oshodi/Isolo; Alimosho respectively [15]. The major industrial sectors ranges from pharmaceutical, food and beverages, pulp and paper, textiles, dyeing, chemical to electrical appliances. All the wastewaters discharged from different industries in the area are connected by a network of canals and sewers and channeled directly into Iya Alaro River. The river meets Shasha River at the Northern part of Lagos and flows to join Aromire River in the vicinity of Nigerian Bottling Company along WEMABOD site. The downward flow creeps through Oregun and Ojota and finally empties into Lagoon (Figure 1). In- between Oregun and Ojota, along Access Road, the water is being used by dwellers for washing and fishing purposes.

Ilupeju is located 10km North of Lagos City Core. The key processing industrial sectors include engineering products, cosmetics, foods and beverages ,plastics, printing and textile industries [16].The sewers carrying the effluents pass through Oshodi/Anthony expressway and channeled into Arowojobe River until it eventually empties into the Lagoon (Figure 2).

Isolo is located 10 km North of Lagos City. It is bounded on the North, South, East and West by Ikeja, Mushin,Oshodi and Okota respectively. The major industrial sectors include textiles, plastic, clothing, beverages, leather, steel and aluminium. The processing industries have their effluents discharged into Osolo River which flows from Fatai Atere through Ladipo market behind Ajao Estate and down to Oke-Afa (Figure 3). The water was being used for bathing and washing

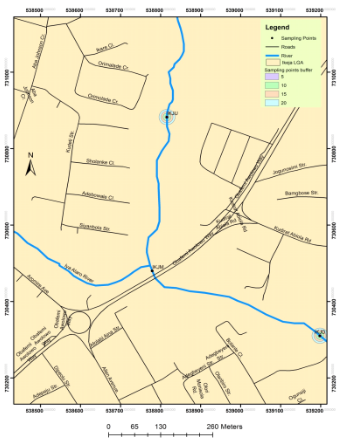
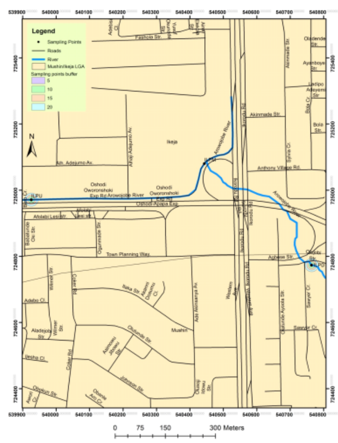


Figure 1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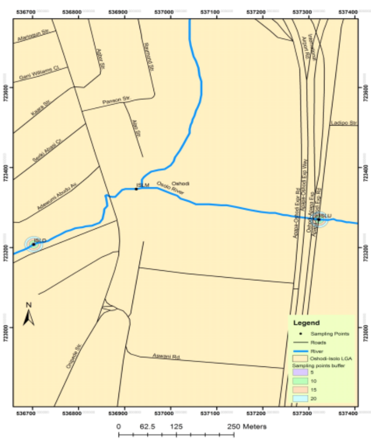
Figure 3

Figures 1-3. Sampling points in Ikeja, Ilupeju and Isolo industrial areas respectively

MATERIALS AND METHOD

Glassware Cleaning Procedures

Prior to sample collection, sampling materials (long rope tied to 500ml clean plastic containers) and collection bottles (1 Litre standard bottles) were thoroughly washed with dilute (0.1 percent) low phosphate soap and tap water. They were rinsed with dilute (5 percent) nitric acid solution, followed by deioned water. At the points of sample collection, these bottles were rinsed two to three times with some quantity of the water being sampled.

Sampling points and duration

At the onset, a reconnaissance survey was conducted on the rivers so as to define point sources as well as sampling points. Along each river that receives wastewaters from an industrial estate; three points were carefully chosen that would best represent the river sampled as well as ready accessibility for sampling. The samples were collected at (a) point of industrial wastewaters discharge into the river (Middle), (b) upstream point (Upper) of about 200 meters from discharge point and (c) downstream point (Down) located at about 200 meters away from discharge point. Upstream and downstream points were 400 metres apart. The sampling was carried out bi-monthly for two years spanning two dry and two rainy seasons. A dry season covers November to March and rainy season covers May to September.

Sample collection and preservation

Composite sample of industrial wastewater with river water at the point of discharge into the river (MDS) was collected. Composite samples of water upstream (UPS) and water downstream (DWS) were also taken. At any sampling site The set of samples was used to determine heavy-metals (HM_u, HM_m, HM_d). The samples were filtered and the filtrate treated with 3 ml 1: 1 $HN0_3$ per litre in order to keep the metal ions in solution before analysis. The fifth set of samples was used to determine other physico-chemical parameters (OPM_u, OPM_m, OPM_d).

Samples were collected in clean standard plastic bottles ($1000cm^3$) in such a way that no bubbles were formed in the bottles as they were tightly closed. To enhance homogeneity and uniformity, the water samples were collected at the sub-surface and middle depth of the river. After collection, the samples were taken to the laboratory, Department of Chemistry, University of Lagos, Akoka where all analytical work was carried out within 5 days.

Heavy metals analysis was carried out by Atomic Absorption Spectrophotometer (AAS). 500ml of the sample was acidified with 1 ml conc. HNO_3 per 100ml of the sample and digested at 121^0C for one hour to solubilise the particular matter content. The digested sample was filtered into a 250ml standard flask, made up to the mark with distilled-deionized water and stored in a nitric acid pre-washed polyethylene bottle in the refrigerator. The 2ml of sample was aspirated into a flame where it becomes atomized. Based on characteristic wavelength of each metallic element, correct hollow cathode lamp made up of that element was chosen, installed and aligned in Atomic Absorption Spectrophotometer (Perkins Elmer Model 2380). AAS was calibrated for each element using standard solution of known concentration before sample injection [17]. The paired t-test was used to compare the mean of seasonal variations

RESULTS AND DISCUSSION

Table 1. Seasonal Mean composition of heavy metals at the point of effluents discharge into waterways in Ikeja Industrial Zone (mean ± SD) n=3

Parameters	[1]Dry Season	[1]Rainy Season	p≤0.05 Ind. T – test	[2]Dry Season	[2]Rainy Season	P≤0.05 Ind. T-test
Cr (mg/L)	0.71±0.01	0.77±0.03	0.94	0.25±0.02	0.25±0.01	0.99
Mn (mg/L)	0.15±0.04	0.40±0.06	0.01*	2.62±0.03	0.91±0.04	0.43
Fe (mg/L)	0.92±0.06	0.64±0.03	0.31	6.23±0.31	10.23±0.10	0.34
Cu (mg/L)	0.78±0.03	0.69±0.09	0.75	0.08±0.01	0.06±0.02	0.31
Zn (mg/L)	0.75±0.03	0.28±0.08	0.26	2.54±0.05	1.76±0.06	0.70
Cd (mg/L)	0.02±0.01	0.50±0.05	0.50	0.01±0.01	0.14±0.01	0.47
Pb (mg/L)	ND	0.09±0.01	ND	0.16±0.02	ND	ND

Table 2. Seasonal Mean composition of heavy metals at the point of effluents discharge into waterways in Ilupeju Industrial Zone (mean ± SD) n=3

Parameters	[1]Dry Season	[1]Rainy Season	p≤0.05 Ind. T – test	[2]Dry Season	[2]Rainy Season	P≤0.05 Ind. T-test
Cr (mg/L)	0.50±0.06	0.65±0.08	0.76	0.20±0.01	0.13±0.06	0.79
Mn (mg/L)	0.14±0.04	0.84±0.01	0.21	0.57±0.05	0.20±0.01	0.60
Fe (mg/L)	0.76±0.07	0.93±0.05	0.74	3.45±0.03	2.97±0.04	0.88
Cu (mg/L)	1.62±0.08	0.56±0.04	0.33	0.38±0.01	0.41±0.03	0.93
Zn (mg/L)	1.53±0.02	0.43±0.01	0.25	2.32±0.07	1.77±0.03	0.75
Cd (mg/L)	0.01±0.01	0.16±0.09	0.38	0.01±0.01	0.21±0.06	0.64
Pb (mg/L)	ND	0.18±0.01	-	0.24±0.01	ND	-

Table 3. Seasonal Mean composition of heavy metals at the point of effluents discharge into waterways in Isolo Industrial Zone (mean ± SD) n=3

Parameters	[1]Dry Season	[1]Rainy Season	p≤0.05 Ind. T – test	[2]Dry Season	[2]Rainy Season	P≤0.05 Ind. T-test
Cr (mg/L)	1.63±0.04	0.86±0.05	0.37	0.26±0.01	0.13±0.05	0.64
Mn (mg/L)	ND	5.65±0.06	-	6.37±0.08	0.85±0.09	0.42
Fe (mg/L)	0.81±0.05	0.98±0.06	0.60	3.62±0.03	4.02±0.01	0.87
Cu (mg/L)	0.53±0.03	1.37±0.02	0.13	0.26±0.05	0.07±0.02	0.39
Zn (mg/L)	0.41±0.07	0.35±0.05	0.55	2.41±0.50	1.70±0.42	0.73
Cd (mg/L)	ND	0.24±0.03	-	0.00±0.00	0.21±0.06	0.39

Note: * Independent T-test is significant at the 0.05 level (2-tailed)
[1, 2] First and second year mean concentration ND: Not Detected

At the point of wastewater discharge into water bodies, the chromium levels were still high ranging from 0.25 ± 0.01 mg/L to 0.77 ± 0.03 mg/L, 0.13 ± 0.06 mg/L to 0.65 ± 0.08 mg/Land 0.13 ± 0.05 mg/L to 1. 63 ± 0.04 mg/L in Ikeja, Ilupeju and Isolo industrial zones respectively. This might be attributed to chromium in wastewater from tannery and textiles industries used as tanning and oxidizing agents respectively [18-19].

Manganese was not detected in the dry season of the first year of sampling in Isolo industrial zone. Evidence of significance difference (P≤0.05) observed in the first year of sampling in Ikeja industrial zone showed seasonal variation. This might be accounted for by the mobility and effect of dilution during rainy season.. Higher levels of manganese at downstream point caused by effluents discharged into water ways reported in the literature corroborated findings from this study [20-21]. However, the report of similar research conducted in the rainy season (May to July) which showed lower concentration of Manganese below acceptable limit in the range between 0.025mg/L and 0.094mg/L did not agree with the findings from this study[22]. Considerable levels of manganese in form of permanganate are harmful and could kill fish at concentration between 2.0 - 40mg/L [2].

Higher level of Iron (Fe) was observed in the rainy than dry season at the point of industrial wastewater discharge into the waterways. In the rainy season, the level of iron fluctuated from 6.23 ± 0.31 mg/L to 10.23 ± 0.10 mg/L in Ikeja; 2.97 ± 0.04 mg/L to 3.45 ± 0.03 mg/L in Ilupeju and 3.62 ± 0.03 mg/L to 4.02 ± 0.01 mg/L in Isolo industrial zones. The higher levels in the· rainy season might be attributed to iron salts in wastewater from iron and steel industries aided by water flow.

The variations of mean concentration of copper between seasons and across zones displayed some peculiarities. The low concentration at the point of wastewater discharge into the water bodies in wet seasons was in contrast with some findings in the literature [23]. Even higher concentration of copper as high as 91.2mg/kg was reported in a similar study conducted in wet season [24]. This was attributed to the impact of industrial discharge effluents mainly from paints and steel industries.

The higher zinc concentration in the dry seasons than rainy season might be due to low dissolution of zinc as a result of water temperature. [1] reported the concentration of some heavy metals in dry and wet seasons. They observed that zinc levels were significantly higher in warm period than cold period due to change in river flow and water temperature. [25] observed that a concentration effect of dissolved zinc could also occur in water during dry season due to water evaporation. In a similar study which corroborated this study, seasonal variation of zinc was found to be higher in summer than winter periods [7].

At the point of wastewater impact with river, cadmium was estimated in lower concentration than other heavy metals. The concentration range in the three industrial zones lies between 0.0lmg/L and 0.50mg/L which might arise from industrial and domestic activities. In support of this finding, similar study reported cadmium concentration range between 0.01 mg/L and 0.69 mg/L [26]. Though there was no significant difference in cadmium concentration at this point, its concentrations were generally higher in rainy than dry seasons for all industrial zones.

Slight concentration of Lead was detected in the rainy seasons and dry seasons of Ikeja and Ilupeju zones in the first and second year of sampling respectively. The concentration of Lead at the point of industrial wastewater impact with water bodies range between 0.09 ± 0.01 mg/L and 0.16 ± 0.02 mg/L in Ikeja, 0.18 ± 0.01 mg/L and 0.24 ± 0.11 mg/L in Ilupeju zones. This could be attributed to some domestic and commercial activities.

Table 4. Upstream and Downstream water quality parameters for Ikeja Industrial zone in the second year of sampling (Mean ± SD) n=3

Water Quality Parameters	Dry Season		Rainy Season		WHO recommended limit
	IKJu	IKJd	IKJu	IKJd	
Cr (mg/L)	0.20±0.07	0.31±0.08	0.24±0.01	0.25±0.01	0.05
Mn (mg/L)	0.99±0.01	4.06±0.09	0.66±0.04	0.81±0.02	0.1
Fe (mg/L)	4.64±0.85	5.70±0.26	8.95±0.18	8.96±0.88	0.3
Cu (mg/L)	0.21±0.02	0.05±0.03	0.05±0.02	0.04±0.02	1.0
Zn (mg/L)	1.68±0.24	2.62±0.49	1.68±0.02	1.39±0.01	5.0
Cd (mg/L)	0.01±0.01	0.25±0.02	0.20±0.05	0.14±0.01	0.05
Pb (mg/L)	0.18±0.01	0.18±0.02	ND	ND	0.06

Table 5. Upstream and Downstream water quality parameters for Ilupeju Industrial zone in the second year of sampling (Mean±SD) n=3

Water Quality Parameters	Dry Season		Rainy Season		WHO Recommended Limit
	ILPu	ILPd	ILPu	ILPd	
Cr (mg/L)	0.27±0.05	0.29±0.09	0.12±0.06	0.12±0.05	0.05
Mn (mg/L)	1.66±0.22	1.15±0.89	0.20±0.01	0.40±0.07	0.1
Fe (mg/L)	6.94±0.08	4.66±0.81	1.40±0.17	15.94±1.56	0.3
Cu (mg/L)	0.12±0.08	0.48±0.02	0.13±0.06	0.10±0.02	1.0
Zn (mg/L)	2.05±0.60	2.43±0.06	2.17±0.09	2.52±0.07	5.0
Cd (mg/L)	0.05±0.02	0.01±0.01	0.21±0.04	0.20±0.05	0.05
Pb (mg/L)	0.09±0.04	0.29±0.01	ND	ND	0.06

Table 6. Upstream and Downstream water quality parameters for Isolo Industrial zone in the second year of sampling (Mean ± SD) n=3

Water Quality Parameters	Dry Season		Rainy Season		WHO Recommended Limit
	ISLu	ISLd	ISLu	ISLd	
Cr (mg/L)	0.26±0.06	0.21±0.02	0.13±0.04	0.13±0.03	0.05
Mn (mg/L)	6.75±0.73	4.57±0.70	0.90±0.04	0.46±0.01	0.1
Fe (mg/L)	4.89±0.16	3.63±0.65	9.10±0.64	4.98±0.76	0.3
Cu (mg/L)	0.05±0.02	0.05±0.01	0.07±0.01	0.06±0.02	1.0
Zn (mg/L)	2.59±0.06	2.64±0.09	1.95±0.07	1.37±0.04	5.0
Cd (mg/L)	0.01±0.01	0.01±0.00	0.20±0.06	0.20±0.06	0.05
Pb (mg/L)	0.08±0.04	0.18±0.01	ND	ND	0.06

In both dry and rainy seasons, across the industrial zones, the concentration range of Chromium (Cr) from water samples taken upstream was between 0.12 ± 0.06 mg/L and 1.41 ± 0.35 mg/L. This exceeded the internationally recommended desirable levels of 0.05mg/L for drinking water. Higher level of chromium in water upstream than the recommended value has been reported in support of this finding [27]. More downstream accumulation of chromium was observed in the dry than rainy seasons of Ikeja and Ilupeju except Isolo industrial zone. This could be explained on the basis of low solubility of heavy metals as a result of less dilution of water and warm temperature. An average concentration of 3.25 mg/L chromium in warm dry and 1.44 mg/L in cold wet seasons reported was in harmony with this study[1]. Although, chromium (III) compounds are less damaging to the health due to their limited absorption (4%) by the body, but chromium (IV) compounds are actually poisonous. When in contact with the skin, it could trigger dermatitis, allergies and irritations, thus considered carcinogenic to humans [28].

The upstream and downstream levels of manganese were higher beyond permissible level.

Similarly, the downstream concentrations of iron were higher than upstream especially in rainy season. In the rainy season the highest downstream concentration of iron was in Ilupeju zone (15.94 ± 1.56 mg/L) with highest accumulation factor of 11.38. The concentrations of iron in Ikeja and Isolo industrial zones were 8.696 ± 4.88 mg/L and 4.98 ± 2.76 mg/L respectively.In consonant with this study,higher concentration of iron has been repoted in a similar study in the literature [28] .Although, iron could serve as an essential nutrient of the blood and skeleton, accumulations of large amount in the body could lead to tissue damage and hyperhaemoglobularia [29].

The upstream low levels of copper in the range of 0.05± 0.03-1.21± 0.04;0.12± 0.08-1.25± 0.04;0.05± 0.02-0.70± 0.07 in Ikeja,Ilupeju,Isolo were in some cases greater than upstream levels of 0.01 - 0.09mg/L reported from similar studies in the literature [30-31]. This showed impact from non-point sources.However, related findings where downstream levels of copper were low in water bodies as the ones obtained from this study have also been reported in harmony with this study [26]

The levels of zinc at all points of sampling were below (5.0 mg/L) the highest permissible level for drinking water. Although, this level may not pose immediate visible danger, however, when it accumulates, it becomes problematic to aquatic ecosystem [32-33].

In effect, concentration of zinc tended to accumulate downstream during dry season especially in the second year sampling. The considerable levels of zinc observed in water upstream especially in Ikeja industrial zone might be attributed to impact of nearby Olusosun land fill. According to the findings, zinc was reported as the most predominant metal in the Olusosun landfill which have tendency of leaching to nearby stream and enhancing its concentration downstream [34].

The detection of cadmium in water upstream and downstream was not consistent. The levels of cadmium were below detection level especially in the dry season of first year and rainy season of second year of sampling. This might be due to the fact that cadmium battery- producing industries and other sources of cadmium were scanty and not heavily located in the zones. At some points and locations where cadmium was detected, the levels were higher than maximum permissible level of 0.01mg/L recommended [35]. The high levels could be attributed to bioaccumulation of cadmium being typical of any trace metal. [36] have reported that the process of bioaccumulation especially of heavy metals was responsible for major pollution of water bodies receiving effluents.

Upstream and downstream levels of Lead showed similar trend in seasonal variation. The levels were above the permissible level in water. Concentration of Lead in water above permissible limit has been reported in the literature [7]. However, in support of this findings, high concentration of Lead upstream in the range of 0.32 ± 0.04 mg/L due to domestic activities has also been reported elsewhere [1]. Downstream, concentration of Lead has been reported in a similar study [29, 37]. They reported that the concentration was due to Lead battery -based units and heavy vehicular transaction used for industrial activities. Direct use of untreated water for drinking by downstream dwellers could be detrimental to health. It has been reported that neurological damage of fetuses; abortion and other complications in children less than three years of age were major health hazards of Lead [14, 38].

Lead was not detected at all in Isolo industrial zone and some seasons of Ikeja and Ilupeju zones. This might be due to absence of Pb producing industries and reduced impact of vehicular transaction to the industries. Similarly, complexation ability of Lead might reduce its availability in elemental form for detection. In similar studies, it was reported elsewhere that Lead was not detected in dry season [23], rainy season [39-40], upstream [41] and downstream [42]. They attributed this to ready absorption by the sediment which could act as sink for trace metals of high toxicity.

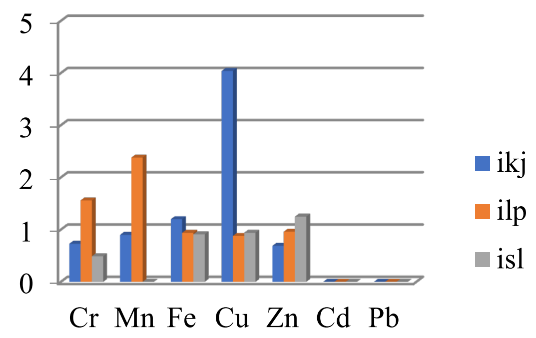

Figure 4. First year dry season accumulation factor

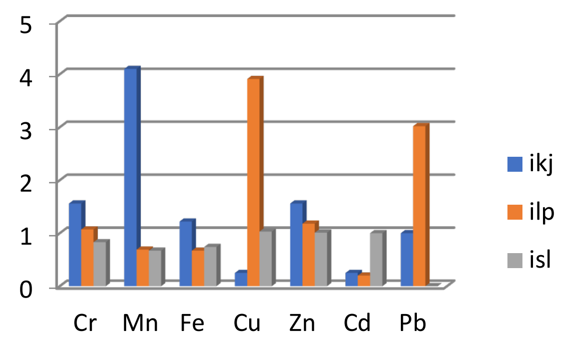

Figure 5. Second year dry season accumulation factor

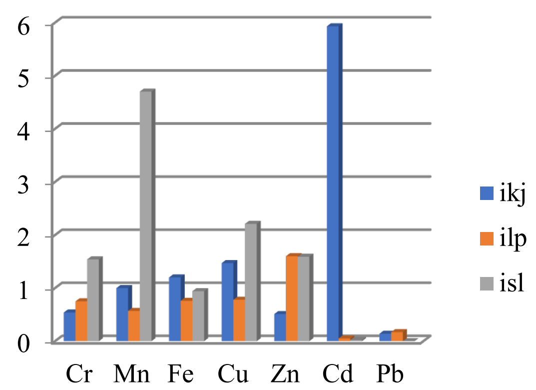

Figure 6. First year rainy season accumulation factor

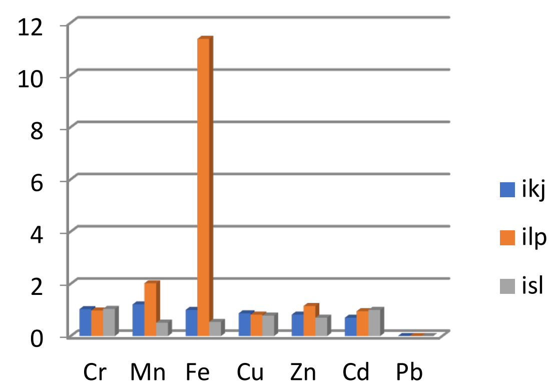

Figure 7. Second year rainy season accumulation factor

In the dry season, higher downstream accumulation factor of 4.10 and 2.38 were observed for manganese in Ikeja and Ilupeju industrial zones respectively. However, accumulation factor of 4.70 obtained in the rainy season for Isolo industrial zone might be attributed to the presence of manganese salts from wastewater discharge from industries. Leaching from nearby waste dumps could also account for its higher content.

Report from this study showed accumulation factor of 4.04, 3.91 and 2.21 in Ikeja, Ilupeju and Isolo industrial zones respectively. However, high accumulation factor (18.4) of copper in support of the finding has been reported [21].

Cadmium (Cd) concentration in water even in small quantity is inimical to living organisms.

Downstream accumulation of cadmium generally increased in rainy season with Accumulation Factor of 5.93 observed in the first year of Ikeja industrial zone. Reports on variations of dissolved trace metals and quality of water downstream were in support of this finding[41-42]. Accumulated cadmium level has been linked with a number of health and significant kidney damage in people that drink cadmium contaminated water [43]. However, women are prone to breast cancer through water contaminated with high level of cadmium.

The downstream accumulation of Lead in the factor of 3.02 as observed in Ilupeju industrial zone might be due to impacts of industrial wastewaters containing Lead.

CONCLUSION AND RECOMMENDATIONS

In both seasons, there were high levels of heavy metals in discharged industrial wastewaters from all the industrial areas, however only manganese level showed seasonal impact in Ikeja. Higher levels at downstream than upstream showed that industrial wastewater was responsible for high impact on water quality. All heavy metals were higher at upstream and downstream than WHO permissible level which may limit their use for drinking and routine purposes. Thus regular assessment and seasonal treatment are required. Also, combined treatment is necessary at the points where wastewater discharges into the river.

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