SEDIMENT QUALITY ASSESSMENT OF OKE-ITOKU RIVER, ABEOKUTA, SOUTHWEST NIGERIA

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ABSTRACT

This research investigated contamination of sediments due to continuous tie and dye effluents discharge into Oke-Itoku River, Abeokuta, Nigeria. Surface and subsurface sediment samples were collected upstream, at point of discharge and downstream. The contamination factor (C_f), degree of contamination (C_d) and geo-accumulation index (I_{geo}) were also determined. Physico-chemical parameters such as Temperature, Total Dissolve Solids (TDS), Electrical Conductivity (EC), pH, Dissolved Oxygen (DO) and five selected heavy metals: Chromium (Cr), Copper (Cu), Cobalt (Co) and Lead (Pb) were measured. Results revealed mean TDS, EC, Temperature and DO pollution of 485.6±134.66 mg/L, 2153.6±1122.19 µS/cm, 32.46±0.57^{0}C and 4.01±0.43 mg/L respectively at the discharge point. The heavy metal concentrations for the surface and subsurface sediments obtained had a range of 11.5-18.3, 30.1-39 mg/L for Cr; 12.6-27.0, 23.8-42 mg/L for Cu; 16.2-31.0, 23.8-42.0 for Co and 1.8-3.2, 1.8-3.5 mg/L for Pb in surface and subsurface sediment respectively. Heavy metal contamination in the sediments of Oke-Itoku river showed order of enrichment of Co>Cu>Cr>Pb according to C_f, C_d and I_{geo} for the study area. There are only natural inputs of chromium and copper into the river while Cd, Co and Pb concentrations are due to anthropogenic input mainly from tie and dye by-products.

Keywords: Surface sediments, sub-surface sediments, heavy metal, pollution, tie and dye

INTRODUCTION

Heavy metals are members of elements that exhibit metallic properties and they include transition metals, some metalloids, lanthanides and actinides. These metals are known for their high toxicity which poses serious environmental health hazards to humans. They are found in the effluents of some industrial processes such as textile making, paints production, metal plating, glass fabrication, battery production and fertilizer compounding, sometimes discharged into wastewater stream without prior removal. Unlike other constituents of a typical industrial wastewater, heavy metals are non-biodegradable and their continuous release into the environment can lead to intolerable concentration above the maximum allowed limits specified by World Health Organization (Anyakora *et al.*, 2010). The most common heavy metal contaminants are Cd, Cr, Cu, Hg, Pb, and Zn (Tangahu *et al.*, 2011). Heavy metals have been continuously studied and confirmed by World health Organization and other international bodies as been toxic to human health (Järup, 2003).

In Nigeria, there are various local tie and dye producers that have strengthened their existence by creating colonies and associations (Oyeniyi *et al*., 2013). The Itoku Batik colony situated in Itoku, a commercial center in Abeokuta, South West Nigeria is a typical example. With over 100 production points, Itoku batik producers attract customers from within and outside Abeokuta. Effluents produced are usually emptied into accessible drainages which flow directly into Oke-Itoku river. The river empties into Lafenwa River, a tributary of Ogun River. This study investigated the sediment quality and level of heavy metals concentrations of Oke Itoku river.

MATERIALS AND METHODS

Study Area

Abeokuta, the Capital of Ogun state, situated in Southwest Nigeria covers an approximate area of about 40.63 km^2. Oke-Itoku river is a natural channel which derives its source from the Olumo rock waterfall in Abeokuta. It collects storm water, commercial wastewater and domestic wastewater directly from the surrounding communities and discharges downstream to Ogun river. A section of the Itoku waterway from an upstream point (7^{0}9'30", 3^{0}20'38") to downstream point (7^{0}9'32", 3^{0}20'29") is surrounded by local Adire-making colonies as shown in Figure 1. Within this section, the waterway constantly receives by-products of the tie and dye processes either by direct discharge or flow from small network drainages around the settlement.

Field Measurements

Physico-chemical parameters which include dissolved oxygen (DO), total dissolved solids (TDS), temperature, pH and electrical conductivity (EC) were obtained insitu at 15 sampling locations using standard methods according to APHA (2005).

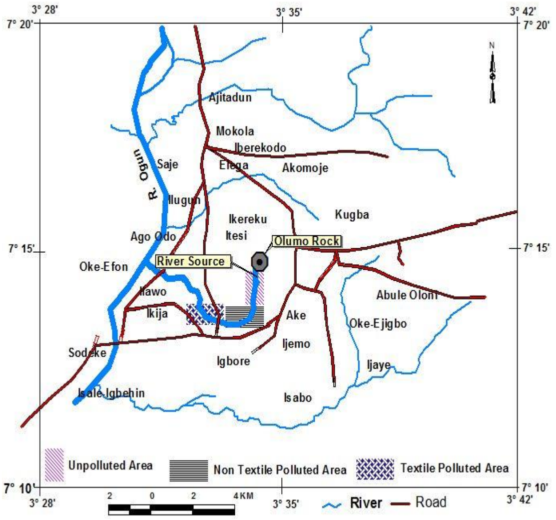

Figure 1: Map of the Study Area

Sample Collection and Analysis

Sediment samples were collected along Oke-Itoku river as shown in Table 1 and Figure 1. Sub-surface sediment 25 cm below the river bed were also collected upstream and within Textile Polluted Area (TP). Some portion of the sediment samples were oven-dried at 105^0C until constant weight is obtained and then grinded in agate mortar for homogenization. Sediment samples which passed through No. 200 sieve were equally analysed for heavy metal determination. Moisture content analysis, organic matter content test and sieve analysis were also performed on the sediments. Cr, Cd, Cu, Co and Pb contents were determined using AAS at the Faculty of Public Health laboratory, UCH Ibadan.

Table1: Location of sampling points across the Oke-Itoku River

River Sections	Sampling Points	Latitude	Longitude
River Source Area	1	$7^0$9'30"N	$3^0$20'38"E
	2	$7^0$9'29"N	$3^0$20'38"E
	3	$7^0$9'29.4"N	$3^0$20'38"E
	4	$7^0$9'29"N	$3^0$20'37"E
	5	$7^0$9'29"N	$3^0$20'36"E
Non-textile Polluted Area	6	$7^0$9'30"N	$3^0$20'36"E
	7	$7^0$9'29"N	$3^0$20'38"E
	8	$7^0$9'30"N	$3^0$20'35"E
	9	$7^0$9'30"N	$3^0$20'34"E
	10	$7^0$9'30"N	$3^0$20'33"E
Textile Polluted Area	11	$7^0$9'31"N	$3^0$20'33"E
	12	$7^0$9'31"N	$3^0$20'32"E
	13	$7^0$9'31"N	$3^0$20'31"E
	14	$7^0$9'32"N	$3^0$20'30"E
	15	$7^0$9'32"N	$3^0$20'29"E

RESULTS AND DISCUSSION

Heavy Metal Concentrations

The heavy metal concentrations of the surface sediments for all the sampling points in the three sections of the study area are represented in Table 2. Metals concentration ranges in surface sediment of the river source were from 5.2 to 7.0 mg/Kg for Cr and 12.4 to 16.1 mg/Kg for Cu dry weight. In the section 2 the metal concentration was between 6.0 and 8.3 mg/Kg Cr; 16.2 mg/Kg to 18.8 mg/Kg Cu dry weight. Co, Pb and Cr were not detected in the two sections. Section 3 of the study area is the textile polluted region and the metals concentration vary as follows: Cr – 11.5 to 18.3 mg/Kg; Cd – 0 mg/Kg; Cu – 12.6 to 27.0 mg/Kg; Co-16.2 to 31.0 mg/Kg; Pb – 2.6 to 3.2 mg/Kg dry weights. Mean concentrations of metals in the river sediments are Cr – 9.23 mg/Kg; Cd – 0mg/Kg; Cu – 17.72 mg/Kg; Co – 6.67 mg/Kg; Pb – 0.81 mg/Kg dry weights. The metal concentration level of surface sediment of the river is in the order: Cu > Cr > Co >Pb> Cd.

The metal concentration of sub-surface sediments of textile polluted region in Oke Itoku river are 34.04±3.86, 0.64±0.05, 40.7±3.29, 34.44±7.38 and 2.6±0.64 mg/Kg for Cr, Cd, Cu, Co and Pb respectively.

Pearson's correlation coefficient matrix among the five heavy metals in sub-surface sediments of the textile polluted region is reported in Table 3. Positive correlations between contaminants pair of Cr and Co is r = 0.069, Cr and Pb is r = 0.781, and Cu is 0.042, Cd and Co is r = 0.484, Cu and Co is r = 0.251, Cu and Pb is r = 0.404, Co and Pb is r = 0.543 indicates linear relationship exist between most of the pairs of the metals concentration in respect of the isolated textile effluents.

Table 2: Concentrations of heavy metals in surface sediment samples from the Oke-Itoku River

RIVER SECTIONS	Concentration of Heavy Metals (mg/Kg dry Weight)					
	Sample No.	***Cr***	***Cd***	***Cu***	***Co***	***Pb***
SECTION 1/ RIVER SOURCE (RS)	1	5.2	0	16.1	0	0
	2	7	0	13.9	0	0
	3	4.5	0	12.4	0	0
	4	3.8	0	13.6	0	0
	5	6.1	0	14.7	0	0
SECTION 2 /NON-TEXTILE POLLUTED (TP)	6	8.3	0	16.7	0	0
	7	7.6	0	18.8	0	0
	8	6	0	16.2	0	0
	9	7.5	0	18.3	0	0
	10	6.5	0	17.5	0	0
SECTION 3/ TEXTILE POLLUTED (TP)	11	15.4	0	27	31	3.2
	12	11.5	0	23.1	16.2	2.2
	13	13.6	0	12.6	19.4	2.4
	14	17.2	0	19.5	16.3	1.8
	15	18.3	0	25.4	17.2	2.6
	Mean	9.23	-	17.72	6.67	0.81
	Max	18.3	-	27.00	31.00	3.20
	Min	3.80	-	12.40	0	0
	SD	4.75	-	4.47	10.33	1.22

Table 3: Correlation matrix between heavy metals in sub-surface sediment samples from the textile polluted area

	Cr	*Cd*	*Cu*	*Co*	*Pb*
Cr	1				
Cd	-0.482	1			
Cu	-0.118	0.042	1		
Co	0.069	0.484	0.251	1	
Pb	0.781	-0.213	0.404	0.543	1

The standard deviation between metal concentration in sub-surface sediments and fine portion sediments of the textile polluted section varies from metal to metal and are greater than zero. This implies that the spatial distribution pattern of metal concentrations in the area is irregular.

It was observed that there is low linear relationship (r = 0.1) in the organic matter (OM) and moisture content (MC) of the river without any isolation as shown in Figure 2. This could be due to the heavy discharge of textile wastewater at some point which is expected to alter the natural physico-chemical properties of the river. However, the moisture content and organic matter content of an isolated textile polluted region of the river in respect to surface sediment and subsurface sediment exhibit higher linear relationship (r = 0.3) as shown in Figure 3.

The heavy metals contamination of the Oke-Itoku River sediments was compared with the USEPA sediment quality shown in Saha and Hossain (2011). The sediments of the Oke-Itoku River are not heavily polluted with heavy metals, however, sediments of the textile effluents point showed an increasing trend for all the metals from their low concentrations at the river source area (Table 4).

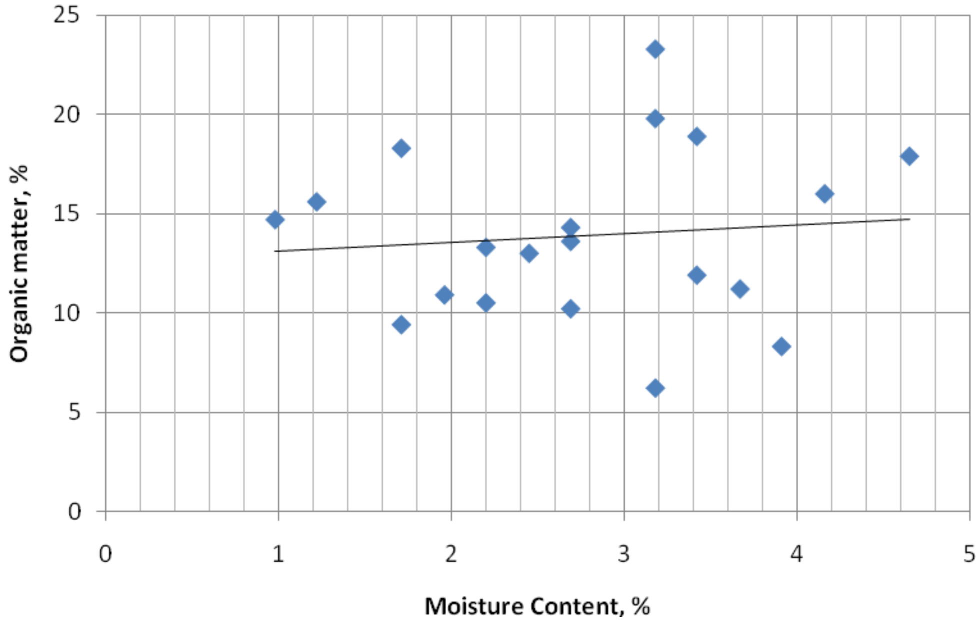

Fig. 2: Correlation between OM and MC of sediment for the entire area (r=0.1)

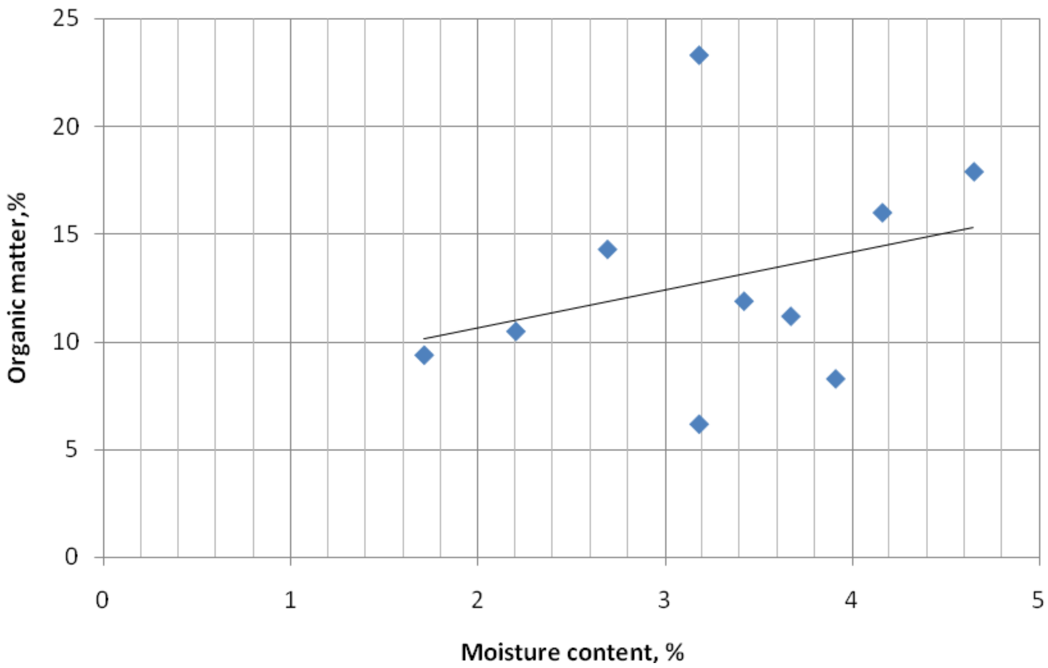

Fig. 3: Correlation between OM and MC of sediment for textile polluted area (r=0.3)

Table 4: Comparison of the present study to the USEPA guidelines for sediments (mg/Kg dry weights)

Metal	Not Polluted	Moderately Polluted	Heavily Polluted	Present Study			
				RS	**NTP**	**TP**	**STP**
Cr	<25	25-75	>75	3.8-7	6-8.3	11.5-18.3	30.1-39
Cd			>6	0	0	0	0.6-0.7
Cu	<25	25-50	>50	12.4-16.1	16.2-18.8	12.6-27	36.2-44.7

The evaluation of the contamination status of sediment in the present study is as shown in Table 5. Contamination factor (C_f) as given by Martin and Meybeck (1979); Abbasi*et al*. (1989); Merian(1985) and Smith and Carson (1981) is the measured concentration of metals in sediment divided by background concentration of metals in world surface rock average. Degree of contamination is the sum of all contamination factors for each location.

The C_f was less than 1 for all the metals in the river source and non-textile polluted section indicates low contamination, similarly C_d was less than 6, indicating low contamination degree (Hakanson, 1980). In surface sediment of textile polluted section of Oke itoku river, the C_f and C_d values increased with Cobalt having C_f classification of $1 < C_f < 3$ which indicates moderate contamination and the C_d is 1.93. The C_f and C_d values for the subsurface sediment of the River show significant priority. Apart from the increasing trend in C_f and C_d Cadmium exhibited considerable contamination factor ($3 \leq C_f < 6$) while the degree of contamination showed moderate contamination degree ($6 \leq C_d < 12$) as opined by Hakanson, (1980).

Generally, it can be inferred that the textile effluent discharge is likely to have upsurge the enrichment of metal concentration particularly Cadmium, Cobalt and Copper from the effluent point downstream the River. The order of enrichment of metals is Cd>Co>Cu>Cr>Pb.

Table 5: Contamination factors and contamination degree of heavy metals in the sediment of the Oke-Itoku River

River Section	Contamination Factor (Cf)					Degree of Contamination
	Cr	***Cd***	***Cu***	***Co***	***Pb***	
RS	0.05	0	0.44	0	0	0.50
NTP	0.07	0	0.55	0	0	0.62
TP	0.16	0	0.67	1	0.1	1.93
STP	0.35	3.2	1.27	1.72	0.13	6.67
Background	97	0.2	32	20	20	

Assessment of metal contamination in the sediment in terms of geo-accumulation index (I_{geo}) was evaluated by comparing the metals concentrations of the present study with pre-industrial levels using the equation: $I_{geo} = \log_2 \left(\frac{Cn}{1.5Bn} \right)$ (Muller, 1979). Where C_n is the concentration of metal, B_n is the world surface rock average and average concentration of cobalt in the earth crust given by Martin and Meybeck (1979); Abbasi *et al*. (1989); Merian (1985); Smith and Carson (1981).

Figure 7 presents the geo-accumulation index values for the sediments of the Oke-Itoku River. According to the Muller scale for geo-accumulation, the geo-accumulation index obtained implies that Oke-Itoku River is naturally free of heavy metals accumulation since all I_{geo} values within the river source and non-textile polluted area are in class Igeo ≤ 0. However, there is migration from unpolluted class to moderately polluted class in the sediment quality of subsurface textile polluted area given 0 ≤ Igeo ≥ 1. Generally, the mean Igeo values of the sediment quality of Oke Itoku river are in the order: Cd>Co>Cu>Cr>Pb.

CONCLUSION

The results of this study gave valuable information about heavy metal contents and physical characteristics of sediments from different sampling sections of Oke-Itoku River, a network of Ogun River. The order of the mean concentrations of the analysed heavy metals is Cu>Cr>Co>Pb>Cd. Isolating the river source (RS), the non-textile polluted (NTP) and textile polluted (TP) sections of the River, shows that there are only natural inputs of chromium and copper while cadmium, cobalt and lead concentrations are due to anthropogenic input mainly from tie and dye by-products.

It is also found that the spatial distribution pattern of metal concentration due to anthropogenic input in the area is irregular.

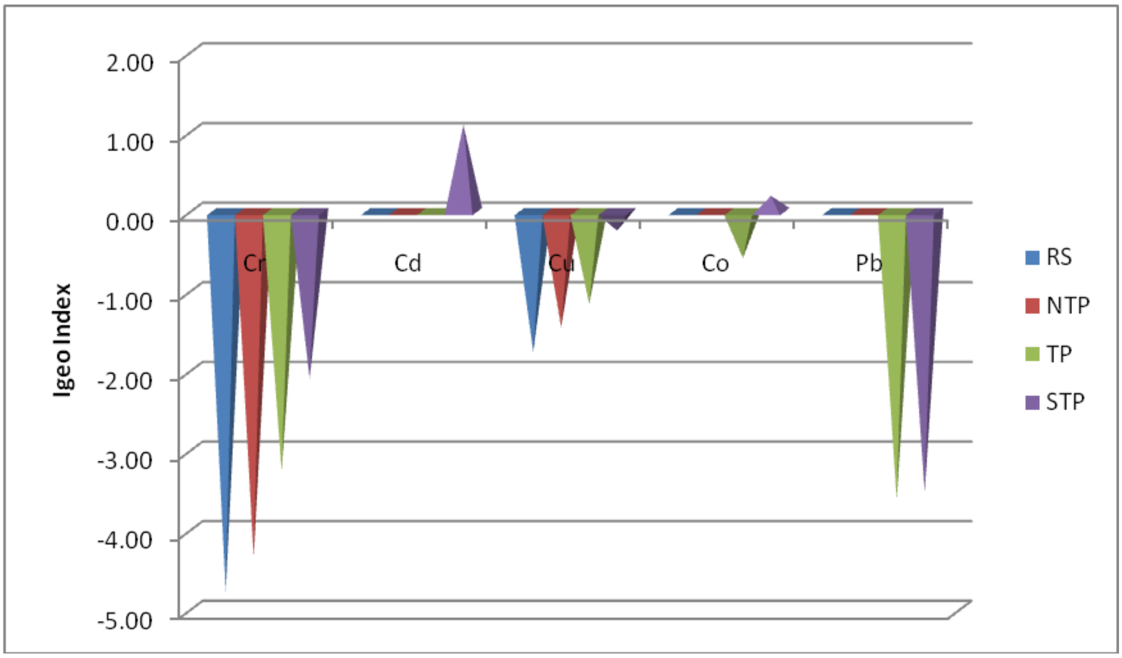

Figure 4: Geo-accumulation index for sediments of the Oke-Itoku River

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