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Heavy metals pollution index of surface water from Commodore channel, Lagos, Nigeria

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Surface water pollution poses a major risk to all biotic entities dependent on the water body. This study assessed the surface water quality of commodore channel, Lagos lagoon with respect to its heavy metals pollution level using indexing approach to determine the sources of heavy metal and its associated pollution risk. Samples were collected at a depth of 10-15 cm within a distance of 4 km from the shore line. Metal concentrations were evaluated using Atomic Absorption Spectrometry. The Concentrations of Pb (0.203-2.601 mg/L), Fe (0.253-1.049 mg/L), Cd (0.017-0.133 mg/L), and Co (0.000-0.226 mg/L) exceeded the recommended limits set by the World Health Organization, while Zn concentration (0.007-0.319 mg/L), was within acceptable limits for all locations investigated. Heavy metal pollution index (HPI) of the study area was found to be 3532.1, exceeding the critical pollution index value of 100. Similarly, the Metal Index (MI) of 150.5 of the study area was above threshold limit value of 1, suggesting that the area is seriously polluted with heavy metals. Sample t-test, confirms that there is a significant statistical different (with p value at p<0.05) between samples collected from the industrial areas and non-industrial area. The study revealed the sources of the heavy metals are primarily from anthropogenic source attributed to the untreated industrial discharge, and municipal solid waste disposed in the area. Prompt enforcement of environmental protection laws is needed to prevent continuous pollution of the area.

Key words: Water quality, heavy metals, atomic absorption spectrometry, surface water, heavy metal pollution index, metal index.

INTRODUCTION

Water is exposed to numerous anthropogenic effects in the form of pollutants including toxic metals such as lead, cadmium and chromium. The impairment of water quality due to introduction of these pollutants is regarded as a

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Major problem faced by most industrial cities around the world. The uncontrolled discharge of waste effluents to large water bodies has and is still adversely impacting on both water quality and aquatic life (Das and Acharya, 2003).

Heavy metals are bioaccumulated in several compartments across the food webs (Oyewo (1998). Metal bioaccumulation can be hazardous at all trophic levels, especially for human at the end of the food chain. Heavy metals are inorganic pollutants of great environmental concern as they are non-biodegradable, toxic and persistent with serious negative ecological ramifications on aquatic ecology (Jumbe and Nandini, 2009). Poorly planned urbanization and industrialization in some developing countries has been attributed to continuous pollution of the environment (Bhagure and Mirgane, 2010; Varalakshmi and Ganeshamurthy, 2010).

Poor enforcement of environmental protection laws by government agencies in Nigeria has aided the discharge of untreated effluent and municipal waste into the water bodies (Oludayo (2012). Various industries and refineries discharge their effluent without treating it and these unhealthy practices have the tendency of deteriorating water quality.

Tsai et al. (2003) had established that the distribution of heavy metals in surface water can provide an evidence of the anthropogenic impact on aquatic ecosystems and therefore aid in the assessment of the risks associated with the discharged waste. Heavy metal pollution index (HPI) and Metal Index (MI) had been widely deployed as an effective tool for the assessment of heavy metal risk in surface water bodies (Ameh and Akpah 2011; Goher et al., 2014, Ojekunle et al., 2016) and ground water (Kumar et al., 2012, Tiwari et al., 2016)

Philips et al. (2012) has identified Commodore channel as an essential part of Lagos lagoon intricate system which connects the Lagos lagoon to the Atlantic Ocean. Abiodun and Oyeleke (2016) assessment of sediment in the Lagos lagoon had observed discharge of industrial and domestic waste within the Commodore channel. To the best of the authors knowledge there is no published report on the heavy metal pollution of surface water of this area.

Hence, the overall objectives of this research work are to:

1. Evaluate the heavy metals concentrations of the surface water within Commodore channel;
2. Assess the associated pollution risk using indexing approach;
3. Determined the possible source of contamination.

MATERIALS AND METHODS

Study area

The study area is Commodore channel, Lagos State. It is situated within the Lagos lagoon (Figure 1). The brackish coastal lagoon lies within latitude 6°26'20.7" N and longitude 3°21'32.7" E. Lagos Lagoon empties into the Atlantic Ocean through Lagos harbour. The study area covers four kilometres (4 km) from the shore, and 500 m width. It is a tidal estuary with an average depth of 10 m. The area has a tropical climate and average annual rainfall is 1693 mm, the average temperature is 27.0°C. The fauna is composed of marine and brackish water species; depending on the season, among the fauna exploited for commercial purposes are finfish and shellfish. The channel is bounded by commercial offices, industries, ports and shipping companies (Table 1). The industries are mainly engaged in sugar refinery and paint production. There is visible discharge of sewage into the channel from the industries and shipping companies.

Sampling and sample treatment

Surface water were sampled in April, 2016 from ten sampling stations determined using the Global Position System (GPS); nine samples were collected from areas of industrial activities and one was taken from a non-industrious area (P6) Table 1. The samples were collected at 10-15 cm depth using decontaminated polypropylene bottles. Collected samples were acidified with concentrated nitric acid to a pH below 2.0 to minimize precipitation and adsorption on container walls. The samples were kept at 4ºC in an ice-container and transported to the laboratory for analysis. The samples of water were digested and then transferred into plastic bottles, labeled for analysis. They were analyzed for Pb, Zn, Fe, Cd and Co using atomic absorption spectrophotometer. The selected heavy metals are some of the major toxic metals as identified by USEPA (2002) in waste and water bodies. The analysis was carried out in accordance with the standard procedures specified in APHA 2005 and USEPA 3005 (USEPA 1987).

Digestion of sample and quality assurance

50 mL of each sample was digested with HNO_3 as described by USEPA SW Method 3005 (USEPA 1987) procedure for the digestion of water sample: 50 ml HNO_3 was added to sample in the beaker, covered and heated using hot plate placed in a fume cupboard until the volume has been reduced to 15-20 mL. Samples were allowed to cool and filtered using Whatman No. 42 filter paper. It was then transferred quantitatively to a 50 mL volumetric flask and made up to the mark with distilled water.

Quality control measures and blanks were utilized in the course of the analysis. Sample blanks and replicate samples were analyzed along with samples to ensure precision and accuracy of analyses.

Data evaluation

Heavy metal pollution index (HPI)

Heavy metal pollution index (HPI) was applied for the assessment of water quality on the basis of heavy metal concentration. Heavy metal pollution index (HPI) according to Mohan et al. (1996) is determined as thus:

$$\text{HPI} = \sum_{i=1}^{n} \frac{Wi*Qi}{Wi} \quad (1)$$

Where Qi represent Sub index of the ith parameter, Wi denote unit weight of the ith parameter and n is the number of parameters determined. The sub index (Qi) of each parameter is calculated as:

$$\text{Qi} = \sum_{i}^{n} 100\; X \left(\frac{Mi-Li}{Si-Li}\right) \quad (2)$$

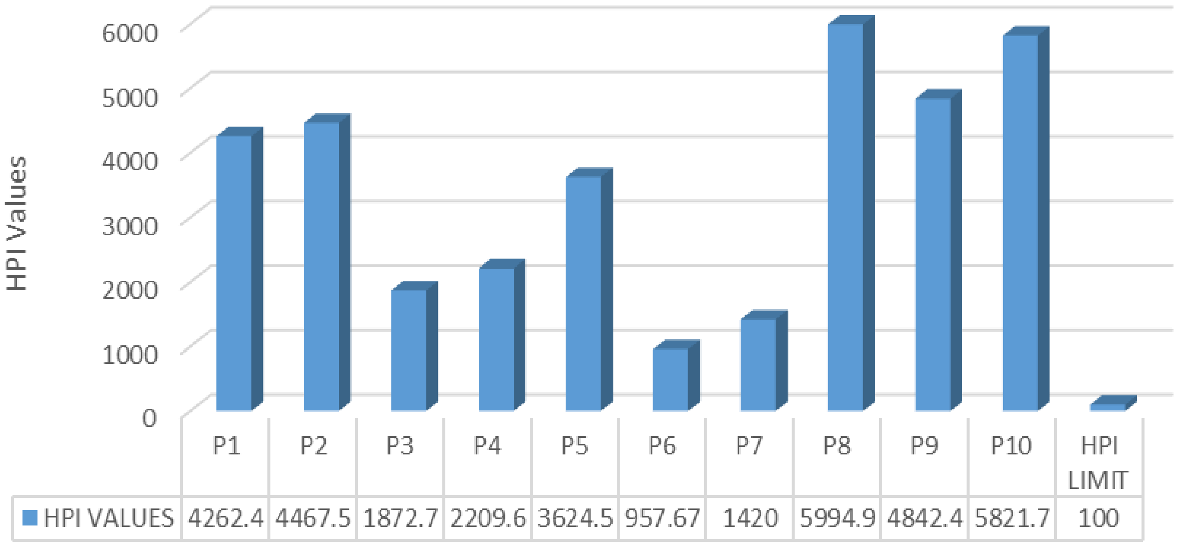

Figure 1. HPI values at various sampling points.

Table 1. Sample location and brief location description.

Sample location	Location description
P1	Industries present, port facilities
P2	Industrial activities, sewage discharge
P3	Ports and shipping anchorage
P4	Pathway, industrial presence
P5	Dangote refinery, jetty
P6	Beach, fishing activities, nearby rural settlement
P7	Energy industry, Sewage discharge
P8	Paint manufacturing industry, Jetty
P9	Sewage discharge, nearby dumpsite
P10	Bua sugar refinery, sewage discharge

Where Mi is the evaluated value of heavy metal of the ith parameter, Ii denoted the ideal value of the ith parameter, Si represent standard value of ith parameter.

Metal index (MI)

The metal index (MI) was defined by Tamasi and Cini (2004) as:

$$\mathrm{MI} = \sum_{i=1}^{n} \frac{Ci}{(MAC)i} \qquad (3)$$

Where MI is the metal index, C is the concentration of each element in solution, MAC is the maximum allowed concentration for each element, and the subscript i is the i^{th} sample.

RESULT AND DISCUSSION

Heavy metal concentrations

Heavy metals concentrations (mg/L) of samples investigated is shown in Table 2. The ranges of the heavy metal concentrations varied widely: Pb (0.203-2.601), Zn (0.007-0.319), Fe (0.253-1.049), Cd (0.017-0.133), and Co (0.0000-0.226). The mean concentrations of Pb, Zn, Fe, Cd, and Co are 1.232, 0.193, 0.629, 0.053 and 0.075 mg/l, respectively. Mean concentrations of Pb, Fe, Cd, and Co exceeded the permissible limit for portable water set by World Health Organization (WHO, 2006) While Zn was within the desirable limit. This could be attributed to the poor content of zinc in the discharge effluent or municipal waste and its low content within the sampling area. The relative abundance of the heavy metals were in the order Pb>Fe>Zn>Co>Cd. The elevated heavy metal concentrations of the study area could pose serious health challenges to most dwellers within the areas that largely depend on the water for agricultural and domestic uses. The possible effects of these heavy metals in humans and animals are presented in Table 3.

Table 2. Chemical analysis of waters in the study area.

Location	Longitude	Latitude	Heavy metal concentrations(Mg/L)				
			Pb	Zn	Fe	Cd	Co
P1	6.441326N	3.391041E	1.422	0.011	0.886	0.078	ND
P2	6.438612N	3.395637E	1.75	0.29	0.61	0.056	0.026
P3	6.433634N	3.393293E	0.61	0.317	0.45	0.028	0.084
P4	6.433720N	3.389129E	0.86	0.221	0.511	0.026	0.037
P5	6.435582N	3.384398E	1.016	0.317	0.591	0.077	0.074
P6	6.433870N	3.378352E	0.325	0.007	1.049	0.017	ND
P7	6.432827N	3.368201E	0.203	0.094	0.565	0.044	0.07
P8	6.441326N	3.363216E	2.601	0.319	0.634	0.039	0.184
P9	6.437801N	3.359049E	2.113	0.243	0.75	0.039	0.053
P10	6.437987N	3.358626E	1.422	0.119	0.253	0.133	0.226
Minimum			0.203	0.007	0.253	0.017	ND
Maximum			2.601	0.319	1.049	0.133	0.226
Mean			1.232	0.193	0.629	0.053	0.075
WHO (2006)			0.01	3	0.3	0.003	0.01

Table 3. Evaluation of heavy metals in waters of the study area for drinking/domestic purposes and possible health effects (Modified after WHO, 2006; Levinson, 1980).

Heavy metals (mg/L)	WHO (2006) guideline		Values from study area		Evaluation for drinking and/possible health effects
	Desirable limit	Permissible limit	Range	Mean	
Cd	<0.01	<0.01	0.017-0.133	0.053	Very high. May be carcinogenic; May cause kidney damage, lung cancer, ostemalcia or osteoporosis, anaemia, teeth discolouration.
Co	<0.01	<0.01	0.000-0.226	0.075	Very high. May cause vomiting, dermatitis, asthma, skin rashes, vision and heart problem.
Zn	<1.0	<1.0	0.007-0.319	0.193	Excellent to good. High levels may cause stomach cramps, nausea and vomiting.
Fe	<0.1	<0.3	0.253-1.049	0.629	Very high. May cause vomiting and conjunctivitis, stains and taste.
Pb	<0.001	<0.003	0.203-2.601	1.232	Very high. May cause kidney damage, anorexia, encephalopathy (brain swelling), dizziness, digestive disorder, lung cancer, coma and death.

Assessment of metal contamination

Two quantitative methods were used in assessing the risk level of heavy metal concentrations contamination in the samples: Heavy metal pollution index (HPI) and metal index (MI).

The heavy metal pollution index for the study area was calculated using the mean concentration values of the selected metals (Pb, Zn, Fe, Cd and Co); the mean HPI was found to be 3532.1 (Table 4) which exceeds the critical pollution index value of 100. This implies that the study area (commodore channel), is critically polluted with very high concentrations of heavy metals. HPI for all sampling point were found to be greater than acceptable (HPI> 950) with the highest value (5994.92) recorded at P8 and the lowest value (957.67) recorded at P6 (Figure 2 and Table 5). Although P6 is characterized by non-industrial activities in the area, this outcome could be linked to dilution effect from discharge point towards the area (Kithiia, 2006). This shows that concentration of metals decreased with increasing distance from the pollutant emission sources. Metal index for the study area revealed very poor water quality with MI value of 150.5 (Table 6) which is above the threshold limit of MI value >1

Table 4. HPI recorded at different sampling locations.

Sampling location	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
HPI	4262.4	4467.5	1872.7	2209.57	3624.5	957.67	1420	5994.92	4842.37	5821.74

Σ HPI = 3544.

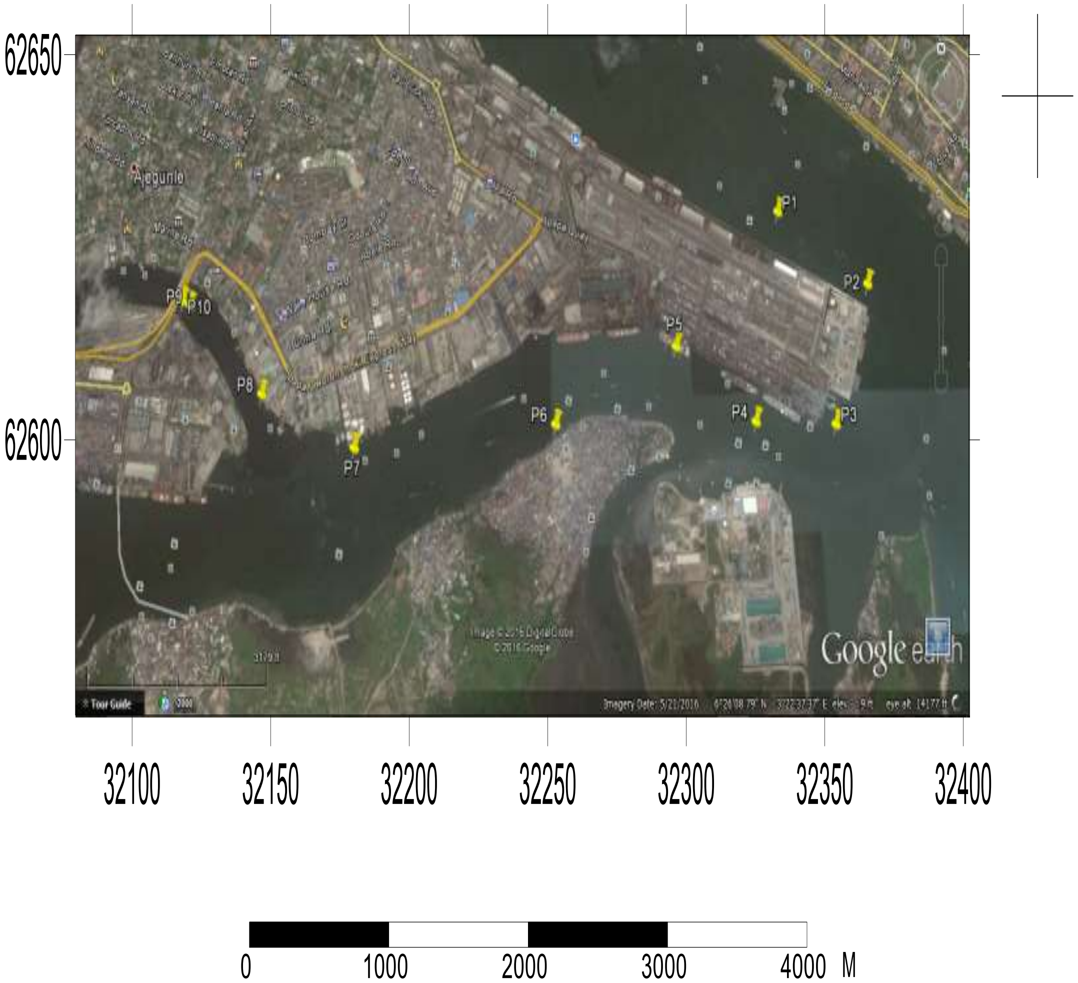

Figure 2. Google Earth image showing the sampling points in study area.

(Table 7). This observation buttress the initial observation that the channel has high burden of heavy metals concentration (Lyulko et al., 2001; Caerio et al., 2005).

This findings is higher than index values reported by Manoj et al. (2012) for Subarnarekha River (India) in which HPI value is 49.12, Reza and Singh (2010) for river water Angul-Talcher region, India in which the HPI value is 36.19 in summer and 32.37 in winter seasons. The findings are in agreement with research by Kumar et al. (2012), in which heavy metal pollution index was utilized to evaluate contamination in Chennai city, India. His result showed the sources of contamination were primarily anthropogenic had a common origin.

To determine if the presence of industrial activities played any role in concentration of heavy metal in the study area, a statistical tool (Sample t-test) was utilized, mean concentration of each heavy metal from areas of industrial activities were tested against each heavy metals from an area of non-industrial activity (P6); results showed that there is significant difference in concentration of heavy metals between the industrial areas and the non-industrial area with P value ($p<0.05$), using a 95% confidence level for a 2-tailed test and degree of freedom (n-1) 8. The location of non-industrial activity (P6) recorded fairly low concentrations of all investigated heavy metals except for Fe concentration which was

Table 5. Mean HPI calculation for surface water sample

Heavy metal (mg/L)	Mean concentrations (Vi)	Highest permitted value (Si)*	Unit weightage (Wi)	Subindex (Qi)	Wi x Qi
Pb	1.232	0.01	100	12320	1232000
Zn	0.193	3	0.333	6.43	2.14
Fe	0.629	0.3	3.3	209.67	691.91
Cd	0.053	0.003	333.33	1766.67	588884.11
Co	0.075	0.01	100	750	75000
Σ			536.96		1896578.16

HPI = 3532.1. ***** World health organization drinking water guideline, 2006.

Table 6. Mean MI of commodore channel.

Heavy metal (mg/L)	Mean concentration (C_i)	Highest permitted value $(MAC)_i$	MI
Pb	1.232	0.01	123.22
Zn	0.193	3	0.064
Fe	0.629	0.3	2.096
Cd	0.053	0.003	17.66
Co	0.075	0.01	7.5

Σ MI = 150.5.

Table 7. Water quality classification using MI (Lyulko et al., 2001; Caerio et al., 2005).

MI	Characteristic	Class
<0.3	Very pure	I
0.3 - 1.0	Pure	II
1.0 - 2.0	Slightly affected	III
2.0 - 4.0	Moderately affected	IV
4.0 - 6.0	Strongly affected	V
>6.0	Seriously affected	VI

found to be very high (1.049 mg/L) compared to other sampled locations This could be associated to iron mobility in water bodies. According to Kabata-pendias (2001), iron is relatively immobile under most environmental conditions mainly due to the very low solubility of iron (III) hydroxide in its various form. Its solubility is strongly influenced by redox conditions; his findings recorded highest concentration of iron in regions of base-poor buffering capacity and he further suggested that the non-degradable nature and possible slow rate of dispersion may be responsible for higher levels observed near the shore region.

Conclusion

The study revealed that Zn concentration was fairly low and within recommended limit, while levels of Pb, Fe, Cd and Co in water samples exceeded the World Health Organization (WHO, 2006), standard limits portable water. Heavy metal indexing approach is a very useful tool in evaluating overall pollution of water bodies with respect to concentrations of heavy metals. The HPI and MI models indicated a high degree of heavy metal pollution in the study area which could be traced to primarily anthropogenic sources from untreated industrial discharge, refuse dumping, municipal waste and processing activities in the area. Using the sample t-test, it was confirmed that the industrial activities around the study area could play a major role in the increased level of heavy metal concentration observed. Prompt enforcement of environmental protection laws is needed to prevent continuous pollution of the area. These findings represent the first reported assessment of the study area.

Recommendation

Companies discharging effluent into the commodore channel should be made to put in place waste water treatment plant capable of effectively trapping potential heavy metals in the generated effluents. Further research is needed to assess the direct impact of the pollution on human and plant health within the area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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