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HEAVY METAL CONTAMINATION OF WATER IN NEGOMBO LAGOON AND INTERCONNECTED WATER SOURCES

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Abstract

Water quality in natural lagoons that are located within close proximity to human settlements is generally at contamination risk due to increasing anthropogenic activities. The Negombo lagoon situated in the Gampaha District in Sri Lanka is a lagoonal estuary. It receives surface water runoff mainly from Dandugamoya, Ja-ela, Hamilton and Dutch canals. During the recent past, it has been noted by several researches that there is increasing evidence in anthropogenic activities in Negombo lagoon and surrounding areas. The present study was carried out to assess the contamination levels of heavy metals of water in the Negombo lagoon and interconnected water sources. Sampling was carried out in 19 locations; 6 in the Negombo lagoon and 13 from the interconnected sources (5 samples from Hamilton canal, 2 samples each from Dutch canal, Dandugamoya and Ja-Ela and one sample each from Kelani estuary and Ocean-Negombo). The data collection was conducted during relatively wet (May) and relatively dry (September) months in 2013. Water samples were analysed in the laboratory as per the standards methods of American Public Health Association (APHA manual) by using the Atomic Absorption Spectrophotometer**.** The tests were carried out to detect heavy metals: cadmium (Cd), chromium (Cr), copper (Cu), Lead (Pb), manganese (Mn), and zinc (Zn) in water. Data analysis was accomplished using ArcGIS (version 9.3) software package along with Microsoft Excel. Standards for inland water and drinking water of Sri Lanka were used to determine the threshold levels of heavy metals. The results show that concentrations of Cr, Cu, Mn and Zn of all water bodies were below the threshold level of human consumption and quality standards for inland waters in Sri Lanka. The Cd and Pb levels of water in Negombo lagoon and Hamilton canal were comparatively high. Furthermore the Cd and Pb levels of Dandugamoya, Ja-ela and Dutch canals were below the maximum permissible levels in both relatively wet and relatively dry periods. Concentration of Cd and Pb in Negombo lagoon and Hamilton canal showed seasonal oscillation with the rainfall. Both the parameters demonstrate a negative relationship with precipitation. Comparatively a high Cd and Pb concentrations was observed during the dry period. In conclusion, the Cd and Pb levels were high in the lagoon and Hamilton canal while the concentration of Cd and Pb were below the threshold level in Dandugamoya, Ja-ela and Dutch canal waters. The findings were important as the study indicates the spatial and seasonal variations of presence of heavy metals in the lagoonal water and which probably links to anthropogenic activities.

Keywords: Heavy metals, water quality, lagoon, anthropogenic influence, Sri Lanka

1. INTRODUCTION

Estuaries receive different types of contaminants due to anthropogenic influences from both point and non-point sources. Among them, heavy metal contamination in aquatic systems has received considerable attention due to their toxicity, durability and their special depositional properties (Li Xiangdong et al., 2000, Loska & Wiechuła, 2003 and Liang et al, 2004), Toxic metals include mercury (Hg), lead (Pb), cadmium (Cd), chromium (Cr), and copper (Cu) (EPA, 2006). Sources of toxic substances comprise surface water from municipal and industrial discharges, runoff (e.g., from lawns, streets, and farmlands), atmospheric deposition and geological weathering or agricultural, residential waste products (Cheung et al, 2003 and EPA, 2006, Demirak et al., 2006). Heavy metals can be effectively accumulated in plants and animals, transferred to human bodies by food chains and their levels can be increased by biological enrichment. Hg, Cr, Cd, Cu and Pb in environmental water system may pose high toxicities on the aquatic organisms, (Zhou et al, 2008). Agusa et al (2007) emphasized large emission and contaminations of trace elements are of concern at present in Asian developing countries because of the rapid economic growth and increasing population in recent years.

Contamination of heavy metals in estuaries, lakes, rivers and coastal waters are prominent in the present world and number of evidences can be highlighted as examples from different parts of the world. For example concentrations of Pb, Zn and Cu are elevated in the sediments of the Pearl River estuary in South China compared with their national background levels (Li Xiangdong et al, 2000). The Ria of Huelva, in South-western Spain, has been identified as one of the most heavy metal contaminated estuaries in the world (Sainz et al, 2003 and Vicente-Martorell et al 2009).

Another study on Ganga plain in Uttar Pradesh in India found that the impact of anthropogenic agents of heavy metals in its soils was very high. The high contamination was due to random dumping of hazardous waste and free discharge of effluents by number of industries over the of years. The results further indicated that the soil on the river plain is moderately contaminated with Cu, considerably contaminated with Pb and Zn and heavily contaminated with Cr (Gowd Srinivasa et al, 2010). Urbanization and industrial growth have contributed to high accumulation of potentially toxic heavy metals (Cd, Cu, Pb, and Zn) in surface sediments from 35 park public lakes throughout Shanghai (Yang Jing et al, 2014). Therefore, more studies are needed to explore the existing condition of estuaries in areas where anthropogenic activities are high. Even though the effect of anthropogenic activities on estuarine health is increasingly high in many developing countries, there are only a few scientific researches available to study on that. Negombo lagoon in Sri Lanka which is situated in an area with immense anthropogenic pressure is one of such that suffers from inappropriate land use and unsustainable activities in the surroundings. Anthropogenic activities and the development of urban centres on both sides of the Negombo Lagoon are prominent causes for this stress (Katupotha, 2012). The landless poor have reclaimed land for construction of unauthorized dwellings (Conservation Management plan, 1994). This has affected the hydraulic regime of the lagoon causing the problem of increasing sedimentation. The establishment of an Industrial City in Ekala and a Free Trade Zone in Katunayake may also have direct and indirect impacts on the water quality of the Negombo lagoon (Conservation Management plan, 1994 and Silva, 1996). In addition, large quantities of solid and liquid waste are being dumped at various locations in the lagoon resulting in degradation of aquatic environment (Hettiarachchi & Samarawickrama, 2011). As a result, the water quality of Negombo lagoon has deteriorated over the last few decades (Wijesekara & Kudahetti, 2011). Most of the people in the Negombo area fulfil their potential requirements using fishery resources in the Negombo estuary. However, insignificant attention has been given to study heavy metal pollution in the estuary. Hence, the necessity of the regular monitoring of heavy metal pollution in Negombo estuary is timely important as there are multiple sources of heavy metal contamination in the vicinity of the estuary (Indrajith et al., 2008). Therefore the purpose of this study is to identify, measure and map the spatial distribution of heavy metal contamination of water in Negombo lagoon and interconnected water sources.

1.2 STUDY AREA

The study was conducted in the Negombo lagoon locates in the Gampaha District of Sri Lanka (Figure 1). It is a highly dynamic estuarine ecosystem that is regularly affected by tides and river flow. The lagoon is a part of a unique hydrological system which includes the Muthurawajawela marsh, Attanagalu oya, Hamilton and Dutch canals and adjacent coastal belt. Extent of the lagoon is about 3200 hectare and is connected to the Indian Ocean by narrow canals to the north, near Negombo town (Environmental Profile, 1991). The lagoon is approximately 12.5 km in length (Hettiarachchi & Samarawickrama, 2011). The width of the lagoon is about 3-4km. Tidal waves from the Ocean flow into the lagoon twice a day (Conservation management plan, 1994). Fresh water enters from the southern end of the lagoon through the Dandugam oya, Ja-Ela (Attanagalu oya) and several streams from Muthurajawela marsh (Environmental profile, 1991, Hettiarachchi & Samarawickrama, 2011)

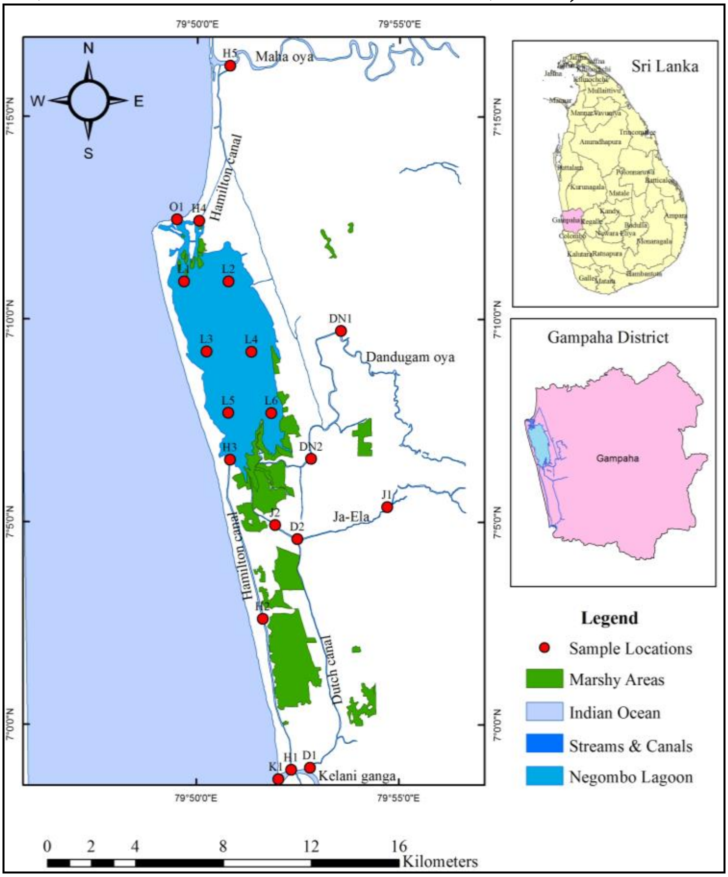


Figure 1: Location of the Negombo lagoon and inter connected water sources

2. METHODOLOGY

Sampling was carried out in 19 locations from the Negombo lagoon, Dandugamoya, Ja-Ela Hamilton, Dutch canal, Kelani estuary and Ocean at the outlet of the Negombo estuary. Details of the sampling sites are presented in Figure-1 and Table-1. Locations of the sampling sites were identified using a 'Magellan eXplorist 610 handheld' GPS (Global Positioning Systems) receiver. The sampling was conducted during relatively wet (May) and relatively dry (September) periods in 2013 during low tide. A standard Ruttner water sampler was used to collect undisturbed water samples and add analytical grade HNO_3 to keep pH<2. The tests were carried out to detect heavy metals: cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), and zinc (Zn) in the water. Water samples were analysed in the laboratory as per the standards methods of American Public Health Association (APHA) manual: 20th Edition by using the Atomic Absorption Spectrophotometer (AA 6300, Shimadzu).

Table-1: Details of samples

Water source	Name of the samples	No of samples
Dandugam oya	DN1-DN2	2
Dutch Canal	D1-D2	2
Hamilton canal	H1-H5	5
Ja-ela	J1-J2	2
Kelani river outlet	K1	1
Negombo lagoon	L1-L6	6
Ocean-Negombo outlet	O1	1
Total		19

Toxic metal and organic pollutants are found in low concentrations in water on the order of parts-per-billion (ppb) and parts-per-trillion levels (ppt) (EPA, 2006) and results of the concentrations of heavy metals were measured in ppb. Proposed Ambient water quality standards for inland waters (Central Environmental Authority-CEA, 2001) were used to determine the threshold levels of heavy metals.

A pilot survey was carried out to identify the crucially impacted heavy metals in December 2012 and May 2013. The heavy metal analyses were repeated in September 2013 only for the above parameters which exceeded the CEA standards in the initial pilot study conducted in December 2012 and May 2013.

Monthly average rainfall for all stations was calculated using the daily rainfall data collected by the Meteorological Department of Sri Lanka for ten stations in the catchment area of Katunayake, Negombo, Colombo, Tammita, Henarathgoda, Nittambuwa, Pasyala, Vicit Estate, Chesterford and Warakapola for April/May 2013 and August/September 2013 were used for the study.

Data analysis was accomplished using ArcGIS (version 9.3) software package along with Microsoft Excel. Interpolation technique in ArcGIS was performed to analyse and mapped the spatial distribution of heavy metals.

3. RESULTS AND DISCUSSION

3.1 Overall Results

The concentrations of heavy metals of nineteen sampling sites in pilot studies are presented in Table 2. Cd levels of all water samples were varied between 0.13 to 6.90 ppb. Cr was not detected in Dutch canal, Dandugam oya and Ja-ela. The Cr concentration was between 0.27 to 0.69 ppb lagoon, Hamilton canal, Kelani estuary and Ocean at the Negombo lagoon outlet. Cu was between 0.22 to 0.82 ppb, but not detected in sample J1 in Ja-ela and DN1 in Dandugam oya. Pb concentration was between 3.70 to 83.80 ppb showed considerable variation between different water sources. The highest Pb concentrations were observed in the lagoon and its outlet. The second highest Pb was reported in Hamilton canal. Mg levels of all the water samples were between 11.90 to 46.70 ppb and did not reveal any considerable variations. Concentration of Zn was between 0.03 to 0.99 ppb and it was not detected in Sample J1 in Ja-ela and DN1 in Dandugam oya. The results of the pilot survey revealed that the concentration of Cr, Cu, Mn and Zn were far below the levels for Inland water quality standards of CEA (Table-2). However, Cd and Pb concentration of most of the samples in Ocean at the Negombo outlet, lagoon and Hamilton canal were above or close to the threshold levels.

The inland water standard for Cd is 5.00 ppb and Pb is 50.00 ppb (Table 2). The main threats to human health from heavy metals are associated with exposure to lead, cadmium, mercury and arsenic. These metals have been extensively studied and their effects on human health regularly reviewed by international bodies such as the WHO (Järup, 2003). Cadmium clearly merits its classification as a ‘priority pollutant’, from the human health perspective and broader ecosystem viewpoint (Campbell & Peter, 2006). Cadmium has been identified as a significant pollutant considering its high toxicity and high solubility in water (Das et al., 1997).

Therefore, a repeat analysis was carried out to identify the dynamics and spatial variation of Cd and Pb during relatively a dry period in September 2013. May was considered as relatively a wet month as the average of all ten weather stations was 303.15mm and September was considered as relatively a dry month as the average rainfall was 125.89mm.

Table 2: Concentration of heavy metals of pilot survey in December 2012 and May 2013

Name of the sample	Heavy metal types and concentrations (ppb)					
	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Manganese (Mn)	Zinc (Zn)
O1	3.70	0.69	0.24	83.80	22.50	0.91
L1	4.80	0.48	0.71	41.30	20.30	0.62
L2	4.60	0.61	0.23	51.40	21.30	0.83
L3	2.50	0.55	0.76	44.50	46.70	0.54
L4	6.90	0.49	0.74	45.80	26.40	0.51
L5	2.80	0.38	0.82	37.30	42.10	0.31
L6	4.30	0.27	0.44	48.20	17.10	0.47
K1	0.13	0.27	0.29	10.80	13.00	0.11
H1	0.16	0.32	0.46	4.80	25.00	0.54
H2	0.99	0.29	0.28	30.60	27.80	0.32
H3	1.50	0.34	0.33	36.50	21.20	0.25
H4	1.89	0.52	0.22	15.00	22.50	0.35
H5	0.18	0.28	0.65	3.70	16.10	0.33
D1	0.85	ND	0.24	4.70	20.90	0.06
D2	0.13	ND	0.52	6.30	17.40	0.99
J1	0.15	ND	ND	4.40	19.30	ND
J2	0.47	ND	0.80	22.00	11.90	0.05
DN1	0.15	ND	ND	16.30	11.50	ND
DN2	0.52	ND	0.38	10.10	16.30	0.03
Thresholds levels for Inland water quality standards (ppb)	5.00	50.00	100.00	50.00	1000.00	1000.00
Detection limit (Furnace -ppb)	0.02	0.25	0.10	0.25	0.03	0.02

*ND – Not Detected

3.2 Cadmium and Lead

Concentrations of Cd and Pb in all 19 samples for both May and September 2013 are shown in the Figure 2 and 3. Water in lagoon, Hamilton canal and the Ocean close to the Negombo outlet showed high Cd and Pb levels while other sources recorded low Cd and Pb concentrations (Table 2, Figure 2 and 3).

Figure 2 : Concentration of Cadmium (Cd)

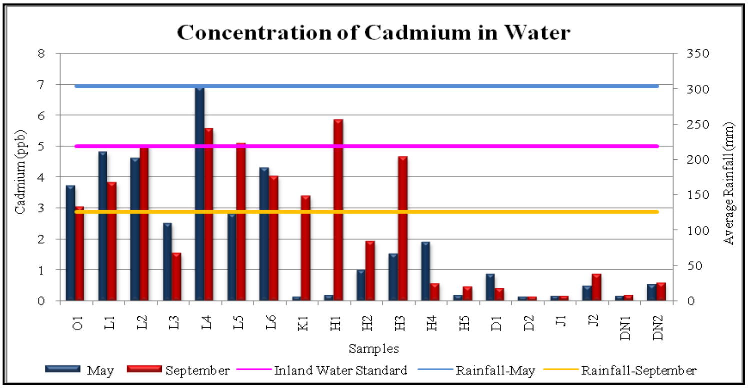
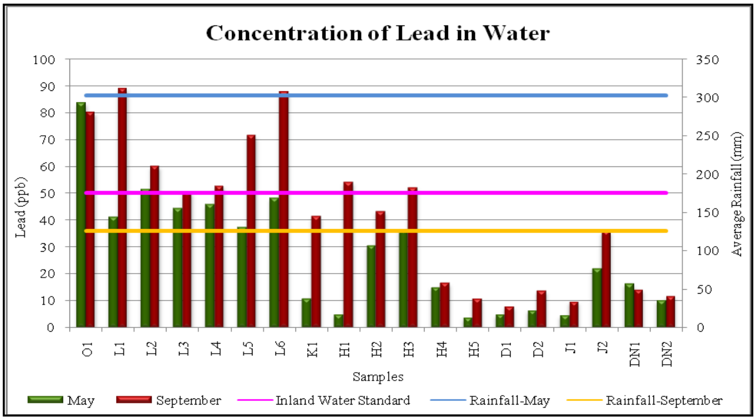


Figure 3 : Concentration of Lead (Pb)



Deviation of the concentration levels of Cd and Pb from the inland water standards in May and September are revealed in figure 4, 5, 6 and 7. Cd concentration of the sample L4 (6.90 ppb) in the East end of the lagoon was exceeding the threshold level (5.00 ppb) of the inland water standard during relatively wet period in May.

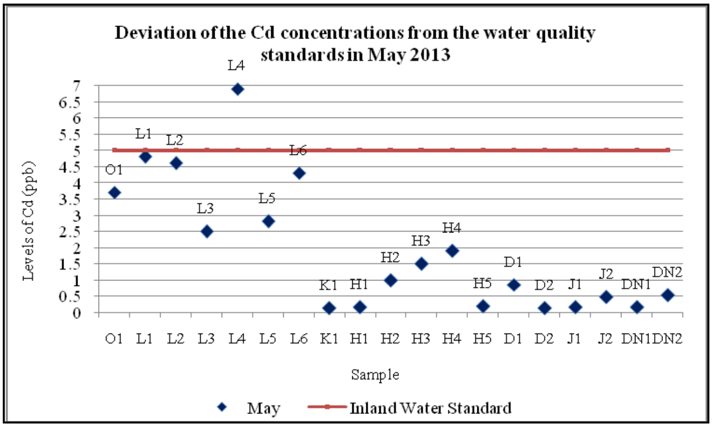


Figure 4 : Deviation of Cd concentration from standard water quality level in May 2013

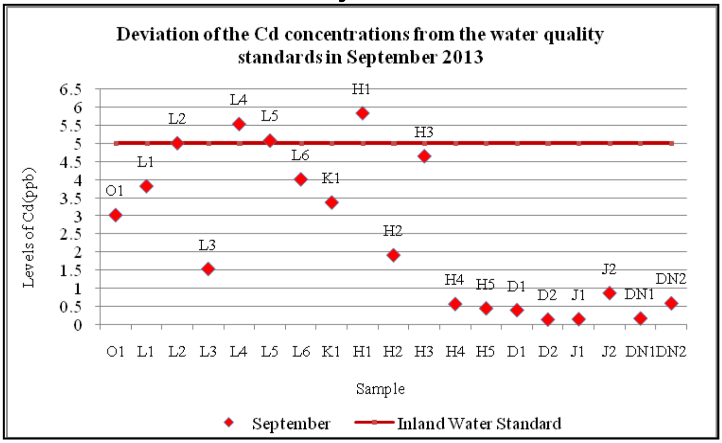


Figure 5 : Deviation of Cd concentration from standard water quality level in September 2013

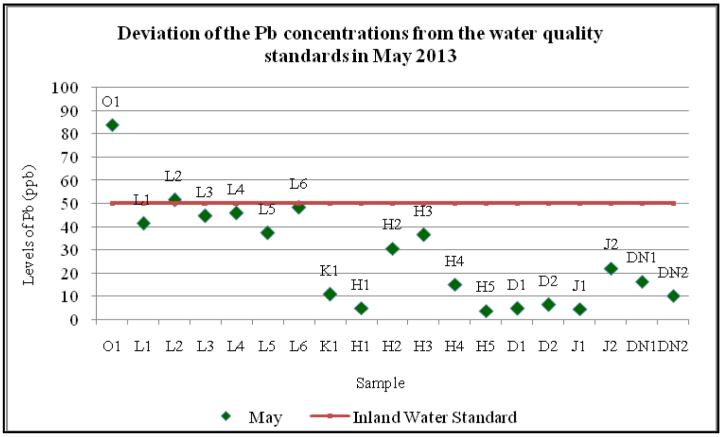


Figure 6 : Deviation of Pb concentration from standard water quality level in May 2013

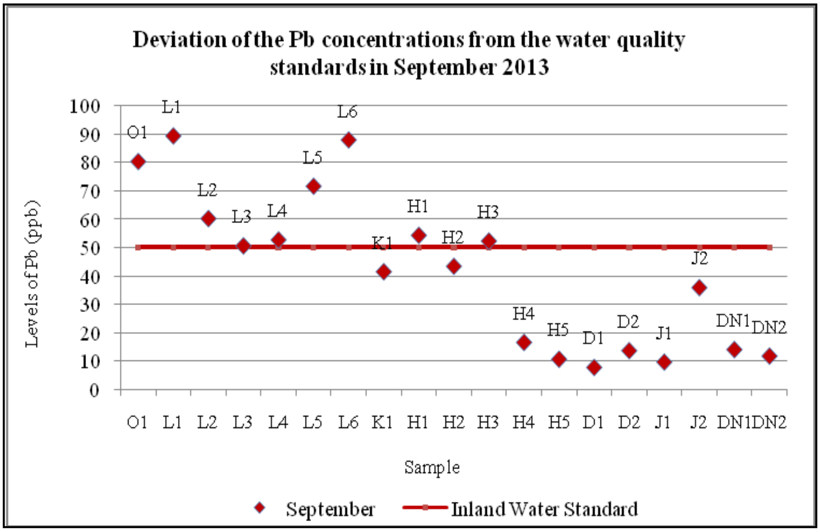
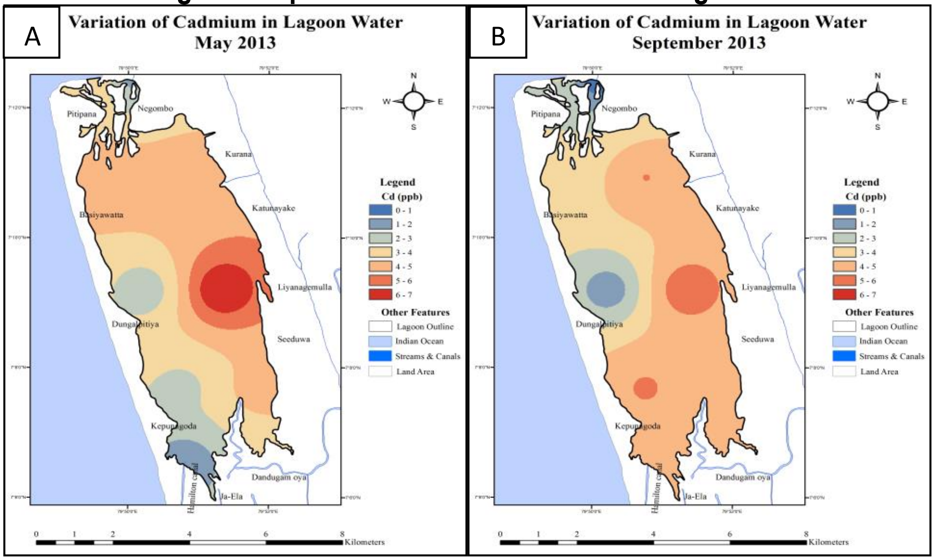


Figure 7 : Deviation of Pb concentration from standard water quality level in September 2013

Three samples namely L2, L4 and L5 taken during relatively dry season of September were 5.01 ppb, 5.54 ppb and 5.08 ppb respectively and were exceeding the standard threshold level (Figure 2, 4 and 5).

Results revealed that there are spatial and seasonal variations of Cd levels. Spatially the highest Cd levels were recorded in the Northern and Eastern regions of the lagoon during the wet period (Figure 8A). However, the highest Cd levels were observed in Southern and Eastern region during the dry period (Figure 8B). Therefore, seasonal variations can be observed in the spatial distribution of Cd. Concentration of Cd in Eastern half of the lagoon remained constant while the concentration of Cd in Northern and Southern regions fluctuated with the rainfall changes. Cd level of the lagoon was associated with the freshwater flow and the annual rainfall pattern during the wet period in May. Therefore, the concentrations of Cd in the wet period of the Southern and Western segments of the lagoon are comparatively low due to fresh water influence from Dandugam oya and Ja-ela (Figure 8A). During the dry period, the influence of the sea is prominent and the concentration of Cd in water pushed towards the lagoon inlet (Figure 8B). Indrajith et al, 2008 reported that the Cd levels of lagoon water varied between 0.60 – 2.10μgL^{-1} (ppb) according to their study in 2003. However, the present study identified an increasing trend of Cd levels in lagoon water with ranges of 2.50 – 6.90 ppb and 1.53 – 5.53 ppb in dry and wet periods respectively (Figure 2).

Figure 8: Spatial variation of Cadmium in lagoon water

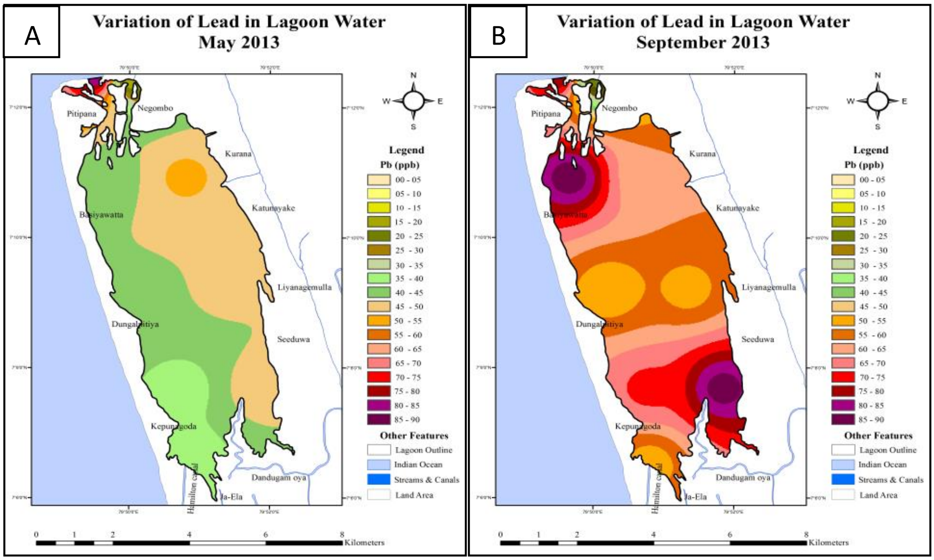


Cd concentration of Hamilton canal was low during the wet period in May. It was above the inland water quality standards (5.84 ppb) in sample H1 which is close to the Kelani estuary. Sample H3 also recorded 4.65 ppb and it was also close to the threshold limit. Sample in the Kelani estuary (K1) showed a low Cd concentration of 0.13 ppb during the wet period while the same sample recorded 3.37 ppb during the dry period. Almost similar conditions were observed in both wet and dry periods at the sample located in Negombo outlet (O1). However, careful assessments are needed to identify the temporal changes.

Concentrations of Pb in wet season of the lagoon were between 37.30 - 51.40 ppb. It was 50.50-89.20 ppb during the dry period (Figure 3). The inland water standard for Pb is 50.00 ppb (Table-2). Only one sample (L2) in the northern segment of the lagoon was exceeded the standard limit of Pb during the wet period and rest of the samples were close to the threshold limit (Figure 3 and 6). However, all the samples in the lagoon exceeded the standard limit for Pb in the dry season (Figure 3 and 7). According to Indrajith et al, 2008 the Pb levels of lagoon water varied between 1.00 – 5.70 $\mu g L^{-1}$ (ppb) according to their findings in 2003. Those were below the inland water standards. The present study indicates that Pb concentration of the lagoon water were exceeded the threshold limit of inland water standards (Figure 3 and 7).

Spatially, high Pb concentrations were observed in Eastern half and Northern tip of the lagoon in wet period (Figure 9 A) which agrees with the findings of Indrajith et al, 2008. The highest Pb levels 65 -90 ppb were identified in North West and South East region of the lagoon (Figure 9 B). North region is being polluted due to various anthropogenic activities such as solid waste dumping, waste from industries, slaughter houses, shrimp farms and hatcheries and boat yards. Due to discharge of burned and unburned fuel from motor boats, the estuarine water is contains high level of Pb. East region receives effluents from mainly Katunayake industrial processing zone, hotels and a housing scheme (Indrajith et al, 2008).

Figure 9: Spatial variation of Lead in lagoon water



Pb concentrations of Hamilton canal, Kelani estuary and Ja-ela have seasonal variation with the rainfall pattern (Figure 3). Pb levels were low during the wet period; however sample H2 and H3 showed relatively high concentration in May. Levels of Pb in H1 and H3 exceeded the standard limit while H2 remained close to the threshold limit. The samples located in Kelani estuary recorded low concentration (10.8ppb) of Pb in the wet period and the same sample showed comparatively high concentration (41.40 ppb) in dry period. One sample in Ja-ela close to the lagoon (J2) recorded 22 ppb in wet period while it was 35.80 ppb in dry period. Silva, 1996 has been reported that most of the effluent originating from Ekala trade processing zone which is not properly treated discharges directly or indirectly into Dandugam oya and Ja-ela. It was observed almost similar condition of Pb in both wet and dry periods at the sample O1 located in the Ocean Negombo outlet (Figure 3, 6 and 7). The concentrations were comparatively high.

4. CONCLUSIONS

Concentrations of Cr, Cu, Mn and Zn of all water bodies connected to Negombo lagoon are in accepted levels for human consumption according to inland water quality standards for Sri Lanka. Nevertheless, Cd and Pb levels of water in Negombo lagoon as well as Hamilton canal are comparatively high with elevated Cd concentration in eastern half of the lagoon and a relatively low level in western part. . The elevated Cd level in the Northern quarter during the dry period can be attributed to the oceanic influence, while during the wet period due to freshwater influence of Dandugam oya and Ja-ela can be attributed to the southern quarter.

Analogically, Pb levels of the entire lagoon water are increased during the dry period and they were above the standard limits of the inland water standards. Concentration of both Pb and Cd in Negombo lagoon and Hamilton canal showed a negative relationship with rainfall while exhibiting a seasonal oscillation with the rainfall. Cd and Pb concentration in the Ocean at the Negombo outlet showed an analogical situation in both relatively wet and relatively dry periods. However the Cd and Pb levels of Dandugamoya, Ja-ela and Dutch canals were below the threshold levels in both relatively wet and relatively dry periods.

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