



Assessment of heavy metal contamination in the sediments of Meda - Ela canal near Karadiyana semi-controlled dumpsite, Sri Lanka

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ABSTRACT

The pollution of natural waterbodies with landfill leachate from dumpsites is a severe environmental issue all over the world. Karadiyana semi-controlled dumpsite in the Western province of Sri Lanka is one of the largest dumpsites in the country. The leachate generated in the dumpsite directly flows into Meda Ela canal which is a tributary of Bolgoda Lake Werasingha Ganga system causing a significant pollution threat on aquatic life. The current study assesses the contamination level of selected heavy metals in the sediments of Meda-Ela close to the dumpsite. The study was carried out for a period of one year from January - December 2018. The sediment samples were characterized with an alkaline pH ranging from 8.40 to 8.70. The electrical conductivity of the sediment was recorded with a mean value of $139.93 \pm 26.7 \mu\text{S/cm}$. The mean concentration of Cu in sediment was of $73.53 \pm 2.52 \text{ mg/Kg}$ and it falls into the EPA guideline for heavily polluted sediments. Total Cu concentration exceeds the threshold effect concentration but falls below the probable effect concentration. The total Fe concentration was relatively high ($110.83 \pm 1.96 \text{ mg/Kg}$) among the measured metal species. The other metals, Cd, Cr and Zn was recorded with mean concentrations of 0.38 ± 0.03 , 103 ± 41.62 , $94.4 \pm 2.08 \text{ mg/Kg}$ respectively. Pollution Load Index of the sediment was 0.87 and therefore it comes under no pollution category. This suggests that there is no appreciable input from anthropogenic sources. Based on geo-accumulation index, sediments are moderately polluted with respect to Cu and Cd.

KEYWORDS: Karadiyana, Sediments, Heavy metal, Geo-accumulation index, Pollution Loading Index

1 INTRODUCTION

Sediments deposited in water bodies are a product weathering of rocks and minerals, and they have been considered as a major source of heavy metals in the aquatic environment (Chakravarty and Patgiri, 2009). The ecological balance of aquatic systems on the planet is supported by the trace quantities of heavy metals (Wijeyaratne, 2016). Sediments have been considered as the final deposit of heavy metals. It even acts as the agent of transfer of pollutants as well as the secondary sources of contaminants in aquatic systems (Sin *et al.*, 2001, Calmano *et al.*, 1990). In addition to natural sources, heavy metals in sediments can also be due to human practices including industrial waste disposal, landfill leachate, agrochemicals and mining operations (Ouyang *et al.*, 2002).

The indiscriminate dumping of industrial and municipal waste to open dumpsites due to lack of adequate facilities for waste management has become a severe environmental issue (Ogwueleka, 2009). Rainwater percolating through these open dumpsites and the liquid-releasing reactions inside the waste piles along with internal biological and chemical processes cause the production of leachate (Renou *et al.*, 2008). The landfill leachate rich in dissolved organic matter, particulate matter, inorganic matter and heavy metals can interact with natural water bodies if leachate collection methodologies such as engineered liners are not incorporated into the landfill (Langler, 2004, Kjeldsen *et al.*, 2002, de Godoy Leme and Miguel,

2018). The extent of contamination of natural water sources by open dumpsites depends on type and depth of water table, the direction of groundwater flows, and the concentration of pollutants (Aderemi *et al.*, 2011). Many toxic metal ions may bind to the dissolved organic carbon, which allows them to transport easily. The strongest environmental impacts are the discharges from aged waste dumping sites, built before advanced engineering standards have become compulsory, as well as from sites in the third world where modern standards were not applied.

Karadiyana Waste Management Facility (6°48'58.32"N, 79°54'9.90"E) located in Kesbewa, Western Province of Sri Lanka has a surface area about 10.11 ha. It contains two waste dumping sites: Site - A (4.85 ha) and Site - B (5.26 ha). One of the major environmental and ecological concerns of the Karadiyana semi-controlled dumpsite is the risk of pollution of the Werar Ganga - Bolgoda Lake system. Bolgoda Lake has two major basins, Bolgoda North and Bolgoda South Lakes and these two lakes are connected by the Werar Ganga stream (Dahanayaka *et al.*, 2016, Asanthi *et al.*, 2017). Meda-Ela, a small canal that flows through Karadiyana semi-controlled dumpsite intercepts the Werar Ganga adjacent to the dumpsite. Leachate generated at the site directly flows into Meda-Ela polluting its waters and therefore, the dumpsite could be one of the major point sources of pollutants to the Werar Ganga - Bolgoda Lake system. Previous studies have shown the accumulation of heavy metals and toxic chemical species in aquatic organisms and

sediments in Werasingha - Bolgoda Lake system. Studies have shown heavy metal concentrations varying in the following concentration ranges in the Bolgoda Lake sediments; Cd 0.8 to 4.2 mg/kg; Cr, 22.6 to 214.8 mg/kg; Cu 13.2 to 135.5; and Zn, 58.2 to 227.6 mg/kg (Dahanayaka *et al.*, 2016, Senarathne and Pathiratne, 2007, Wijeyaratne, 2016).

The main objective of this study was to assess the concentrations of metals: Cu, Fe, Zn, Mn, Cd and Cr in the sediments of Meda Ela which directly receives leachate from the Karadiyana semi-controlled dumpsite.

2 MATERIALS AND METHODS

Sediment samples were collected using a Van Veen grab sampler from Meda-Ela at locations as in Figure 1 at the three-month interval from January to December 2018. These two sampling points directly received leachate throughout the study period from two large leachate plumes originated from Karadiyana semi-controlled dumpsite. In addition, they were relatively undisturbed from digging and widening of the canal carried out in this period. Water flow direction is from location 1 to 2. Samples were collected into ziploc bags and were labelled following removal of large aggregates and plant residues from sub and surface samples. Then the samples were air-dried

at room temperature and the dry sediments were pulverized using mortar and pestle and were sieved through a 2 mm sieve to achieve homogeneity throughout the mixture (Chrastný *et al.*, 2012, Kanmani and Gandhimathi, 2013). The water extracts (1:1 sediment to water) were analyzed for pH, electrical conductivity and powdered, pre-heated (105 °C) dry sediment samples were used to analyze Total Organic Carbon (TOC) using the standard methods (Akan *et al.*, 2012, ASTM, 2006).

Thermo Scientific iCE 3000 series Atomic Absorption Spectrophotometer was used for the analysis of Cu, Fe, Zn, Mn, Cd and Cr of acid digested sediment samples. Exactly about 2 g of the pre-prepared sediment samples were weighed out to the nearest 0.1mg into the acid-washed glass beaker. Sediment samples (2 g) were digested by addition of a mixture of 5 cm³ HNO₃ and 15 cm³ HCl (aqua regia) and 10 cm³ of 30% H₂O₂. The H₂O₂ was added slowly to avoid any possible overflow. Then, the mixture was heated over a hot plate at 90 °C for 2 hours. The heated mixture was filtered out to separate the insoluble solid from the supernatant liquid. The volume was adjusted to 100.00 cm³ with distilled water. The method was duplicated (Søndergaard *et al.*, 2003, Heron *et al.*, 1994, Jumbe and Nandini, 2009, APHA, 1998, ASTM, 2006).



Figure 1: Sediment collection points (1, 2) at Meda-Ela

2.1 Data Analysis and Interpretation

The following pollution indices were calculated by the measured concentrations of elements; contamination factor (*Cif*); Pollution Loading Index (PLI) and geo-accumulation index (*Igeo*) as described previously (Wijeyaratne, 2016, Martin and Meybeck, 1979, Buccolieri *et al.*, 2006, Banat *et al.*, 2005). Sediment quality was further analyzed by consensus-based sediment quality guidelines (CBSQGs) and quantitative sediment quality guidelines (SQGs). Statistical analysis for the comparison of

metal concentrations was carried out using Origin Pro 8 software.

3 RESULTS & DISCUSSION

The sediment samples collected from Meda-Ela from the location 1 and 2 showed an alkaline pH in the range of 8.40 to 8.70. The mean electrical conductivity of the sediment samples was recorded as $139.93 \pm 26.7 \mu\text{S}/\text{cm}$. TOC mean value is of $120.33 \pm 15 \text{ mg}/\text{Kg}$. The mean metal concentration of selected metals in the sediments is presented in Table 1.

Table 1: The mean metal concentrations in sediment samples (mg/Kg -dry weight, n=36)

Sampling date	Cu mg/Kg	Fe mg/Kg	Zn mg/Kg	Mn mg/Kg	Cd mg/Kg	Cr mg/Kg
Location 1	71.23±1.05	106.77±1.22	92.37±2.56	73.40±2.71	0.27±0.04	94.33±32.72
Location 2	73.53±2.52	110.83±1.96	94.40±2.08	78.63±2.15	0.38±0.03	103.00±41.62
Weras Ganga - Bolgoda lake system ¹	55.2 ± 5.2	63.00 ± 0.25	25.0 ± 2.4	N/A	0.02±0.02	288.8 ± 18.6

¹Data was extracted from Pathiratne *et al.*, 2009 and Wijeyaratne, 2016 (Pathiratne *et al.*, 2009, Wijeyaratne, 2016).

The mean Fe concentration was recorded as the relative highest value among the measured metal species, which was noted as 110.83 mg/Kg. The concentration of the Cu, Fe, Zn and Cd in the sediments of Meda-Ela is significantly greater (Cu; standard error of the mean (SEM) 0.87 and p-value 6.21×10^{-6} , Zn; SEM 1.086 and p-value 1.06×10^{-6} , Cd; SEM 0.015 and p-value 1.62×10^{-5}) than the concentrations of these metals of the sediments of Weras Ganga – Bolgoda Lake system. The mean Cr concentration in the Weras Ganga - Bolgoda Lake sediments was higher than that of Meda-Ela as stated in Table 1. The pollutants leaching from dumpsite can be suggested as the major source of the metal ions in Meda-Ela. This assumption is confirmed by the presence of Fe and Zn at concentrations of 10.30 mg/L and 1.63

mg/L in Karadiyana landfill leachate (Koliyabandara *et al.*, 2017). Ecological balance can be altered due to the intolerable high levels of heavy metals in the aquatic environment (Jumbe and Nandini, 2009, Katip *et al.*, 2012). Sediments have a high capacity to store contaminants and it may serve as a depository of pollutants (Katip *et al.*, 2012). Aesthetic properties of waterbodies can be reduced due to the contaminated sediments (Jiang and Zhu, 1999, Alberto *et al.*, 2001).

The concentration of heavy metals in aquatic ecosystem sediments has been studied extensively in many parts of the world (Zhang and Wang, 2001, Cardellicchio *et al.*, 2009). Sediment performance evaluation standards such as pollution risk indexes and recommendations on sediment quality are

commonly used to measure the risks of metal contamination in aquatic environment sediments (Chakravarty and

Patgiri, 2009). Indexes developed using sediment data are depicted in Table 2.

Table 2: Indexes developed by sediment analysis

Metal	Cu	Fe	Zn	Mn	Cd	Cr
*Background concentration (mg/Kg)	32	35,900	127	720	0.2	71
Contamination factor <i>Cif</i>	2.29	0.003	0.74	0.11	1.88	1.45
Level of pollution according to <i>Cif</i>	Moderate	Low	Low	Low	Moderate	Moderate
<i>I_{geo}</i>	0.62	-8.9	-1.01	-3.78	0.32	-0.04
Level of Pollution according to <i>I_{geo}</i>	Unpolluted to Moderately polluted	Unpolluted	Unpolluted	Unpolluted	Unpolluted to Moderately polluted	Unpolluted

* Background concentration = World surface rock average

A recent study carried out in Bolgoda lake has shown *Cif* values for Cd, Cr, Cu and for Zn are 3.1, 11.5, 2.2 and 0.3 respectively (Wijeyaratne, 2016). These values are comparable to the *Cif* values calculated for Meda-Ela sediments. Sediments closer to Shanghai Laogang Landfill in China, have recorded *Cif* ranging from 1 to 3 for Cr, Cu, Cd, and Zn falling into a moderately polluted category which is similar for Cu and Cd in the present study. The recorded mean values for Cu, Zn, Cd, Cr concentrations in sediments close to Shanghai Laogang landfill are as 29.7 ± 0.2 , 98.3 ± 15.8 , 0.23 ± 0.08 , 87.1 ± 24.8 mg/Kg respectively (Liu *et al.*, 2013). Comparing these sediment metal concentrations, the levels present in the current study also are

similar by values. Sediment samples collected along the western part Egyptian

Mediterranean coast had *Cif* values for Cd, Cr, Cu, Mn, Ni, Pb and Zn as 3.080, 0.318, 0.714, 0.227, 0.466, 1.503 and 0.586 respectively (Ahdy and Khaled, 2009). Calculated *I_{geo}* values are shown in Table 2. *I_{geo}* below zero is categorized into unpolluted and *I_{geo}* 0 to 1 is termed as unpolluted to moderately polluted where Cu, Cd in sediments fall into that.

The PLI of the sediments was calculated as 0.87 which falls into the class of PLI <1 which is no pollution category. Lower values of PLI imply no appreciable input from anthropogenic sources. The USEPA sediment quality guideline categorizes sediment quality into three groups such as non-pollution, moderately pollution and

heavily pollution. Consensus-based SQGs are divided into two categories as threshold effect concentration (TEC) and probable effect concentration (PEC) (MacDonald *et al.*, 2000).

Table 3. Relation of the concentration spectrum (mg/kg) of the metals tested in this study with recommendations for SQG and CBSQGs

Metal	EPA guideline for sediments- Pollution level according to Numerical sediment quality guidelines of USEPA (Ahdy and Khaled, 2009)			CBSQG (MacDonald <i>et al.</i> , 2000)		Mean Concentration mg/Kg
	Non	Moderately	Heavily	TEC*	PEC**	
Cu	<25	25 - 50	>50	32	150	73.53
Zn	<90	90 - 200	>200	120	460	96.07
Fe	-	-	-	20,000	40,000	110.0
Mn	<300	300 - 500	>500	460	1,100	77.0
Cd	-	-	>7	0.99	5	0.38
Cr	<25	25-75	>75	43	110	103.0

The amount of Cu present in sediments falls into the EPA guideline for heavily polluted sediments. It exceeds the threshold effect concentration but falls below the PEC. Similar results have been found by previous studies carried out by Bolgoda Lake - Weras Ganga system (Pathiratne *et al.*, 2009, Senarathne and Pathiratne, 2007, Wijeyaratne, 2016). Cu²⁺ is an essential element in many organisms because of its involvement in the carbohydrate metabolism and in functions of several enzymes. However, excessive concentrations of Cu²⁺ can be toxic. Besides, Cu²⁺ is one of the most toxic metals in an aquatic environment

(Beaumont *et al.*, 2000, Bojakowska and Krasuska, 2014) with algae being particularly sensitive to this metal. Cu²⁺ is also a component of algacides, fungicides and molluscicides. It is released to the environment from many sources, including coal combustion, copper ore processing, copper processing in metallurgy, transport, agriculture (micro fertilizer, pesticides, feed additive, control of algae and pathogens in fish breeding ponds). Due to the harmful effects of copper to aquatic organisms, its permissible level in sediments has been set at 149 mg/kg (MacDonald *et al.*, 2000). The pH, alkalinity and hardness of

water strongly influence the speciation of copper in sediments and consequently its availability to aquatic organisms (Carvalho and Fernandes, 2006). In the hypergene zone, copper is mobile under aerobic conditions, especially in an acidic environment (Bojakowska and Krasuska, 2014). However, it is readily captured by sediment components, mainly organic matter and hydrated iron oxides. It is doubtful that harmful effects will be found if the metals in sediments are below the TEC. If the metals are above the PEC, there are likely to be adverse effects. Research notes that most TECs provide a precise basis for predicting the absence of toxicity of sediments and that most PECs provide a reasonable basis for predicting sediment toxicity (MacDonald *et al.*, 2000). There is a spike in toxic effects as the concentrations of contaminants between the TEC and the PEC increase.

4 CONCLUSIONS

The pollution of natural water bodies with landfill leachate is a severe environmental issue and this problem is greatly exaggerated when the landfills do not have protective liners to collect the landfill leachate. Karadiyana semi-controlled dumpsite situated in Sri Lanka is one of the largest dumpsites in the country. The leachate generated in the dumpsite directly flows into Meda-Ela canal. A significant pollution threat can be anticipated with this. The mean metal concentrations of sediment samples varied as $Cd < Cu < Mn < Zn < Cr < Fe$. Fe recorded the highest value (110.83 mg/Kg). The other metals studied have recorded mean concentrations of $0.38 \pm$

$0.03, 103.0 \pm 41.6, 94.4 \pm 2.08, 78.63 \pm 2.15, 73.53 \pm 2.52$ mg/Kg for Cd, Cr, Zn, Mn and Cu respectively. The Cu, Cd concentrations in the sediments fall into the unpolluted to moderately polluted category according to the geo-accumulation index. In addition, the amount of Cu present in sediments falls into the EPA guideline for heavily polluted sediments. It exceeds the threshold effect concentration but falls below the PEC. The PLI was calculated as 0.87 which falls into no pollution category. The lower values of PLI imply no appreciable input from the human-induced source.

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