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Geochemical Assessment of Upper Mahaweli River and Polgolla Reservoir Sediments, Sri Lanka

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Abstract

The river Mahaweli which receives discharges of agricultural fields and urban runoff was investigated using geochemical analysis. The present study focuses on the levels of As, Pb, Zn, Cu, Fe, P, Ca, Ni and Cr in order to assess environmental pollution in this area. Thirty six surface sediments of the upper catchment of the river and one core (28cm) from the Polgolla reservoir were analyzed on XRF. Pollution assessment was carried out using the geoaccumulation index (GAI). The GIA indicates that all the analyzed sediments are very highly polluted for phosphorus, Zn and Cr, moderate for Pb and Ni. Fe and As are moderate to unpolluted. Cu is moderate to high in the Polgolla reservoir and surface sediments. High phosphorus with high organic matter indicates that it derived from biogenic processes. The strong enrichments of Zn, Cr, Ni, Pb and Cu are due to the association of Fe and sulfur in an oxic environment. The lacing of the geochemical variation of the core sample implies that there is no considerable anthropogenic input in this area but controlled by natural processes. The geochemical characteristics of the core show that temporal changes of the study area are insignificant.

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Keywords: Heavy metals, Pollution, Upper catchment, Polgolla reservoir, Mahaweli River;

1. Introduction

Heavy metal pollution of the natural environment is a wide-reaching problem because these metals are permanent and most of the metals cause adverse health effects on living organisms, when they exceed a certain concentration [1]. Due to self purification heavy metals are not removed from water while they accumulate in reservoirs and enter the food chain [2] The bottom sediments of a reservoir show the accumulation and enrichment of heavy metals while the occurrence in the environment results primarily

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from anthropogenic activities and natural processes such as weathering of rocks [3]. In addition, sediments are the ultimate sinks for heavy metals discharged into the environment [4]. Many indexes are used to assess the environmental pollution levels of sediment deposited in various environments. On the other hand, analysis of pollutants in sediments is vital since they are absorbed by material in suspension and by fine-grained particles [5]. Thus, the upper catchment area of the Mahaweli River sediments (30), sediments (6) of the dammed reservoir at Polgolla of the river were used in order to assess the environmental pollution due to heavy metals. Also, one representative core (depth of 28 cm) is used to study the temporal changes in terms of geochemistry of sediments. In this study the geoaccumulation index of Muller, 1979 has been used.

The basement is mainly comprised of Precambrian metamorphic rocks of granulate faces metamorphism. Polgolla is subjected to high urban settlements, developments with roads and intensive agriculture. Heavy rains in the upper catchments of the river cause high flushing of fine grains and suspended matter along the river. Therefore, heavy metals from the runoff of the urban areas and agricultural lands can be accumulated in the river sediments, especially in the reservoir at Polgolla (Fig 1).

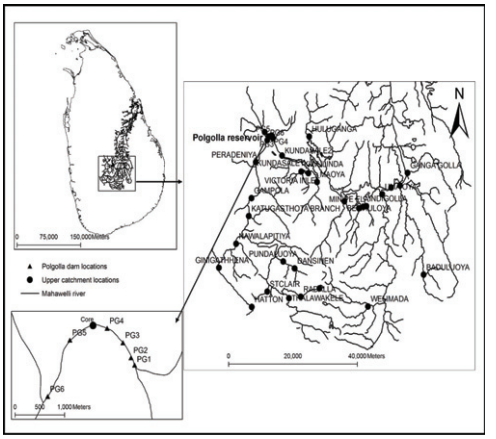

Fig. 1. Location map of the upper catchment of Mahaweli River and the Polgolla reservoir.

2. Methodology

Sediment samples were collected from the upper catchment of the Mahaweli River and the Polgolla reservoir (Fig 1) using grab sampler method. The core was taken from the middle of the reservoir so that it is most representative of the sediment deposition. Samples of the core each 2cm thick and the surface sediments was oven dried at 120°C prior to geochemical analysis at Shimane University, Japan. Approximately 50g of each sample was then oven dried at 160°C for 48 hrs before crushing in a tungsten carbide ring mill. The crushed samples were compressed into briquettes for 60 seconds using a force of 200KN. The concentrations of elements were then determined by X-ray fluorescence spectrometry using a Rigaku RIX-2000 spectrometer equipped with Rh-anode tube. Analytical methods, instrumental conditions, and calibration followed those described by Ogasawara (1987) [6].

3. Results and Discussion

Metal concentrations in core sediments ranged from 4.6 to 7.4 for As 26.9 to 35.2 for Pb, 168.9 to 193.9 (ppm) for Zn, 101.7 to 117 5 (ppm) for Cu, 18.71 and 10.03 (wt%) for Fe. The surface sediments

ranged from and 3.2 to 6.1 (ppm) for As and 19.5 to 31.8 (ppm) for Pb, and 104.2 to 207.1 (ppm) for Zn, and 52.3 to 269.5 (ppm) for Cu 17.02 to 15.99 (wt%) for Fe. The surface sediments are characterized by relatively higher concentrations of Zn and Cu. In contrast, core sediments are high in As, Pb and Fe compared to the surface sediments. The very high Fe indicates that the reservoir sediments are under highly reducing condition.

3.1. Surface processes

The surface process shows that there are no significant changes in all sediments for each element except a few locations in the surface sediments. The Table 1 shows the calculated GAI values for all the sediments. The GAI was calculated using the equation; where, C_n = measured concentration of heavy metal in the sediments, B_n = Geological background value in average shale (Turekian and Wedepohl, 1961) of element n, 1.5 is the background matrix correction in factor due to lithogenic effects. $I_{geo} = Log_2(C_n/1.5B_n)$. There are a number of indexes to account pollution levels. However, the Muller, 1979 GAI is the most used and appropriate for this study. Thus, this GAI has been used to assess environmental activities in this study. The GAI for phosphorus indicates that the sediments are very highly polluted (Table 2). The phosphorus concentrations in the sediments are more than two times higher than Upper Continental Crust (UCC, [7]). Thus, these sediments are mainly of biogenic and is evident by high organic matter. Thus, the elements that indicate high pollution such as Zn, Cu, Ni, Cr is associated with the organic matter and is hindered. Thus high accumulations are seen in the reservoir sediments which also point out a threat of high pollution. However, the As levels are low showing no pollution threat. Since, the sediments are under high oxic conditions, the very high Fe_2O_3 leads to removal of As and display low values. On the other hand, upon heavy rains the suspended solid levels increase. Thus, the heavy metals associate suspended solids and accumulate but cause no adverse effect.

Table 1. Geoaccumulation index (Muller, 1979) of Heavy Metal concentration in sediments. Source Praveena, et al. 2007 [8].

Geoaccumulation index	Class	Pollution Intensity
0	0	Background concentration
0-1	1	Unpolluted
1-2	2	Moderately to Unpolluted
2-3	3	Moderately polluted
3-4	4	Moderately to highly polluted
4-5	5	Highly polluted
>5	6	Very highly polluted

3.2. The upper catchments of Mahaweli River

The Total Sulphur (TS) values and phosphorus are high. However, the plots (Fig 2 a, b, c, d) indicate that the surface sediments do not show any much difference from each other. Zn shows a good correlation with Fe_2O_3 though As, Pb, Cu is highly scatted. On the other hand, this clearly shows that the core sediments of the Polgolla dam are enriched by all the elements. Nonetheless, there is no special variation in the upper catchments of the Mahaweli River. This indicates that there is no significant geochemical process taking place within this area.

Table 2. Geoaccumulation index of the upper catchment of Mahaweli River and Polgolla reservoir.

S-No	As	Pb	Zn	Cu	Fe_2O_3	P	Ni	Cr
Upstream of Polgolla								
2	2	3	4	3	2	6	3	4
6	2	2	4	3	2	6	3	4
3	2	3	4	3	2	6	3	4
5	2	2	4	3	1	6	3	4
10	2	3	4	3	2	6	3	4
1	2	3	4	3	1	6	3	4
7	2	2	4	3	1	5	3	4
4	2	2	4	3	1	6	3	4
11	2	2	4	3	2	6	3	4
13	2	2	4	3	2	6	3	4
9	2	2	4	3	1	6	3	4
14	2	3	4	3	2	6	3	4
8	2	3	4	3	2	6	3	4
12	2	3	4	3	2	6	3	4
16	1	2	4	3	2	5	3	4
Polgolla core								
PC1	2	3	4	3	2	6	3	4
PC2	2	3	4	4	2	6	3	4
PC3	2	3	4	4	2	6	3	4
PC4	2	3	4	4	2	6	3	4
PC5	2	3	4	4	2	6	3	4
PC6	2	3	4	4	2	6	3	4
PC7	2	3	4	4	2	6	3	4
PC8	2	3	4	4	2	6	3	4
PC9	2	3	4	4	2	6	3	4
PC10	2	3	4	3	2	6	3	4
PC11	2	3	4	4	2	6	3	4
PC12	2	3	4	3	2	6	3	4
PC13	2	3	4	3	2	6	3	4
PC14	2	3	4	4	2	6	3	4

S-No	As	Pb	Zn	Cu	Fe_2O_3	P	Ni	Cr
Polgolla reservoir								
PG1	1	2	4	3	2	6	3	4
PG2	2	3	4	3	2	6	3	4
PG3	2	2	4	3	2	6	3	4
PG4	2	3	4	3	2	6	3	4
PG5	2	2	4	3	1	6	3	4
PG6	2	2	4	4	2	6	3	4
Downstream of Polgolla								
15	2	3	4	3	1	6	3	4
17	1	2	4	3	1	6	3	4
18	2	3	4	3	2	6	3	4
20	1	2	4	3	1	6	4	4
19	2	3	4	3	2	6	3	4
21	2	3	4	3	2	6	3	4
22	1	2	4	3	1	5	3	4
23	1	2	4	3	1	6	3	4
24	2	3	4	3	2	6	3	4
25	2	3	4	3	2	6	3	4
26	1	2	4	3	1	6	3	4
27	2	3	4	3	2	6	3	4
28	1	2	4	3	2	6	3	4
29	2	3	4	3	1	6	3	4
30	2	3	4	3	2	6	3	4

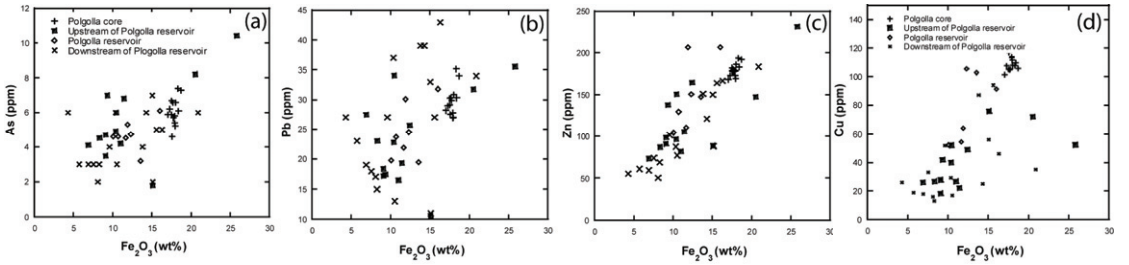

Fig 2: Graphs of Fe_2O_3 and As, Pb, Zn and Cu for the upper catchment of Mahaweli River and Polgolla reservoir.

3.3. The Polgolla reservoir core sediments

The Polgolla core sediment GIA shows that the sediments are very highly polluted due to phosphorus, highly polluted due to Cr, Ni, Pb, Zn and Cu and moderately polluted for As (Table 1). However, vertically there is no significant change in the core samples (Fig 3). This shows that there is no considerable pollution due to anthropogenic activities affecting the reservoir even though there are

significant agricultural activities taking place in the upper catchment of Polgolla area and rapid urban developments. Nevertheless, the Zn, Cu, Ni and Cr are very much higher than UCC [7] values which is more than two times higher. The CaO, Sr and P_2O_5 show that the increases of these elements are biogenic. Thus, the basement rock weathering could be the main source and process of these elements. Unfortunately, there is no age data for the core sediments yet. Since the area is subjected to heavy rains the sediment deposition rate increases and the core itself would represent a short term, presumably less than twenty years. The sediments are composed of mud and high organic matter. Thus, the accumulation of heavy metals could also be associated with organic matter and the very fine mud particles. However, though the accumulation is high there is no considerable threat to the health of the population around the area due to the association of sulfur and iron.

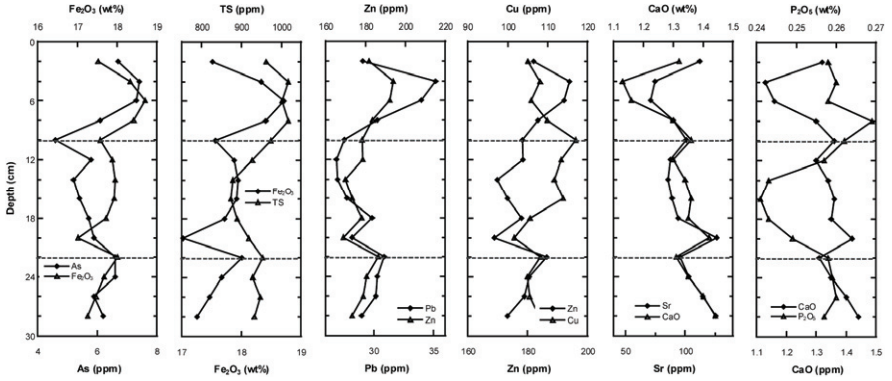

Fig. 3. Vertical distribution of As, Fe_2O_3, Zn, Total sulfur (TS), Pb, Cu, Sr CaO and P_2O_5.

4. Conclusions

The high GAI's for phosphorus in the sediments is due to biogenic sources. The strong oxic conditions results the deficiency of As values and enrichments of Zn, Cu, Ni, Cr. High organic matter, sulfur, iron and intense weathering processes of the area thus may be the result for higher accumulation of Zn, Cu, Ni, Cr. There is no significant change vertically in the core samples. This implies us that the anthropogenic input is not considerable. However, the natural processes in the area contribute for the accumulation of measured heavy metals. High suspended particles and the organic matter may hinder the heavy metals of the sediments, and therefore, there is a indication of pollution of the heavy metals. Ultimately, it can be suggested that there is no threat on the environment from the human activities.

Acknowledgements

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