

Determination of heavy metal content in surface sediments and soil from the River Nile Khartoum City (Sudan)

Muna I. Shumo

College of Applied and Industrial Sciences, Department of chemistry, University of Bahri, Sudan

Mazin M. Mohammed

College of Applied and Industrial Sciences, Department of chemistry, University of Bahri, Sudan

Hawa A. Musa

College of Applied and Industrial Sciences, Department of chemistry, University of Bahri, Sudan

Tarig Osman Khider (✉ tarigosmankhider@gmail.com)

University of Bahri, College of Applied and Industrial Sciences, Khartoum, Sudan

<https://orcid.org/0000-0003-4494-8402>

Research Article

Keywords: heavy metals, Trace elements, River Nile, sediment and soil

Posted Date: July 16th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-42895/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

The surface sediment and surface soil samples were taken from the River Nile (Abroof, Shambat, AL-Halfaia, and AL-Hetana), Khartoum, to determine the available levels of Lead (Pb), Zinc (Zn), and Cadmium (cd) to establish a baseline concentration of each of these available metals, and to investigate their possible correlations with soil and sediment properties. The content of each of the three heavy metals in soil and sediment samples was determined using atomic absorption spectroscopy, AAS.

The values of Zinc in the soil and sediment samples, were found to be between (0.192 to 0.294 ppm) and (0.101 to 0.181) respectively, showing the highest content in soil and sediment samples in Shambat (S) and Abroof (A), and the lowest values recorded for samples in AL-Halfia (H) and AL-Hetana (E). While Lead content was ranged between (0.105 to 0.136 ppm) for soils samples (AL-Hetana(E) and Shambat(S)), and (0.078 to 0.141) for sediment samples (Abroof(A) and shambat (S)). Whereas, content for Cadmium ranged between (0.010 to 0.015 ppm) for soil samples Shambat, AL-Hetana and Abroof and (0.011 to 0.016) for sediment samples Shambat, AL-Halfia and Abroof.

Soil and sediment physicochemical properties (pH, temperature & conductivity) were found to be correlated with the available heavy metals content, suggesting that the enhanced mobility of heavy metals are related to anthropogenic activities, the high percentage of organic carbon in soil (11.6%) and sediment (15.0%).

Introduction

River Nile is the longest river in the world and it is a source of life to millions of people, flowing 6.825 km (4.238 miles) from south to north [1].

Soil is the mixture of [minerals](#), [organic matter](#), gases, liquids, and the countless organisms that together support life on earth [2]. Sediment is the loose sand, clay, silt and other soil particles that settle at the bottom of a body of water, it can come from soil erosion or from the decomposition of plants and animals. Wind, water and ice help carry these particles to rivers, lakes and streams. The Environmental Protection Agency lists sediment as the most common pollutant in rivers, streams, lakes and reservoirs [3]. One source defines heavy metal as one of the common transition metals, such as copper, lead, and zinc. These metals are a cause of environmental pollution from sources such as leaded petrol, industrial effluents, and leaching of metal ions from the soil into lakes and rivers by acid rain [4]. Living organisms require varying amounts of heavy metals. Iron, cobalt, copper, manganese, molybdenum, and zinc are required by humans [5]. All metals are toxic at higher concentrations and all soils and sediments contain some concentration (usually low) of trace and toxic metals from natural sources. However, these background levels can vary widely depending on a number of factors such as parent material [6]. It is usually a result of human activities that levels of metals increase and due to this pollution in soils and sediments can rise to the point where they represent a potential health or ecological risk [7].

The most common types of soil pollutants are heavy metals such as cadmium, chromium, copper, zinc or mercury, pesticides or herbicides, organic chemicals, oils and tars, explosive or toxic gases, combustible or radioactive materials, biologically active compounds and asbestos [8].

Several analytical techniques including X-ray fluorescence (XRF), instrumental neutron activation analysis (INAA), atomic absorption spectrometry (AAS), inductive coupled plasma optical emission spectroscopy (ICP-OES), and Inductive Coupled Plasma Mass Spectroscopy (ICP-MS) are applicable to trace element analysis [9].

The objectives of this study are to determine the of the heavy metals concentrations; zinc (Zn), lead (Pb), and cadmium(Cd) in the sediment and soil of Abrook, Shambat, AL-Halfia, AL-Hetana Khartoum, Sudan, in order to assess the impact of past anthropogenic activities on soil and sediment quality, to give suggestions of methods to analysis heavy metal.

Materials And Methods

Study area and sample collection

In the River Nile and its tributaries there are many activities like burning of coal for the production of bricks and modern constructions buildings [10].

The surface sediment and surface soil samples were taken from the River Nile. The samples taken from areas near bridges to learn concentrations and see if there is environmental pollution or sourced naturally and areas where the burning of coal for the production of bricks.

Four sampling locations were chosen in each River (near estuary: Abrook (A) and Shambat (S) in River Nile) and (downstream: AL-Halfia (H) and AL-Hetana (E) in River Nile).

Location A and S in middle of city after the White River (WN) and Blue River (BN) are merged together at this point the mixing and dilution was supposed to have attained equilibrium. Location S impacts by clay pits for manufacture of building blocks. Sampling point H and E were located downstream the city, i.e. north of Khartoum. At each sampling location, about 2 kg of surface soil and sediment samples were taken (0–5 cm) by hand digging at 4 sampling sites within a maximum area of 40 m².

Experimental

Electrical conductivity (EC), temperature, organic carbon content and pH were measured. The pH for the samples was determined using Geotechnical Test Method (GTM–24) method by dissolved the samples in the deionized water with ratio of (1:5) (sample: water) and pH measured after 30 minutes using pH meter. An alternate current electrode was used to measure electric conductivity at 25.0°C.

The organic matter determined using Standard Test Methods (ASTM D2974) by heating sample at 550°C in a furnace for 6 hours, the samples were weighted many times until reached to constant weight.

The samples were digested in heating mantle inside a Fume Hood (Missunshi 64132) using HNO₃ (65%) & HClO₄(60%) in the ratio 2:1 respectively, then the digested samples were transferred into a beakers(100ml) and filtrated with nitric acid (20%), then the filtrate was placed in a volumetric flask (100ml), ready for analysis by AAS spectrophotometer.

The solutions of the digested samples were analyzed using air/acetylene atomic absorption spectroscopy model (210 VGP) (CAT#28750.15) with the use of prepared standards for Pb, Zn & Cd. Nitric acid (65%) was used in the preparation of standard solutions (20%). Calibration curves were used to calculate the concentration of the metals. A reagent blank was used to zero the instrument. This was followed by aspiration of standard solution and finally the soil sample extract was aspirated.

Results And Discussion

Table 1. Average values of pH, conductivity & organic matter of soil samples

O. M. ² content%	EC ¹ (mS m ⁻¹)	PH	Areas	NO
11.58	0.38	7.28	A	1
8.59	0.25	7.24	E	2
9.77	2.18	7.55	S	3
9.43	0.33	7.17	H	4

Where, EC¹ = Electrical conductivity, O.M²= Organic Matter

A= Abrook

E= AL-Hetana

S= Shambat

H= AL-Halfia

Table 2. Average values of pH, conductivity & organic matter of sediment samples

O. M. ² content%	EC ¹ (mS m ⁻¹)	pH	Areas	NO
8.05	0.26	7.15	A	1
15.00	0.28	7.25	E	2
6.57	0.24	7.36	S	3
3.43	0.11	7.63	H	4

Where, EC¹ = Electrical conductivity, O.M²= Organic Matter

A= Abroof

E= AL-Hetana

S= Shambat

H= AL-Halfia

Soil and sediments samples were subjected to heavy metal analysis and also for physicochemical parameters measure including pH, organic matter and electrical conductivity.

(Tables 1 and 2) showed the average values of physiochemical properties of the all soil and sediment samples, pH was recorded in the normal range while electrical conductivity of all soil samples was not far from the normal range. Mohamed (2007) [1] found that the WN was more alkaline than the BN, pH 8.2, and 7.5, respectively. At the point where the two rivers merge, there was a dilution of the H⁺ concentration compared to the Blue Nile. The pH observed in the water after passing Khartoum city was 7.9.

Organic matter in the sediment and soil played an important role in the adsorption of trace metals, it could be used as a simple pollution index of the sediment and soil. In soil (floodplains) the organic increase to wet season in order of RN > BN > WN, the values are 3.72, 2.99 and 1.90 % respectively [11]. The higher content in the soil in site A which near estuary and the higher content in sediment in site E. In 2013 areas around E is used sand and gravel as building materials, thus lead to change the bed sediment and soil, in 2015 new high way street was building.

Segarra *et al.* (2007) [12] showed that the mineralogical results reveal the riverine origin of the sediments of the [Gda.sk](#) Basin, with the coarser mineral grains deposited near the river mouth and the finest terrigenous particles transported further from the coast. This fine material is the best carrier for the external inputs of organic matter, which is then transported and accumulated in surface sediments far from the coast.

In all soil and sediments samples concentration of all heavy metals was recorded below the permissible limits worldwide table (3) and (4). Concentration of lead ranged between 0.078 to 0.141ppm, zinc ranged

between 0.101 to 0.294 ppm and concentration of cadmium was recorded to range between 0.011 to 0.016 ppm.

Table 3. Concentration (ppm) of heavy metals (Pb, Zn & Cd) in soil samples

Mean Conc. Of Cd	Mean Conc. Of Zn	Mean Conc. Of Pb	Soil Sample
0.000	0.000	0.000	Blank
0.015	0.231	0.110	(A)
0.010	0.245	0.105	€
0.013	0.192	0.123	(H)
0.010	0.294	0.136	(S)

Where A= Abroof

E= AL-Hetana

S= Shambat

H= AL-Halfia

Table 4. Concentration (ppm) of heavy metals (Pb, Zn & Cd) in sediment samples.

Mean Conc of Cd	Mean Conc of Zn	Mean Conc of Pb	Soil Sample
0.000	0.000	0.000	Blank
0.014	0.181	0.078	(A)
0.016	0.101	0.127	(E)
0.011	0.134	0.141	(S)
0.011	0.171	0.135	(H)

Where, A= Abroof

E= AL-Hetana

S= Shambat

H= AL-Halfia

Heavy metal concentrations in sediment and soil are affected by particle size and composition of sediments and concentrations generally increased with decreasing particle size of sediments and concentrations generally increased with decreasing particle size of sediments [10].

Figures (1) and (2) show the comparison of elements concentration between soil and sediment samples for study, Cd was shown same distribution in all sites, but Zn and Pb were shown different, the presence of a point source of contamination may cause a sharp increase, for the sediment and soil samples and may be the source of Zn in soil from sediment deposition.

Mohamed (2007) [1] reported that exhausts from vehicles might contribute to increased concentration observed downstream the city Khartoum because exhausts are regarded as the major source of environmental contamination by lead and Ni.

Figure (3) showed the concentration of Pb in sediment and higher distribution in all sites compared to A, the presence of additional amounts of Pb is caused by human activity, including emission of furnace or coke dust or combustion of fluid fuel.

Muna I. Sh. Kamal K. T., *et al*, (2014) [13] reported that the River Nile had higher concentrations of Cd, Cr, Co, Zn and Mn than some the European and Asian ecosystems. All elements (Fe, Cu, Cd, Co, Cr, Ni, Zn, Mn, Al) have high mean concentration in BN, WN and RN at wet than dry season except (Ni, Cd and Pb) in WN and (Ni, Pb) in BN which these elements have high mean concentration at dry season this indicate that these two elements have anthropogenic source.

The concentration of Zn in soil was higher compared to sediment figure (4), the concentration of Zn difference between all sites in river, this indicate the difference of elements such sources and the concentration of Cd in E was higher compared to other sites figure (5), the strong association of Cd indicates common sources, and these metals may have been derived from anthropogenic sources, especially the paint industry, the application of phosphate fertilizers to the agricultural soil has led to increase.

Table 5. Comparison of lead (Pb), zinc (Zn) and cadmium (Cd) content in sediment samples and local study

Pb content			
	A	S	H
Study	0.0784	0.141	0.135
Local studies*	0.0128	0.0217	0.0031
Zn content			
Study	0.181	0.134	0.171
Local studies*	0.254	0.078	0.052
Cd content			
Study	0.014	0.011	0.011
Local studies*	0.00027	0.00003	0.00094

The figure (6) and (7) showed that the concentration of Pb and Cd elements in all study areas is greater than local study, the source of Pb element is automobile exhausts. Higher levels of Pb often occur in water bodies near highways and large cities due to high gasoline combustion. The concentration of Zn for all study areas is greater than local study except in site A (figure 8), the variation of heavy metal concentration in the study area was due to irrigation of land by industrial waste water and other agronomic practices.

Conclusions

The content of metals varied across the study areas.

1. The highest concentration of Zn was found in Shambat and Abrook sites (0.294, 0.181ppm), this high level cannot be accounted for naturally and is the result of pollution from out site anthropogenic activities.
2. In comparison, higher concentrations of Pb are shown in Shambat soil and sediment (0.136, 0.141 ppm) respectively, and high concentrations of Cd in Abrook soil (0.015 ppm) and AL-Hetana sediment (0.016 ppm).
3. These metals are not added to the soils and sediments through anthropogenic processes instead their concentrations on the area are dominated by natural sources, weathering, geology and pH.
4. The pH in all samples were alkaline, ranging between (7.15- 7.55) that is due deposition of mineral salt.

Declarations

Availability of data and materials

We have already included all of data in the manuscript.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Not applicable.

Funding

Not applicable.

Competing interests

The authors declare no competing interests

References

- [1] Mohamed, O. A. B. (2007). Effect of Khartoum City for Water Quality of the River Nile. Water and Environmental Studies. Linköping, Sweden, Linköpings Universitet. Master of science.
- [2] Chesworth, Ward. *ed* (2008). Encyclopedia of soil science. Dordrecht, Netherlands, Springer. xxiv., 1,4020, 8–3994.
- [3] <http://WWW.marc.org> / Enviromental /Water 816/474–4240.
- [4] A dictionary of chemistry, Oxford university press, Oxford reference, Oxford University Press, (2000).
- [5] Lane T. W., Morel F. M. (2009). A biological function for cadmium in marine diatoms, ProcNatlAcadSc.,46, 2–31.
- [6] Chronopoulos J., *et al.,* (1997). Greece. Sci Total Environ., Variations in plant and soil lead and cadmium content in urban parks in Athens, 196, 9, 1–8.
- [7] Greaney, K. M. (2005). An assessment of heave metal contamination in the marine sediment of lastperlas Archipelago, Gulf of protection Edinburgh Heriot-Watt University. M.Sc. Thesis.
- [8] Shao W. L., *et al*, (2016). Pollution Effects & Control,2375–4397,5–12.

[9] Falcina, N. E., *et al*, Determination of metal in soils. Toxicants in terrestrial ecosystems Berlin Heidelberg, (2006)27–78.

[10] Muna I. Shumo (2014). PhD. Thesis, University of Bahri, Determination of heavy metals content and distribution in surface sediments and soil from River Nile and its tributaries around Khartoum City (Sudan).

[11] Lin S, Hsieh IJ, Huang KM and CH, Wang (2000). "Influence of the Yangtze River and grain size on the spatial variations of heavy metals and organic carbon in the East China Sea continental shelf sediments." Chem. Geol.182: 377–394.

[12] Segarra, M. J. Belzunce, Szefer, P, Wilson, M. J., Bacon, J. and Bolalek, J. (2007). "Chemical Forms and Distribution of Heavy Metals in Core Sediments from the Gdańsk Basin, Baltic Sea." Polish J. of Environ. Stud.16 (4).

[13] Muna I. Sh. Kamal K. T., *et al*, (2014). "Digestion with HNO₃/H₂O₂ Mixture for determination of trace elements in sediment using Inductively coupled plasma-Mass Spectrometry". Journal of Applied and Industrial Sciences, 2 (2): 85–92, ISSN: 2328–4595.

Figures

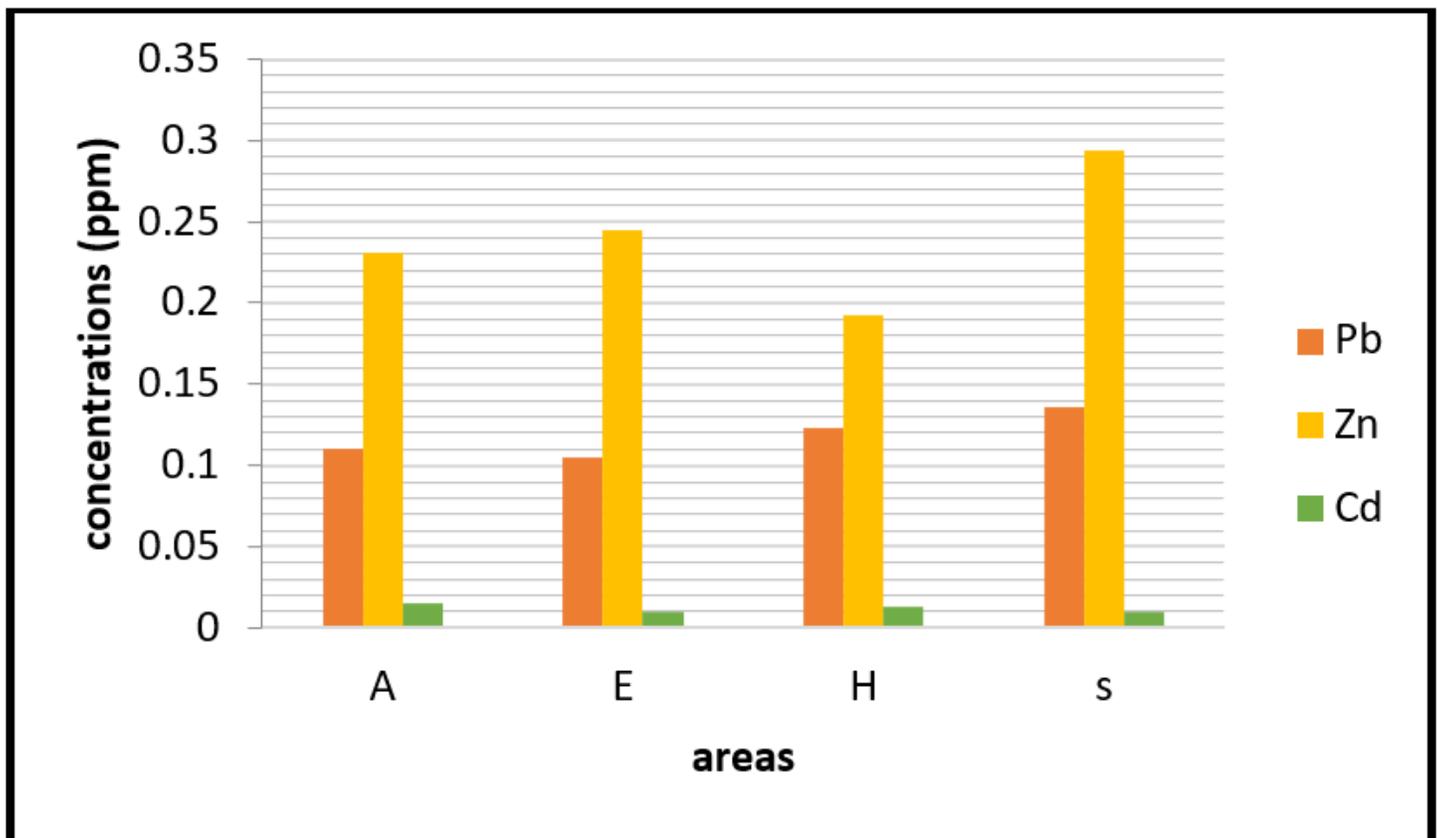


Figure 1

Concentration of lead (Pb), zinc (Zn) and cadmium (Cd) in the Soil samples

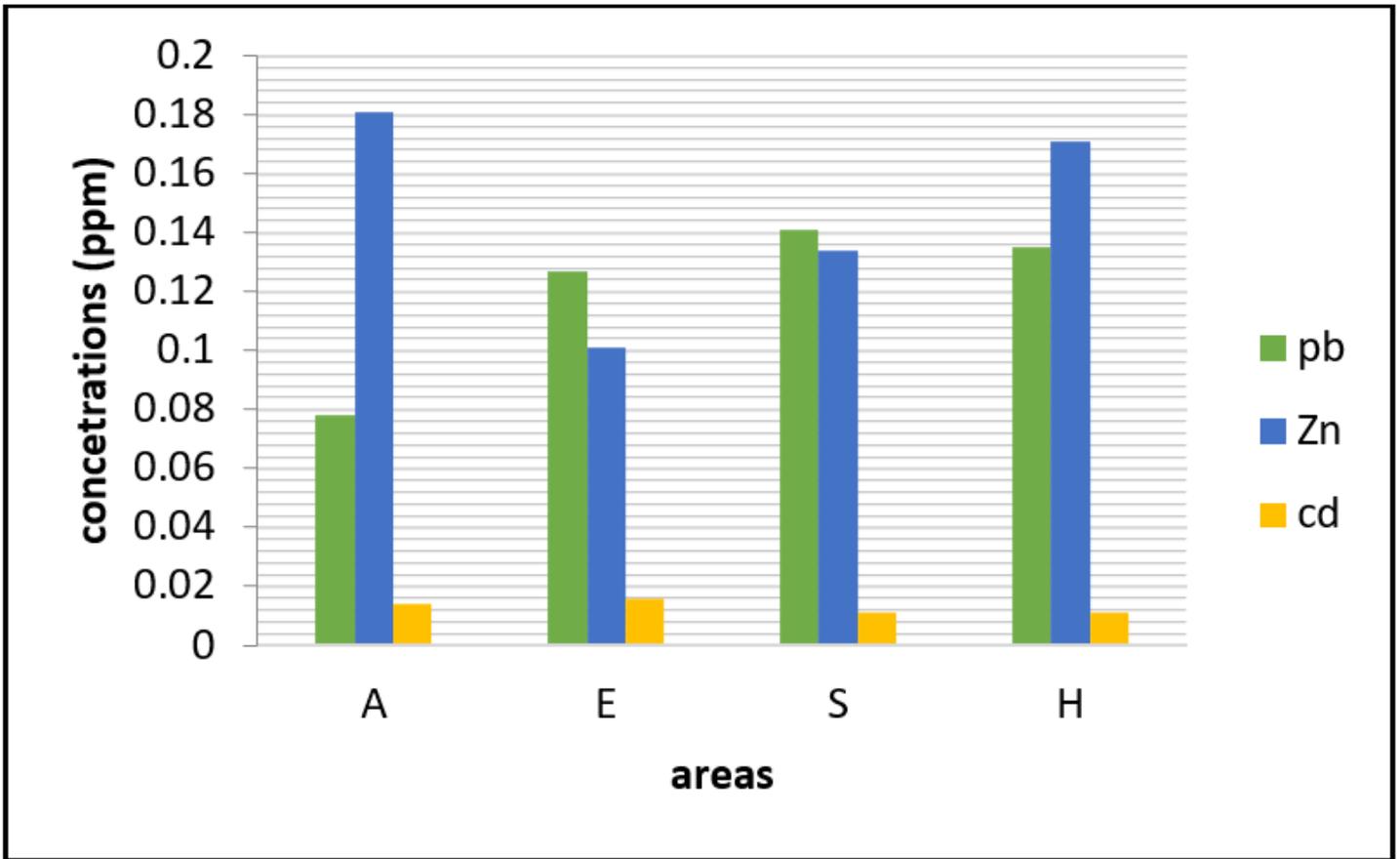


Figure 2

Concentration of lead (Pb), zinc (Zn) and cadmium (Cd) in the sediment samples

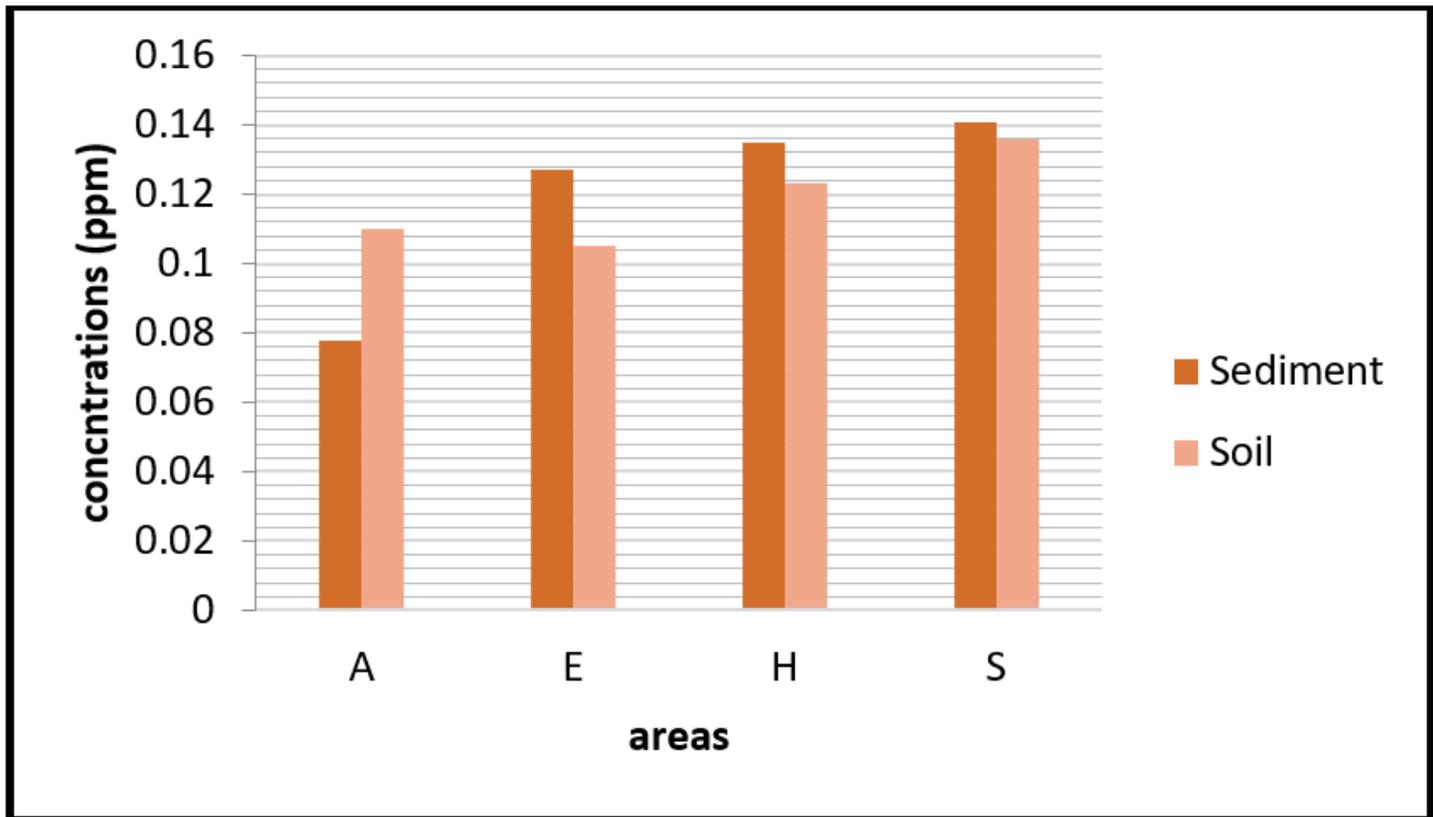


Figure 3

Comparison of Concentration of lead (Pb) content (ppm) in Soil and Sediment samples

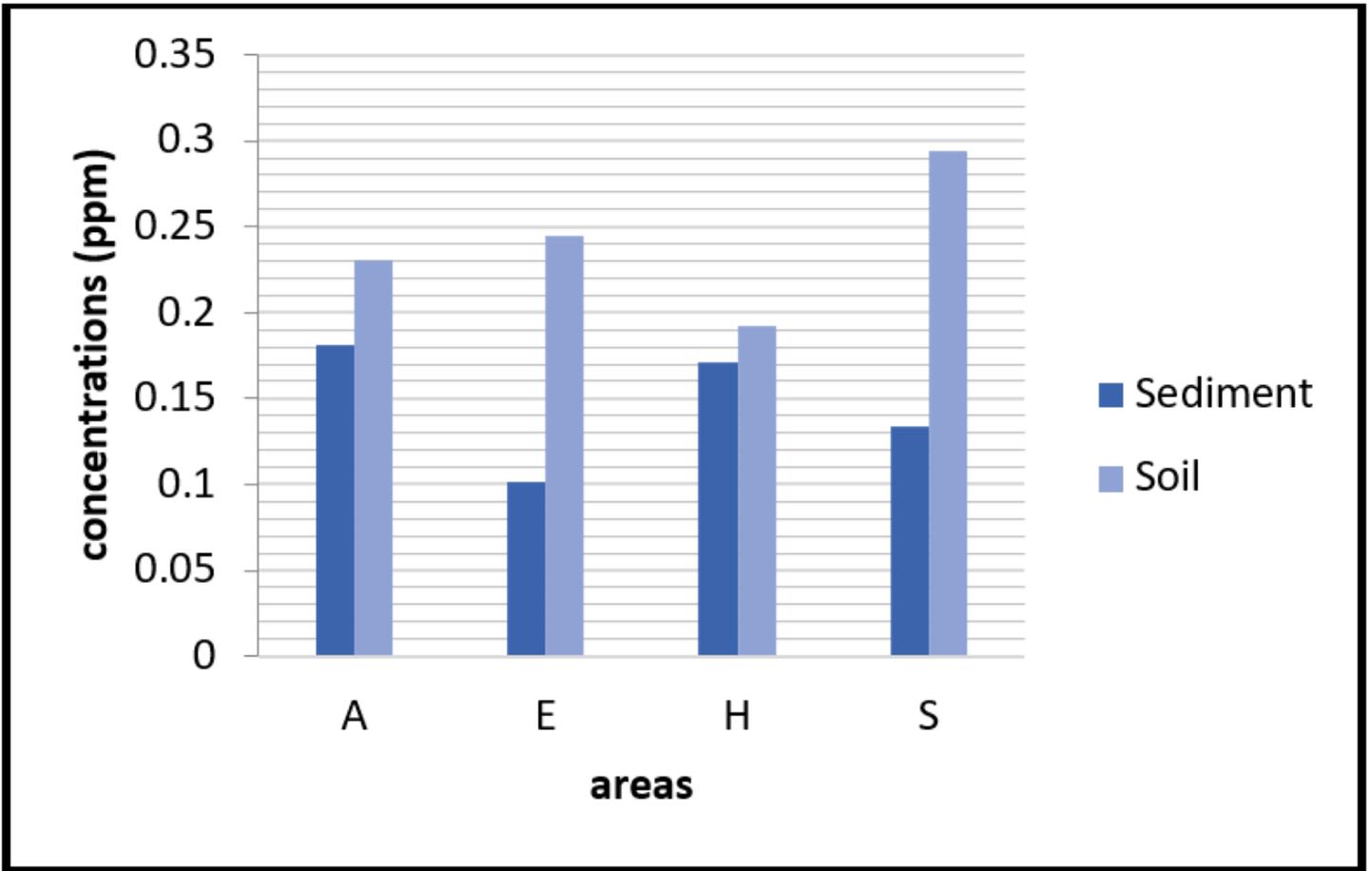


Figure 4

Comparison of Concentration of zinc (Zn) content (ppm) in Soil and Sediment samples

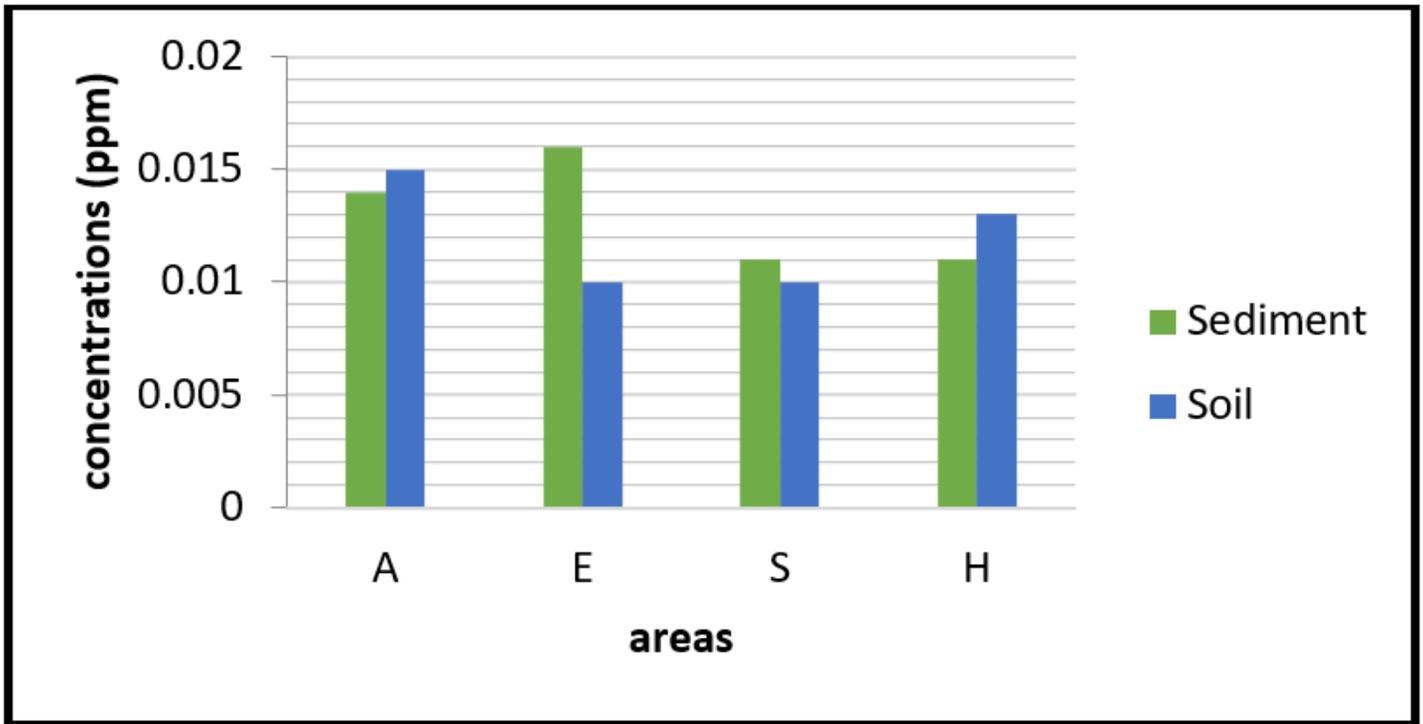


Figure 5

Comparison of Concentration of cadmium (Cd) content (ppm) in Soil and Sediment samples

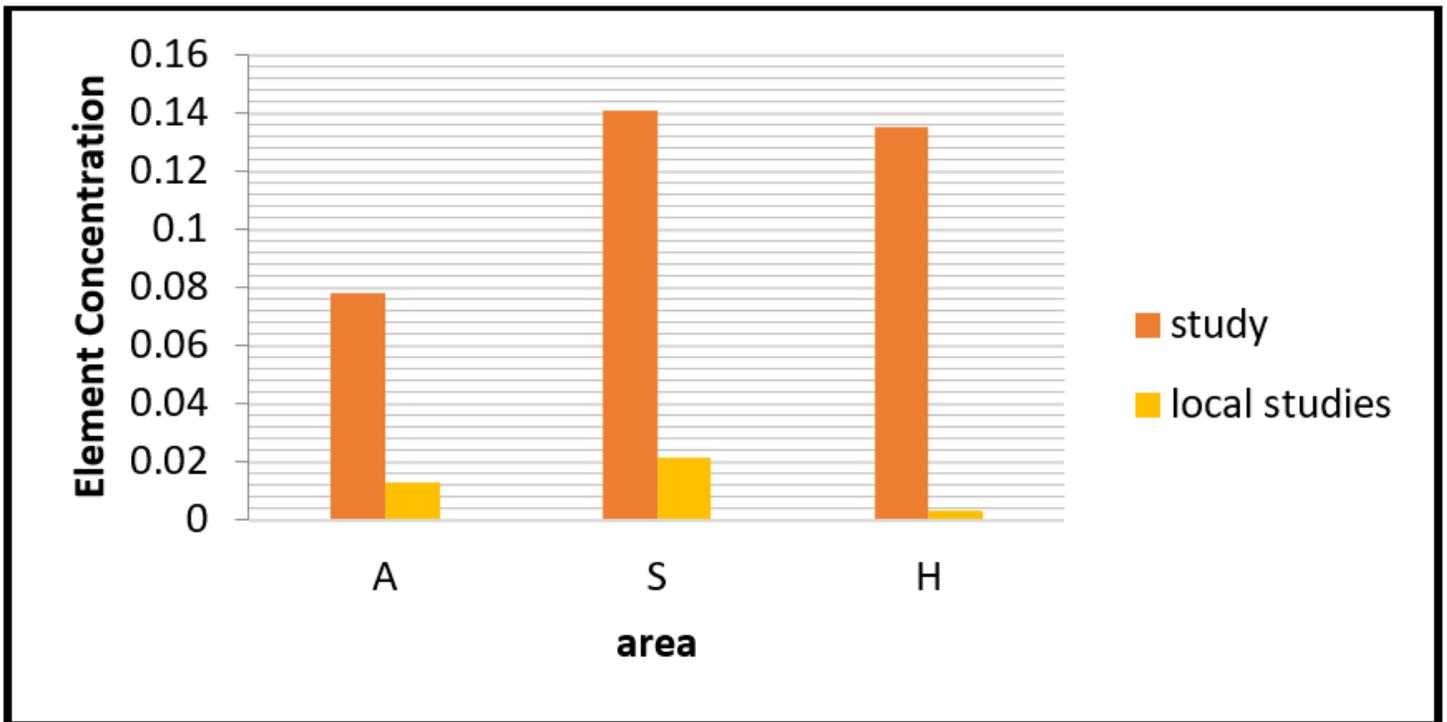


Figure 6

Comparison of lead (Pb) content in sediment samples and local study

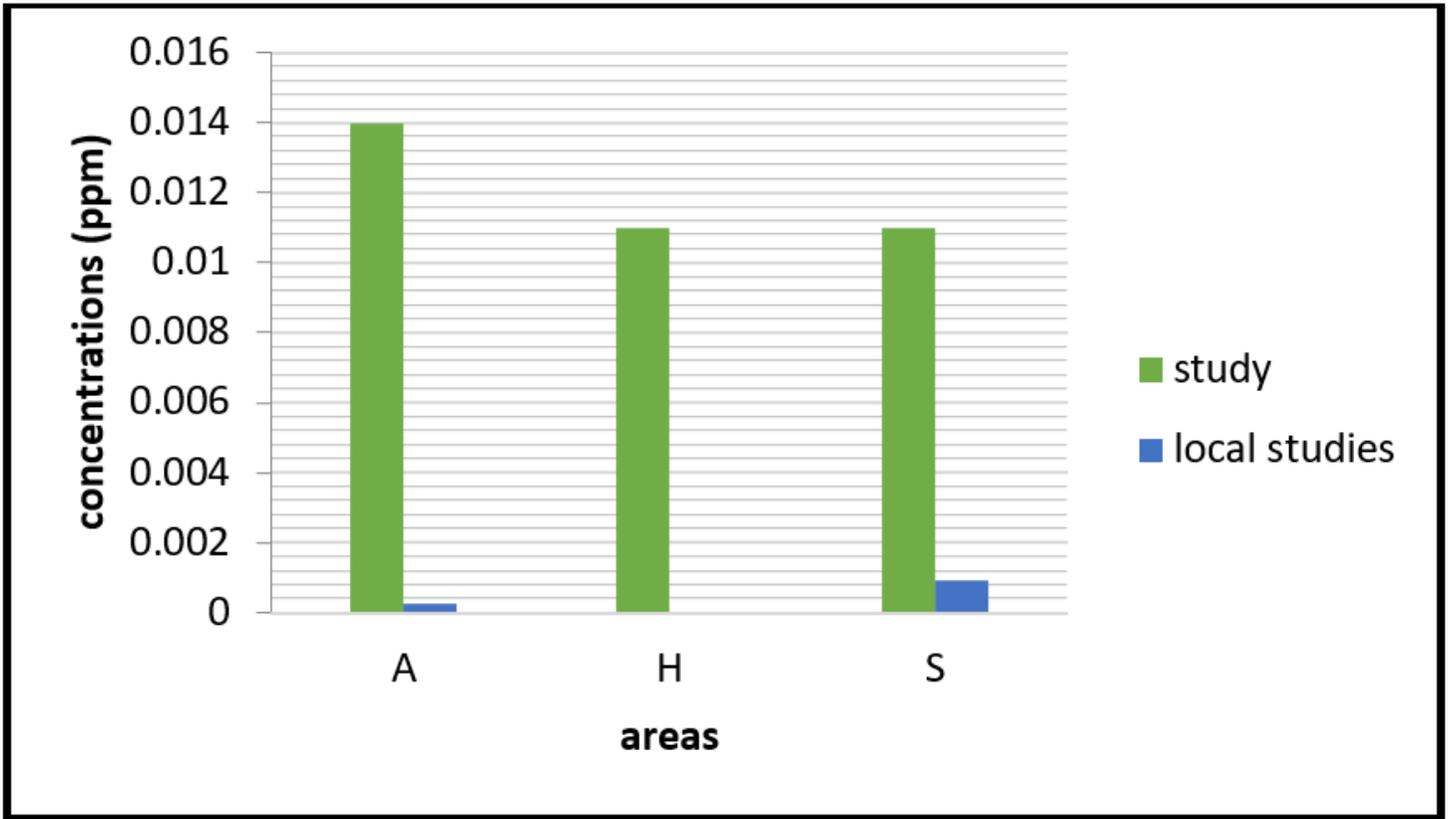


Figure 7

Comparison of cadmium (Cd) content in sediment samples and local studies

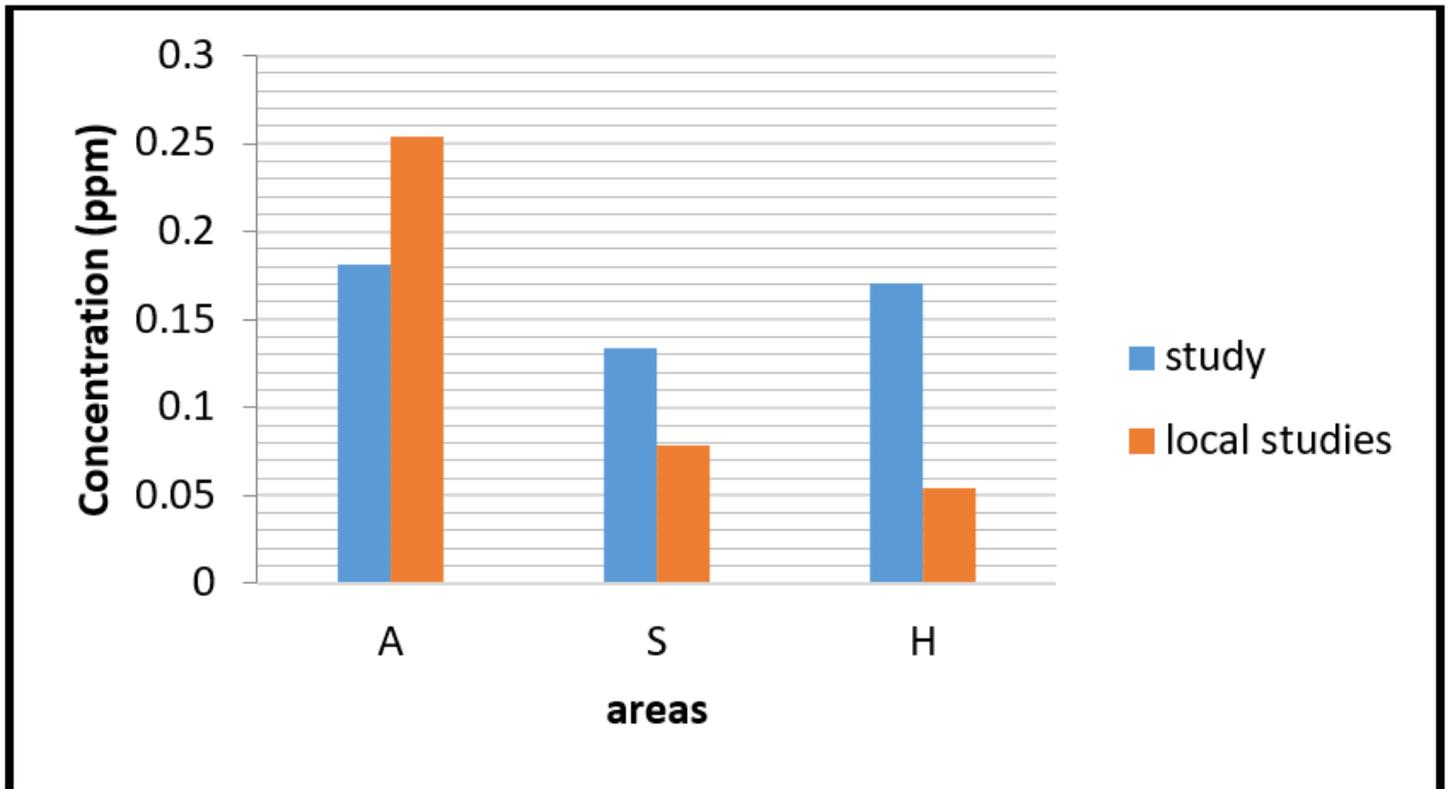


Figure 8

Comparison of zinc (Zn) content in sediment samples and local studies



Figure 9

Study Area