

Exposure assessment of heavy metals pollution enriched in core sediment samples of river Nile, Aswan, Egypt

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Received: 7 October 2016

Accepted: 5 March 2017

Published online: 18 March 2017

Abstract

The river Nile is a dominating physical feature of the north-eastern part of the African continent, covering areas exhibiting varieties and contrasts in topography, climate, vegetation and people. So, in this study, we estimated the contamination of the Nile sediment with some major and trace heavy metals in core samples which can cause some undesirable health effects. Concentrations of all elements show that the maximum enrichment is found in the top subsamples, while the most elements show low contents in the lower layer reflecting the impact of human activity on the sediment contents. Different normalizing methods were used, i.e. geoaccumulation (I_{geo}) and enrichment factor (EF), for the influence of the natural variability in sediment mineralogy and to assess whether the concentrations observed in surface sediment represent background or contaminated levels. The study has also shown the importance of different sediment characteristics in spatial distribution of heavy metals in the sediments of river Nile. To protect the ecological system of river Nile watershed, industrial mining and agricultural activities along river stream should be strictly regulated.

Keywords: core, sediment, metals, Nile, Egypt

1. Introduction

Metals are natural components of ecosystems and many of them are essential for the organisms. Only when their contents exceed certain values could they become contaminants to the environments (Gao et al. 2014). Excessive amount of trace elements is a serious environmental problem in many ecosystems around the world. Most of them are essential and very important such as copper, zinc, manganese and iron. These metals are cofactors in many enzymes and play an important role in many physiological functions of man and animals (Koh and Judson 1986). Some of them, such as copper, nickel, manganese, chromium and iron are essential in very low concentration for the survival of all forms of life (Watson 2001). Only when they are presented in higher quantities, can these, like the heavy metals lead, cadmium be toxic also in very low concentrations and cause metabolic anomalies (Hernandez-Avila et al. 2003). Lead occurs naturally from the decomposition of parent rocks and may

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accumulate from anthropogenic sources, including traffic exhaust, lead–zinc smelters, dumps and other sites receiving industrial and household lead, e.g., paints and batteries (Mulligan et al. 2001).

In recent years, studies about possible health and ecological effects of accumulated toxic metals in sediments have been published (Krishnamurti et al. 1995; Gissera et al. 2004; Franca et al. 2005; Chatterjee et al. 2007 ; Shokrzadeh and Saeedi Saravi 2010; Landre et al. 2011; Wang et al. 2012; Fawzy et al. 2012; Li et al. 2013; Fu et al. 2014; Wang et al. 2015; Chen et al. 2016 and El Azhari et al. 2016). Metals entering into aquatic systems are usually rapidly transported into sediments (Gu et al. 2016). However, with changing environmental conditions, e.g. pH and Eh; they can be released and represent a secondary contamination source, affecting ecosystems of nearby seas and estuaries (Kalantzi et al. 2013). Consequently, sediments are both carriers of metals and potential pollution sources in aquatic systems (Gu and Lin 2016). Because heavy metals are not biodegradable, certain concentrations of them can adversely influence organisms and natural environments and can threaten human health by entering the food chain (Wang et al. 2013).

It is well established that trace metals may be introduced to sedimentary environments by both natural processes (e.g. weathering and erosion) and human activities within the catchments' area. Since trace metals from natural and anthropogenic sources accumulate together, it is difficult to determine the contribution of the sedimentary metal load from these two sources. Metals released to the environment from various natural and anthropogenic sources accumulate in the sediments, providing a record of metal emissions over time (Landre et al. 2011). Different methods have been proposed to distinguish the anthropogenic sources of HMs in sediments from natural sources including statistical methods, geochemical indices, and isotope tracing techniques (Han et al. 2015a; Bing et al. 2016; Chen et al. 2016).

The anthropogenic inputs mainly came from industrial activities of the tributary rivers such as heavy metal mining and smelting, and agricultural practices such as fertilizing and pesticide consumption (Wang et al. 2012). Zn, Pb, Cd and As mainly originated from mining wastewater and industrial wastewater, but Cr and Cu mainly derived from natural erosion and nonpoint agricultural sources (Li et al. 2013). Recognizing the pollution characteristics of trace metals in river sediments and targeting their potential sources are of key importance for proposing effective strategies to protect watershed ecosystem health (Chen et al. 2016).

Sediments are regarded as a mixture of inorganic material; however, concentrations of trace metals in sediments largely depend on inorganic material resulting from physical and chemical weathering of rocks and soils in the catchments' area. This inorganic material is predominantly composed of less weathering primary silicate minerals such as quartz, feldspars and micas, as well as secondary minerals formed during weathering of primary minerals e.g. clay minerals (Verca and Dolenc 2005).

River sediments provide an archive of environmental change within the river region; therefore, have been used across the world in order to study natural environmental change or human impacts. Distribution of trace elements in the river sediments not only reflects pollution from atmospheric deposition, but also reveals the past land-use histories (Oldfield et al. 2003). Detailed work has been carried out on the distribution of heavy metals with depth in sediments cores (Yu et al. 2001; Whelan III et al. 2005; Vreca and Dolenc 2005; Shi et al. 2010). Core sediments have been proved to be an excellent tool for establishing the effects of anthropogenic and natural processes on depositional environments (Harikumar and Nasir 2010), and they can be used to study the pollution history of aquatic ecosystems (Vallius 2014; Veerasingam et al. 2015).

The river Nile is one of the longest rivers in the world, measuring 6,670 km from the headwaters of the Kagera river in Rwanda to the shores of the Mediterranean in Egypt with a surface area about 2,978,000 km². The river Nile has given Egypt a fertility that led to its ancient agricultural civilization and helped in developing this civilization in peace and stability. It well known from historical sources

that Ancient Egypt, in the Greek and Roman periods, mud were used as antiseptic cataplasms to cure skin, stomach and intestinal ailments, as well as for cosmetic purposes (Carretero 2002; Vreca and Dolenc 2005).

This study aims to show the impact of agricultural , industrial and population activities and tourist boats on sediment contamination by the metallic elements in different locations at Aswan city, Egypt using core samples, and comparing the concentrations of elements in the different layers to see their source , whereas the release of these elements to water bodies under different factors (for example, decreasing of pH , increasing of Eh and organic matters) leads to danger on aquatic organisms and human health .On the other hand, the study points out the need to preserve waterways from pollution and the need for waste treatment, whatever their source.

2. Materials and methods

2.1. Samples and Reagents

Sediment core samples were collected using a polyethylene corer down to a depth of about 90 cm from five locations along the river Nile (Aswan city, Egypt), named West Sohiel , West Aswan, Bahareef , El-Aaqab and El-Raqba (Fig. 1). At each location core sample of 90 cm depth was sampled from the river bank, sectioned into 1- surficial sediment horizon (0 - 30 cm), 2- upper sediment horizon (30 - 50 cm), 3- middle sediment horizon (50 - 70 cm) and 4- lower sediment horizon (70 - 90 cm).

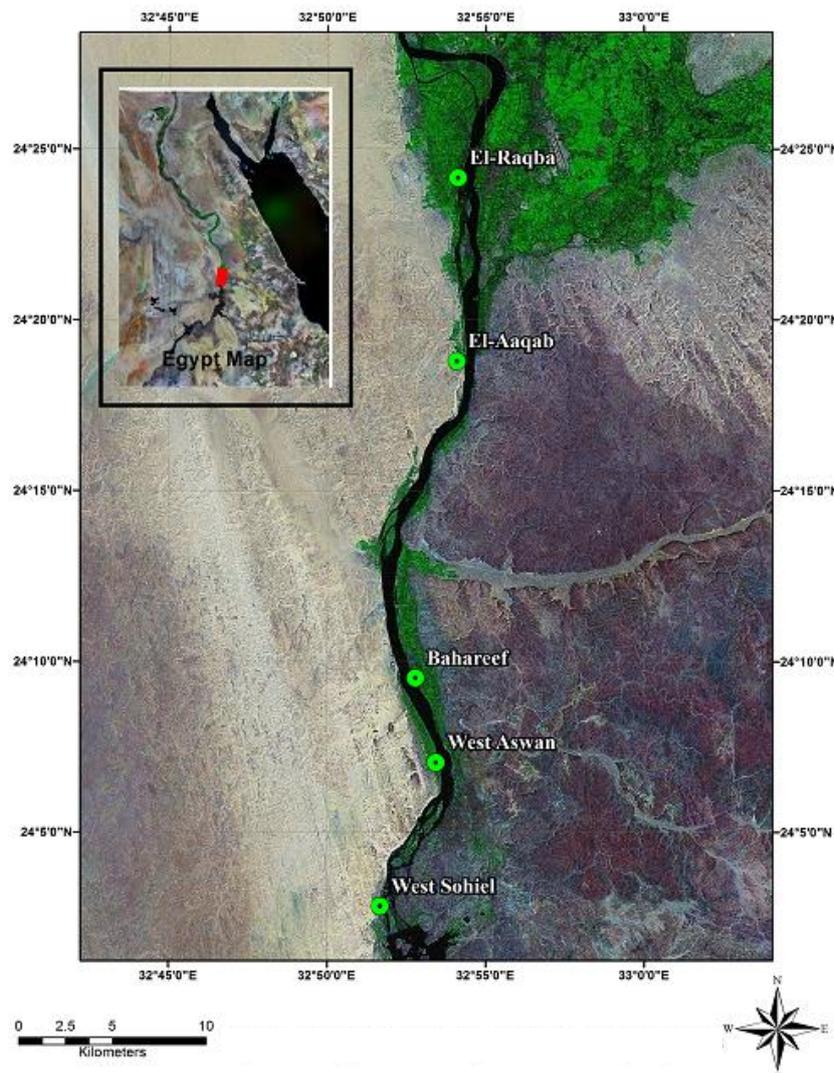


Fig. 1 Map of the study area and sampling sites.

All glass and plastic wares were soaked in 10 % nitric acid overnight and rinsed thoroughly with deionized water before use. For quality control, reagent blanks, replicates were incorporated in the analysis to direct contamination and assess precision. The standard addition calibration method and extraction blanks were employed to avoid interferences in the measurements. All standard for calibration were prepared for adequate analytical grade salts in the various reagent solutions.

2.2. Sediment Analysis

The sediment samples were air dried, homogenized and stored for subsequent analysis. The pH, conductivity and salinity were measured in 1: 2.5 suspension of sample: bidistilled water using pH-meter (Orion Research, Model SA520, U.S.A.) and conductivity meter (HANNA Instruments, HI 8033 Italy), respectively. Total carbonate and phosphate contents were determined by a volumetric method and spectrophotometrically at $\lambda = 690$ nm using molybdenum blue method, respectively (APHA 1992). In the choice of extracting reagents, particular emphasis was placed on the selectivity, suitability and extracting efficiency of each leaching solution. The extraction method that is the most informative for environmental purposes is the total element content. Each a homogenized mixed core sample was digested by sequential total acids attack using concentrated HNO_3 , HF and HCl (1:1:1) mixture (Tessier et al. 1979; Belzile et al. 1989; Li et al. 1995; Whelan III et al. 2005; Janaki et al. 2007). In each digested sample, the total metal concentrations (Pb, Zn, Cd, Cr, Fe, Ni, Cu, Mn, Co, Al, Ca, and Mg) were determined by atomic absorption and flame emission (K and Na) spectrophotometer.

2.3. Assessment of Sediment Quality

The simple approach to the normalization of geochemical data is to compare the total metal concentrations of surface sediment with concentrations characteristics of natural background levels or anthropogenically uncontamination, for assessing Sediment quality, can also be calculated by using the so-called index of geoaccumulation (I_{geo}) proposed by Müller (1979) and defined as: $I_{geo} = \log_2 C_n / 1.5 B_n$.

Where C_n is the measured concentration of the metal {n} in the sediment, B_n represents the geochemical background concentration in average shale (Turekian and Wedepohl 1961) of the metal {n} and 1.5 is the background matrix correlation factor due to lithogenic effects. The index of geoaccumulation consists of seven grades, whereby the highest grad (6) reflects 100-fold enrichment above background values (Müller 1969, 1979; Vreca and Dolenc 2005). The assessment of sediment samples according to this index is summarized in Tab. 2. In order to evaluate the data in more detail, the enrichment factors (Efs) are calculated as follows:

$EF = (X/Y)_{\text{sample}} / (X/Y)_{\text{background}}$ (Szefer et al. 1996; Vreca and Dolenc 2005).

Where X is the concentration of potentially enriched metal and Y is the concentration of the reference metal (Middlenton and Grant 1990), the validity of such an enrichment factor varies with the value used for the background levels (Kersten and Smedes 2002), aluminum is used here as the reference element.

3. Results and discussion

Sediment in rivers not only plays an important role influencing the pollution of river water but also can be used to record the history of river pollution. Thus, sediment acts as both carriers and potential sources of contaminants in an aquatic environment (Yu et al. 2001).

3.1. Elements Distribution

Heavy metal transportation and distribution within the study area are important for the assessment of long term environmental impacts of the metal contamination. The results expressed as

total metals concentrations. Generally, the horizontal variation in the element concentrations presents a complex picture as it is affected by many factors, including variations in the industrial effluents influx, intensity of erosion during periods of high water discharge and agitation of the bottom sediments by river traffic and navigation.

Some of chemical Characteristics for the samples collected from different sediment depths are recorded in Tab. 1. For surface sediment (0-30 cm) in all locations, the content of all elements show that the maximum enrichment is found in the top subsamples. Indeed, most elements show lower contents with depth in all the cores (Fig. 2), the increase in heavy metals in the upper layers of the core samples reflects the combined effects of discharge of fishery boats and trade ships (Fawzy 2000; Moalla et al. 2006).

Calmano et al. (1993) have pointed out that metals in the surface of bottom sediments would be released into the water phase by physico-chemical processes; this means any change in environmental conditions in the system may render the remobilization of metals from sediments. Chen et al. (2017) studied the effects of elevated phosphorus in water on the release of heavy metals in sediments and stated that the Excessive phosphorus (P) input plays an important role on the release of heavy metals in sediments under the eutrophic environment. Nowadays, heavy metals are frequently detected in the environment including both bed sediments and water columns and have gradually become a major concern worldwide due to anthropogenic activities. As shown in Tab. 2 and Fig. 2, most of metals levels specially cadmium (Fig. 2a) are decreased with depth. There are no significant distribution trends for heavy metals between the some sampling locations (Tab. 2).

Tab. 1 Some of chemical characteristics of sediment core samples.

Sample Depth	pH		CEC ($\mu\text{S m}^{-1}$)		Salinity		CaCO ₃ (mgg^{-1})		Phosphates (mgg^{-1})	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Surface	7.85	7.6-8.4	1509.2	898-2724	0.6	0.42-0.66	147.4	137-162.5	9.6	5.5-17.5
30 cm	7.4	7-8.1	6924	3240-9020	2.6	2.14-4.44	118.6	112-137.5	8.3	7-12.5
50 cm	7.9	7.28-8.78	5782	1746-21880	2.86	0.8-10.98	141	137-150	6.6	5.75-8.0
70 cm	8	7.31-8.78	1256.8	864-1444	0.56	0.4-0.7	138.7	125-162.5	10.1	5.5-24.5
90 cm	7.9	7.69-8.52	1456.2	396-3244	0.9	0.56-1.62	140	125-150	9.95	8-13.25

Tab. 2 Levels of metal concentrations in the sediment samples (μgg^{-1}) and I-geo class.

	Surface sediment	Average shale (standard)	*I-geo class	Designation of sediment
Pb	0.64	20	0	uncontaminated
Zn	1.35	95	0	uncontaminated
Co	0.86	19	0	uncontaminated
Cr	2	90	0	uncontaminated
Fe	672	46.700	0	uncontaminated
Ni	0.82	68	0	uncontaminated
Cu	0.75	45	0	uncontaminated
Mn	10.9	850	0	uncontaminated
Cd	0.1	0.3	0	uncontaminated
Ca	17,000	2.200	1	unpolluted to moderately polluted
Mg	29,500	1.500	1	unpolluted to moderately polluted
Na	17,500	10.000	0	uncontaminated
K	44,60	2.700	0	uncontaminated

*I-geo: Geoaccumulation-Index Class.

A portion of measured metals content was from lithogenic origin, because the sediment in this region consists of fine granite particles from igneous rock present in the main stream and sides of the river Nile. In addition, highest metals accumulation of sediment at West Aswan is due to anthropogenic sources resulting from agricultural, industrial and domestic discharge. The mean metal concentrations are below the shale average values (Tab. 3).

Tab. 3 Different metals content measured at various depths in sediment core samples.

	Pb	Zn	Co	Cr	Fe	Ni	Cu	Mn	Cd	Al	Ca	Mg	Na	K
	(μgg ⁻¹)										(mgg ⁻¹)			
West Aswan														
1	0.7	1.27	0.8	2	740	0.8	0.74	9.3	0.12	600	20	30.4	15	4.6
2	0.7	1.22	0.6	2	690	0.8	0.72	8.8	0.11	600	17.5	27.4	14.5	4.5
3	0.6	1.16	0.6	2	690	0.6	0.68	8.2	0.08	600	15	25.8	14.4	4.5
4	0.6	1.15	0.6	2	640	0.6	0.63	8.2	0.07	600	15	22.8	14.3	4.3
5	0.6	1.1	0.5	2	600	0.07	0.61	8.1	0.02	500	15	15.2	12.4	4.2
West Sohial														
1	0.7	1.26	0.7	2	650	0.7	0.74	10.3	0.11	700	20	27.4	16.7	4.5
2	0.6	1.14	0.7	2	650	0.6	0.72	9.2	0.07	600	15	25.8	14	4.5
3	0.6	1.08	0.6	2	650	0.6	0.66	7.9	0.06	600	15	24.3	13.2	4.3
4	0.5	10.3	0.6	1	630	0.6	0.66	7.6	0.06	600	15	22.8	12.9	4.2
5	0.4	0.95	0.3	1	540	0.5	0.58	6.5	0.04	500	12.5	19.8	12.8	4.0
Bahareef														
1	0.6	1.14	0.9	2	690	0.8	0.76	11.3	0.06	700	15	28.9	13.9	4.4
2	0.5	1.06	0.9	2	670	0.6	0.68	10.3	0.06	600	15	27.4	13.6	4.3
3	0.5	1.02	0.7	2	610	0.5	0.66	10.3	0.06	600	15	24.3	13.6	4.3
4	0.4	0.95	0.6	2	610	0.5	0.66	9.0	0.05	600	12.5	24.3	13.3	4.3
5	0.4	0.95	0.5	2	600	0.5	0.64	8.9	0.05	600	7.5	19	12.4	4.2
El-Aaqub														
1	0.6	1.77	1	2	640	0.9	0.76	11.8	0.11	800	15	30.4	25.2	4.4
2	0.6	1.33	0.9	2	640	0.8	0.75	10.4	0.1	700	12.5	30.4	16.3	4.3
3	0.6	1.24	0.8	2	640	0.7	0.67	10.1	0.08	600	10	25.8	16.5	4.3
4	0.5	1.23	0.7	2	610	0.6	0.65	9.2	0.06	600	10	24.3	15.2	4.2
5	0.4	0.95	0.3	2	590	0.5	0.60	7.5	0.05	600	10	24	13.2	4
El-Raqba														
1	0.6	1.33	0.9	2	640	0.9	0.75	11.8	0.1	800	15	30.4	16.5	4.4
2	0.6	1.24	0.8	2	640	0.7	0.67	10.4	0.08	600	12.5	25.8	16.3	4.3
3	0.5	1.23	0.7	2	640	0.6	0.65	10.1	0.06	600	10	24.3	15.2	4.2
4	0.5	1.06	0.7	2	610	0.5	0.62	9.2	0.05	600	10	24	13.2	4.2
5	0.4	0.95	0.3	2	590	0.5	0.60	7.5	0.04	600	7	24	12.5	4.0

(1) Surface sediment, (2) 0-30 cm, (3) 30-50 cm, (4) 50-70 cm, (5) 70-90 cm

3.2. Spatial Distribution

Manganese concentrations in sediment core samples, in general, lower than the average abundance of this element in shale standard (< 850 ppm) and show slight and almost similar variation in the river Nile sediments, this suggests that physicochemical and biological properties (Tab. 1) of the Nile sediments (pH; Carbonate, Phosphate concentration, redox potential, etc.) are major importance in controlling the bioavailability concentrations the element. Decrease in metal content, however, in the deep, consistent with the fact that, this redox sensitive element derived from the early diagenesis of the sediment, is believed to have been oxidized and flocculated by the oxygen-rich Nile water (Balkis and

Çağatay 2001). The relatively high iron concentration is due to abundance of magnetite (Fe_2O_3) and ilmenite (FeTiO_3) minerals in the river Nile sediments (Fawzy 2000).

A comparison of the results of total, Pb, Cu, Zn, Ni, and Cr in core samples display smaller values compared to those of the average shale (Tab. 3). These data supported the Merry et al. (1983) and Lin (2002) contention that surface horizons accumulate Pb. Specific mechanisms that could complex Pb are sedimentation, adsorption by clay minerals, and phosphate bonding. Furthermore, chelation by organic matter is especially in retaining Pb.

Vertical variation of Ca and Mg showed almost high abundance in surface sediments (Fig. 2c), suggests that concentrations of these metals are mainly associated with the carbonate phases (Tab. 1) and they have similar transport mechanisms. The slight variation in Ca and Mg concentrations reflect the endogenic enrichment of these two elements in Nile sediments. High concentration of carbonates (Tab. 1) could be attributed to the abundance of molluscs and calcareous tubeworms (Bernasconi and Stanley 1994). Most of these shell fragments are composed of calcium carbonates, in addition to the geological composition of surrounding rocks. Soltan (2006) studied the sediment quality of the river Nile and the distribution of some trace elements in the bulk sediments of the river. He concluded that the alkaline pH values (Tab. 1) of the Nile sediments reduce the release of the metals from sediments to water.

Nickel contents were very similar in all sampling sites (Tab. 2), while Ca, Mg, Fe and Al were higher. Cadmium levels were surprisingly high in West Aswan (Tab. 2). It is important to observe that the West Aswan is as enriched in heavy metals as compared with the other locations, suggest that these contaminants are generated from fishery boats, discharges of trade ships and direct erosion of igneous rocks by the effect of water movement.

The higher cadmium content in the surface sediment than the other horizons (in all locations, Tab. 2) indicates that the Cd present in these so-called unpolluted soils is of anthropogenic origin (Andersen et al. 2002). The vertical distribution patterns for most studied metals show that, the levels are generally low and do not indicate any significant anthropogenic input, thus are derived predominantly from natural sources lithologic material.

Looking at the mean heavy metal concentrations at different depths within the sediment profiles of river Nile are presented in Fig. 2, the metal contents in surface sediments are generally higher than those in deeper layer. However, the difference between top sediment and bottom sediment layer is not statistically significant for many metals due to the various distribution patterns in individual cores (Tab. 4). The metal concentrations in the rest of the core are very similar (Fig. 2). The metal enrichment at the surface of the profile may reflect the impacts of contaminant inputs from recent industrial development around the Nile (Fig. 3). The river gully area reflects the high water flow and dynamic environment. The metal distribution in the profile can be affected by many factors including the river input, sediment properties and dredging activities (Winkels et al. 1993; Li et al. 2000).

The obtained data of metals concentrations were compared with the data which reported by Fawzy (2000), where it appeared an increase in concentrations of some measured metals in our results.. This is due to the accelerated growth of industry, manufactories and industrial plants have been established near or on the Nile banks. These plants have discharge their industrial waste for several years into the Nile. In addition, most of the population is densely concentrated in the Nile Valley and this has a direct effect on the quality of the river Nile water. Also in the last twenty years, the Nile has been used extensively in Nile cruises with about 300 ships operating between Luxor and Aswan. Thus, not only does Nile water satisfy domestic and industrial needs, it also provides transportation, hydroelectric power, a means of sewage and waste disposal, fish for food and forms of recreation. Therefore, the quality of river Nile water generally reflects the range of human activities within the catchments' area especially in the absence of the annual flushing out by the floodwater.

Tab. 4 Descriptive statistics for measured metals concentration (μgg^{-1}) of core samples in different depths.

	Surface	30 cm	50 cm	70 cm	90 cm
Pb (μgg^{-1})					
Range	0.6-0.7	0.5-0.7	0.5-0.6	0.4-0.6	0.4-0.6
SE	0.02	0.03	0.02	0.003	0.04
SD	0.055	0.07	0.05	0.07	0.09
Zn (μgg^{-1})					
Range	1.14-1.77	1.06-1.3	1.02-1.24	0.95-1.23	0.95-1.1
SE	0.11	0.05	0.04	0.05	0.03
SD	0.24	0.1	0.095	0.11	0.067
Co (μgg^{-1})					
Range	0.7-1.0	0.6-1.0	0.6-0.8	0.6-0.7	0.3-0.5
SE	0.05	0.07	0.04	0.02	0.048
SD	0.11	0.2	0.08	0.055	0.11
Cr (μgg^{-1})					
Range	2-2	2-2	2-2	1-2	1-2
SE	0.0	0.0	0.0	0.2	0.2
SD	0.0	0.0	0.0	0.45	0.44
Fe (μgg^{-1})					
Range	640-740	640-690	610-690	610-640	540-600
SE	19.3	9.7	12.9	6.3	11.23
SD	43.24	21.7	28.8	14.1	25.1
Ni (μgg^{-1})					
Range	0.7-0.9	0.6-0.8	0.5-0.7	0.5-0.6	0.07-0.5
SE	0.037	0.045	0.03	0.02	0.086
SD	0.084	0.1	0.07	0.055	0.19
Cu (μgg^{-1})					
Range	0.74-0.76	0.67-0.75	0.65-0.68	0.62-0.66	0.58-0.64
SE	0.0045	0.015	0.006	0.008	0.0097
SD	0.01	0.03	0.01	0.02	0.02
Mn (μgg^{-1})					
Range	9.3-11.8	8.8-10.4	7.9-10.3	7.6-9.2	6.5-8.9
SE	0.48	0.34	0.5	0.32	0.4
SD	1.08	0.76	1.2	0.7	0.88
Cd (μgg^{-1})					
Range	0.06-0.12	0.06-0.11	0.06-0.08	0.05-0.07	0.02-0.05
SE	0.01	0.0093	0.005	0.004	0.0054
SD	0.02	0.02	0.01	0.0084	0.01
Al (μgg^{-1})					
Range	600-800	600-700	600-600	600-600	500-600
SE	37.41	20	0.0	0.0	24.5
SD	83.7	44.7	0.0	0.0	54.77
Ca (mgg⁻¹)					
Range	15-20	12.5-17.5	10-15	10-15	7-15
SE	1.22	0.93	1.2	1.1	1.5
SD	2.7	2.1	2.7	2.5	3.4
Mg (mgg⁻¹)					
Range	27.4-30.4	25.8-30.4	24.3-25.8	22.8-24.3	15.2-24
SE	0.6	0.84	0.37	0.35	1.7
SD	1.34	1.9	0.82	0.78	3.7
Na (mgg⁻¹)					
Range	13.9-25.2	13.6-16.3	13.2-16.5	12.9-15.2	12.4-13.2
SE	2.0	0.57	0.59	0.43	0.15
SD	4.48	1.3	1.32	0.43	0.34
K (mgg⁻¹)					
Range	4.4-4.6	4.3-4.5	4.2-4.5	4-4.3	4-4.2
SE	0.04	0.05	0.05	0.05	0.05
SD	0.09	0.1	0.11	0.012	0.11

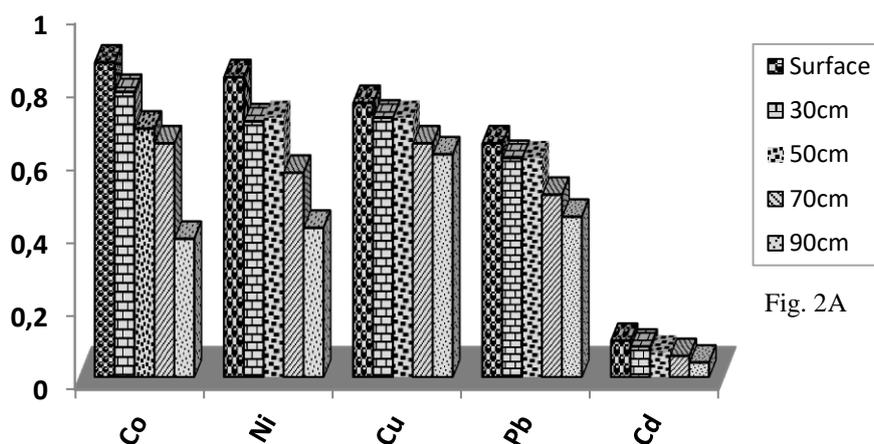


Fig. 2A

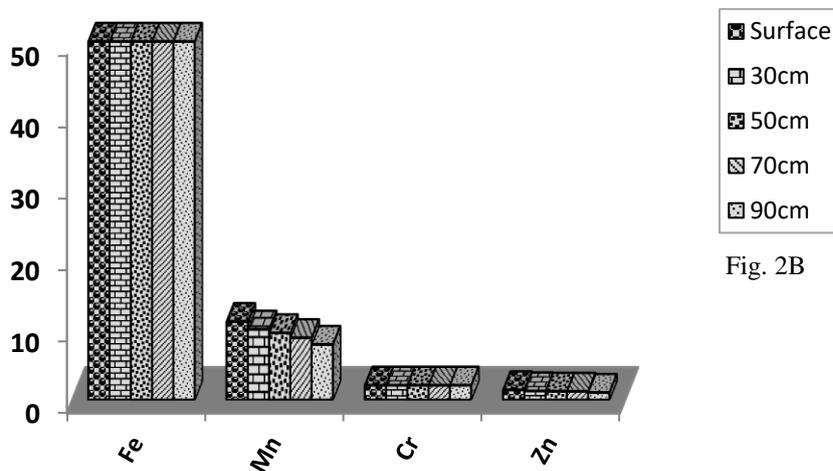


Fig. 2B

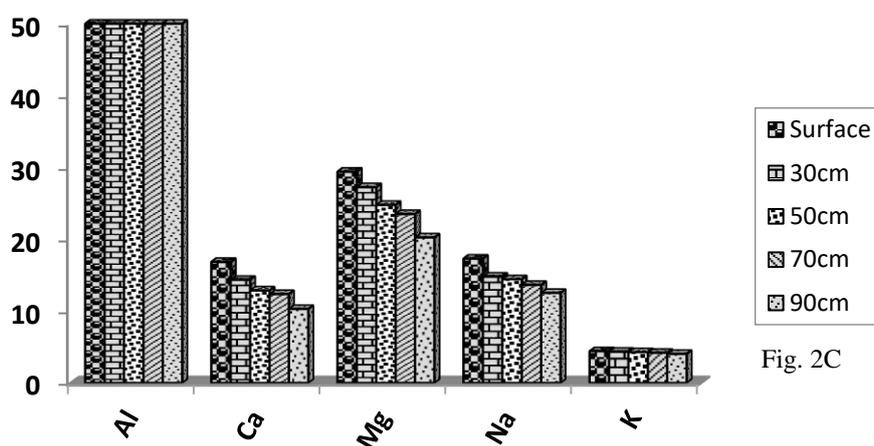


Fig. 2C

Fig. 2 Distribution of mean metals concentration of core samples in different depths.

We also comparing the data with the Average Shale standard (Turekian and Wedepohl 1961), all measured metals concentrations are lower than the background values (Tab. 3). This is due to much shorter industrial history of the Nile.

The index of geoaccumulation (Tab. 3), Müller (1979) was applied on the results of sediments analysis with respect to shale component (Turekian and Wedepohl 1961) standard in order to obtained

the origin of metals (lithogenic or anthropogenic) and to quantification of metal pollution in river Nile sediments. Generally, the results obtained in Tab. 3 indicate that the results show that these sediments are uncontaminated with studied metals and unpolluted to moderately polluted with respect to Ca and Mg (Tab. 3). This increase in Ca and Mg may be to the industrial discharge.

The EFs for measured metals in the surface core samples (0-30 cm) at different locations are presented in Fig. 3.

Heavy metal concentrations, although relatively higher, remain fairly stable and less than Standard Shall scale (Turekian and Wedepohl 1961), among the different depths in the core especially for Co concentrations at different locations (Tab. 2, 3). The trend of decreasing metal content down the profile is less significant in some cores samples (Tab. 2), the slightly higher levels in the top player especially for Pb may be due to mixed of sediment layers during deposition and sedimentation stages.

Metals such as K, Ca, Na and Mg in the total content (Fig. 3b), have EF values significantly greater than unity ($\log EF > 0$). These metals can therefore be classified as “biophiles” or “anomalously” enriched (Szefer 1998). To a less extent Cd at West-Aswan (Fig. 3a) was generally characterized by EFs close to unity ($\log EF \approx 0$). This element is therefore dominantly lithogenous in origin.

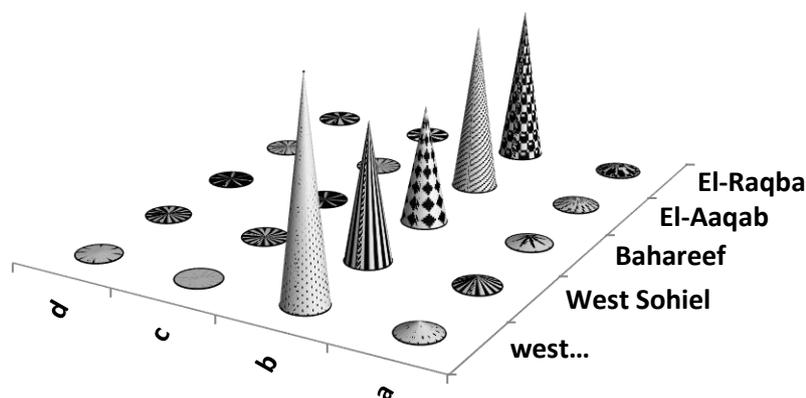


Fig. 3A Enrichment Factors (EFs) for the Studied Metals (a=Pb, b=Cd, c=Cu, d=Ni) in the Surface Sediment (0-30) of the River Nile.

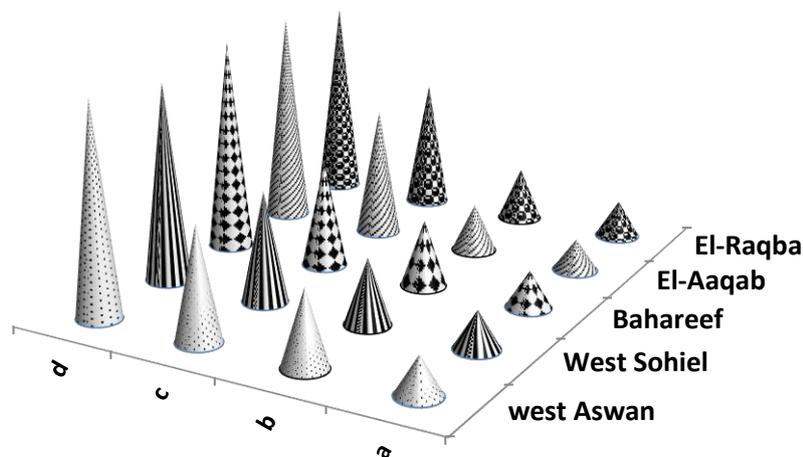


Fig. 3B Enrichment Factors (EFs) for the Studied Metals (a=K, b=Ca, c=Na, d=Mg) in the Surface Sediment (0-30) of the River Nile.

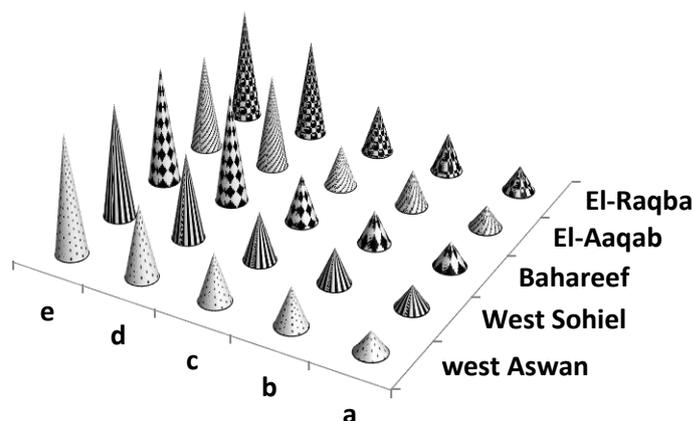


Fig. 3C Enrichment Factors (EFs) for the Studied Metals (a=Mn, b=Zn, c=Cr, d=Co, e=Fe) in the Surface Sediment (0-30) of the River Nile.

Zn, Co, Cr, Fe and Mn (Fig. 3c) , in addition to Ni, Cu, and Pb (Fig. 3a) have $EF < 1$ ($\log EF < 0$), which indicates that these elements are associated with phases other than aluminosilicates (e.g. $CaCO_3$, for Ca). The processes which lead to the accumulation of metals in the sediments are complexation by organic matter and carbonates (Abu-Rukah and Ghrefat 2001).

Previous research has not conducted a study area, therefore Comparison of some heavy metals in sediment (ppm) with different international guidelines and other studies in the world, refers to low levels significantly from the core sediment concentrations in comparison with the other rivers and standard limits, as shown in Tab. 5.

Tab. 5 Comparison of some heavy metals in sediment (ppm) with different international guidelines and other studies in the world.

Sampling site or Standard	Pb	Cd	Cu	Zn	Ni	Cr	Source
Nile River at Aswan	0.5	0.07	0.6	1.1	0.6	2	Mean of Present study
Seybouse River	476	N.A	9.5	1141	16.8	145	Louhi et al. 2012
Meghna River	9.5	0.23	N.A	79	76.1	31.7	Mahmud. et al. 2105
Day River	109	1.27	109	100	NA	102	Barakat et al. 2012
Yamuna River	55	2.82	160	366	111	342	Singh et al. 2002
Shiqiao River	96	2079	100	327	66	133	Xiao et al. 2013
Guangdong Background	36	0.056	17	47.3	18.2	50.5	Wei et al. 1990
Who 2004	NA	0.6	NA	123	20	25	WHO 2004
USEPA 1999	40	0.6	NA	110	16	25	USEPA 1999
CCME 1999	35	0.6	NA	123	NA	37.3	CCME 1999

NA: not available

4. Statistical analysis

The statistical analysis of the database resulting from the chemical analysis of metals in the different core samples was performed using SPSS statistics V21 statistical package programs.

Very significant positive correlation was raised between Cd, Mn, Al, Cu and Co with Mg ($r = 1.000, 0.965, 0.997, 0.966$ and 0.948 , respectively) may be attributed to their existence with Mg-bearing minerals especially olivine (Fawzy 2012). Good correlations were found between Ca and Fe ($r = 0.968$) & K and Pb ($r = 1.000$) in different sectors of core samples, which indicates that accumulation of these

metals have a similar transport mechanism. Strong positive correlation coefficient value ($r = 0.968$) is raised between lead and iron. This supported by the fact that Pb is strongly associated with ferromanganese minerals.

Strong negative correlations are observed in the different core samples between the extractable Ca content and the other metals such as Al, Co, Mg, Mn and Na ($r = -1.000$, -1.000 , -0.997 , -0.993 and -0.969 , respectively). These findings may be related to the presence of Ca-bearing silicate minerals with low metal contents.

No observed correlations between pH and Cr, Cd, and Zn indicate that the adsorption of these metals is weakly pH-dependent (Soltan et al. 2011). Appearance of negative significant correlation coefficient values between pH-value and the metal content of Fe ($r = -0.922$), K ($r = -0.966$), Ca ($r = -0.966$), Cu ($r = -0.927$), Pb ($r = -1.000$) and Ni ($r = -1.000$) These correlations indicate similar adsorption behavior for these metals, whereas, high adsorption capacity were obtained at $\text{pH} < 6$, but at high pH-value the hydrolysis and precipitation of metals were occurred.

On the other hand, good positive correlation coefficients values were recorded between Co ($r = 0.964$), Al ($r = 0.966$), Mg ($r = 0.968$), Mn ($r = 0.951$) and pH value.

5. Conclusion

Generally, all measured metals decrease with increasing depth. These features reflect the contamination from the recent rapid industrial development and urbanization on the sides of river Nile. The sources of heavy metals in the sediments vary for each element, but include the weathering of bedrock, waste discharge from fishery boats and tourist ships. The interrelationships between physicochemical processes, biological and anthropogenic activities affect the spatial distribution of heavy elements in river Nile.

The obtained results also shows that the levels of sediment contamination within the safe side according to different background values (e.g. standard shale). On the other hand, although the concentrations of the heavy elements in the Nile sediments indicate no pronounced threat to public health at the moment, this situation may change, where the element concentrations in the sediments increase with time.. On the other hand, the study points out to the need to preserve waterways free from the pollution and the need for wastes treatment whatever their source, and the urgent need to implement the laws of Nile River protection from pollutions accurately and strict, in addition to, the continuous survey of the Nile sediments to see changes in the concentrations of elements to avoid causes aphid.

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