Environmental Nanotechnology, Monitoring & Management 8 (2017) 53–62

Contents lists available at ScienceDirect

Environmental Nanotechnology, Monitoring & Management

journal homepage: www.elsevier.com/locate/enmm

Fractionation profile, mobility patterns and correlations of heavy metals in estuary sediments from olonkoro river, in tede catchment of western region, Nigeria

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A R T I C L E I N F O

Keywords:
Heavy metals
Bioavailability
Speciation
Distribution and mobility
Correlation matrix
Principal component analysis

A B S T R A C T

This work was carried out to determine the concentrations, bioavailability and mobility of heavy metals in the sediments of Olonkoro River, Tede, Oyo State, Nigeria. The river sediments were sampled at ten selected locations and the samples were analyzed for some heavy metals to determine the concentration, speciation and distribution pattern of the metals. The sediments were obtained specifically at upstream, middle-stream and downstream of the river. In general, the total metal concentrations were in the order: Fe > Zn > Mn > Cu > Pb > Cd in sediment samples and for Tessier's sequential fractionation, manganese was found to be more in the exchangeable phase, Fe in the Residual, Zn in carbonate-bound metal while Pb was greater in the exchangeable form and Cu was found to be more concentrated in the organic phase. **Percent of bioavailable and non-bioavailable proportions of heavy metals for Mn, Fe, Cu, Zn, Pb, and Cd in the sediment samples varied between 12.92-87.08, 11.57-88.43, 0.29-99.71, 10.76-89.24, ND-100 and ND, respectively.** This clearly indicates that with the exception of Cu and Cd the metals are highly bioavailable leading to their having a higher impact on the target system, subsequently leading to contamination of the water. The high percent bioavailability is an indication of poor retention in the residual geochemical form partly due to saturation of the sediment (river). The pH value was found to be basic but within the WHO standards throughout all locations. The high percentage of Mn, Cd and Pb in the bioavailable forms suggested the need to keep close surveillance on these metals because of their high toxicity.

1. Introduction

Shortage of sufficient potable water has led many people to depend on rivers, not only for drinking, but also for other domestic, agricultural and industrial uses. The pollution status of rivers is, thus, of serious concern worth investigation and assessment. A major alarm has been raised over the discharges from industries within the location that the river could be polluted excessively. However, the need to assess the quality and suitability of pollutants becomes imperative. Heavy metals are serious pollutants due to their toxicity, persistence in natural conditions and ability to be incorporated into food chains (Szefer et al., 1997; Klavins et al., 2000; Armitage et al., 2007; Sakan et al., 2009).

Sediments of rivers are sinks for contaminants, such as heavy metals (Yusuf and Osibanjo, 2006; Okoro et al., 2014). Sediment may be regarded as being contaminated when the level of these pollutant (heavy metals) are found in it are higher than the recommended permissible limit (Agirtas and Kilicel, 1999). The contamination of aquatic systems by heavy metals, especially in sediments, has become one of the most challenging pollution issues owing to the toxicity, abundance, persistence, and subsequent bio-accumulation of these materials (Fatoki et al., 2012; Gielar et al., 2012; Varol and Sen, 2012).

Numerous studies, especially during the last decade, have demonstrated that marine sediments from industrialized coastal areas are greatly contaminated by heavy metals (Singh et al., 2007; Fernandes et al., 2011; Filgueiras et al., 2004; Okoro et al., 2013, 2014). Natural

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http://dx.doi.org/10.1016/j.enmm.2017.04.003
Received 13 October 2016; Received in revised form 25 March 2017; Accepted 17 April 2017
2215-1532/

sources of these heavy metals can be traced to the biogeochemical processes, where their burden in sediment are continually on the increase through anthropogenic sources (Giwa et al., 2009).

Moreover, the total concentration of metals often does not accurately represent their characteristics and toxicity. In order to overcome these obstacles, it is helpful to evaluate the individual fractions of the sediment to which the metals are bound to fully understand their actual and potential environmental effects (Okoro et al., 2014; Tessier et al., 1979).

To date, studies on metal speciation in river sediments have been conducted in only a few villages and towns in Nigeria (Okoro et al., 2014). Data on metal speciation in Olonkoro river sediments are lacking. In this study, river sediments collected from Olonkoro River were analyzed using modified Tessier five-step sequential extraction procedure. This study aimed at the investigation of heavy metals (Mn, Fe, Cu Zn, Pb, and Cd) fractionation profile *vis-à-vis* the mobility patterns. The correlations and biding behaviours of the heavy metals in the sediments was also evaluated using Pearson Correlation Coefficient (PCC).

2. Materials and methods

2.1. Description of study area

The study area is the Olonkoro River in the Atisbo Local Government Area of Oyo State and it is located between latitude 8°33′36″N and 3°28′30″E (Fig. 1). Table 1 shows location sites and description referenced with global positioning system (GPS). The typical tropical climate, consisting of the dry and rainy seasons is governed by the northeastern and southwestern winds which generally influence the climate of Nigeria. The river empties into a popular Ago-Are Dam used by two indigenous communities with a population of about one hundred and twenty thousand for domestic purposes. The main sources of pollution in the river catchments are socio-economically related (Shea butter production, cassava milling and agricultural activities). The natives also depend on the river for fishing and as a source of water for domestic purposes. They are also involved in commercial sand dredging. Some industrial concerns within the vicinity of the river catchments empty partially treated effluents into the river.

Table 1
Location sites and description referenced with global positioning system (GPS).

Sample Location	Coordinate	Activity	Depth
L1	N8 33·757 E3 26.710	Industry producing Shea butter	24 cm
L2	N8 33.762 E3 26.697	Industry producing Shea butter	25 cm
L3	N8 33.810 E3 26.630	Industry producing Shea butter	24 cm
L4	N8 33.908 E3 26.599	Industry producing Shea butter	26 cm
L5	N8 34.001 E3 26.536	Industry producing Shea butter	25 cm
L6	N8 34.015 E3 26.505	Industry producing Shea butter	23 cm
L7	N8 34.496 E3 26.480	Agricultural activities	23 cm
L8	N8 34.609 E3 26.334	Fetching for drinking	22 cm
L9	N8 34.809 E3 26.305	Agricultural activities	20 cm
L10	N8 34.926 E3 26.198	Fetching for drinking	25 cm

Domestic waste discharges and makeshift latrines are evident in the river banks.

2.2. Sampling and analytical procedure

Sediment samples that were used for metal determination were collected from ten different locations along the Olonkoro River. Surface sediments were collected at depths of 20–30 cm in the sediment core with a stainless-steel Ekman Grab Sampler (Table 1) following the standard procedure described by America Public Health Association. The content of the sampler was emptied into a black polyethylene bag at each location and later transferred to cooler boxes already containing ice packs and then transported to the laboratory for analysis. Plants, metals or plastics debris in the sediments were removed manually prior to chemical treatment. The sampler was inspected for possible cross-contamination and cleaned with ambient water for individual sample collection. The difference from one sampling point to another was approximately 100 m. The choice of locations was based on the ease of access to the River and the activities carried out along the River at such points. Heavy metal concentrations of the digested solutions were

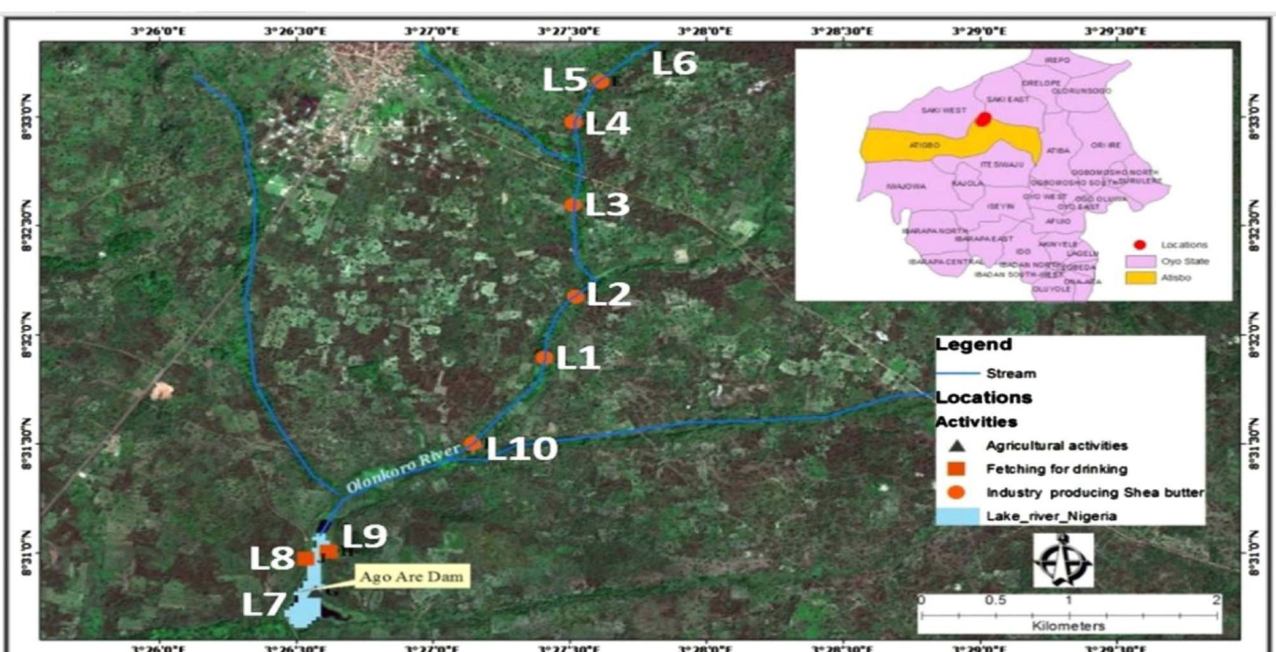

Fig. 1. Map showing the sampling locations and sampling points in Olonkoro River.Note: Cadmium was below detecting limit in all the locations (Table 3).