UNITED JOURNAL OF CHEMISTRY
An International Open Free Access, Peer Reviewed Research Journal

www.unitedjchem.org

ISSN: 2581-7760
CODEN: UJCHEG
2018, Vol. 01, No.(1):
Pg. 68-81

Chemical Speciation and Risk Implications of Some Heavy Metals in Sediment Profiles of Urban Stream Stretches, Yenagoa City, Bayelsa State, Nigeria

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(Received: August 08, 2018; Accepted: September 06, 2018)

ABSTRACT

Chemical speciation of selected Heavy metals using sequential extraction procedure was performed in the sediments collected from urban stream stretches, Yenagoa City, Bayelsa State, South-South, Nigeria, in order to ascertain their mobility, bioavailability and human health risk implications. Speciation study applying the five-step sequential extraction scheme revealed that Pb and Mn in sediment prevail mostly in exchangeable, carbonate and Fe/Mn-oxide fractions. Cu, Zn and Cr were more prevalent in organic and residual fractions, while Cd was below detection limit. Eco-toxicological assessment of the stream sediments using the mobility factor and percentage bioavailability reveals the following sequence: Mn >Cu>Zn >Pb >Cr>Cd and Cr>Zn>Mn>Pb>Cd>Cu respectively. The heavy metal contamination in sediments was further determined using sediment quality guidelines developed for metals in freshwater ecosystems (ecotoxicological sense of heavy metals) reveals that the studied heavy metals in sediments of urban stream stretches of the Yenagoa City, do not exceed consensus-based TEC values which can lead to adverse impact on the ecosystem and human health risk implications.

Keywords: Chemical speciation, risk implications, Mobility, bioavailability, urban stream sediment, Yenagoa.

INTRODUCTION

The indiscriminate dumping of degradable or non-degradable wastes into urban stream stretches and rivers has been considered one of the major causes of the unprecedented mush-rooming of heavy metals and their speciation and the results are effect on ecosystems and human health risk implications globally.

Sediments are considered to be an important carrier as well as a sink of heavy metals in the hydrological cycle (Celo et al., 1999). The majority of heavy metal emissions from anthropogenic activities accumulate in river and ocean sediments, where they are absorbed onto clays and other fine-grained materials (Ho et al., 2010).

Moreover, benthic organisms can take up metals directly from the sediments, which in turn enhance the potential of some metals entering into the food chain (Adamo et al., 2005; Chen et al., 2007).

Heavy metals can cause serious health effects with varied symptoms depending on the nature and quantity of the metal ingested (Adepoju-Bello and Alabi, 2005; Akan et al., 2010). The various ways by which heavy metals associate with various soil/sediment components determine their mobility and availability (Xian, 1987; Kabata-Pendias and Pendias, 1992; Singh, 1997; Ahumada et al., 1999).

Speciation in sediment compartment is a significant step to understand the potential environmental risk, distribution, mobility and bioavailability of pollutants. Determining the total content of heavy metals in the sediments may be useful for the characterization of pollution intensity, however, speciation of heavy metals with selective extracting agents gives further information about the fundamental reactions that govern the behaviour of metals in sediment and helps to assess the environmental impact of contaminated soil and sediment (Salomaons and Förstner, 1980; Ogunfowokan et al., 2009; Ogunfowokan et al., 2013; Leizou et al., 2015).

To assess the bioavailability of heavy metals, sequential extraction procedure consists of a series of chemical extractants, each being more drastic in action and of different nature than the previous one (Chaudhary and Banerjee, 2008; Osakwe, 2010).

Chemical speciation is a powerful and versatile technique for predicting the degree of contamination risk of a river system. This study is the first to assess the levels of heavy metals in sediments of urban stream stretches; work on speciation of heavy metals in sediments of urban stream stretches in Yenagoa City, Bayelsa State has not been reported. Therefore, due to paucity of information, it is expected that the results from this study would form a baseline data for future heavy metal pollution status in sediment of the area under study. The main objectives of this study is to investigate the speciation, elemental mobility factor and bioavailability indices of some heavy metals in sediments of urban stream stretches from Yenagoa city, Bayelsa state, Nigeria using Tessier's five-step sequential extraction schemes.

MATERIALS AND METHODS

Description of study area

Yenagoa is a non-industrialized city situated in the south-south, oil rich Niger Delta region of Nigeria. The geographical location of Yenagoa is on the north and east hemisphere. The study area lies between the coordinates of latitudes 04o15" North and latitude 05o23" South and longitude 05o22"West and 06o45" East. Since attaining the status of a state

Fig. 1: Map of Yenagoa LGA showing sampling sites

capital in 1996, construction and other activities have accelerated appreciably (Fig. 1).

Sampling and Pre-treatment of Sediment Samples

In this study, sediment samples were collected from four stations located along urban stream stretches, Yenagoa City, Nigeria. Details of these sites are given in Table 1. Sediments were sampled using a bottom grab sampler (Hydro-Bios) and then immediately transferred into plastic bags and refrigerated. In order to get a representative sample for each station, several sub-samples were collected and mixed together. The sediment samples were analyzed for total metal (UNEP, 1985) and metal speciation (Tessier et al., 1979).

Reagents Used and Their Source

All the reagents used are of analytical grade. The reagents used are HNO_3 (Riedel-deHaën, Germany), 30% hydrogen peroxide, $H_2O_2$and 70% perchloric acid, $HClO_4$ British Drug House (BDH) Chemicals Ltd, Poole, England. Solutions were prepared using double distilled water. All glass

Table 1: Sites and description of activities

Sites	Description of activities	Details
A	Higher institution, Residential, Dump sites , commercial, traffic, different component of vehicles and natural sources.	Agudama
B	Market, furniture making, Residential, commercial, traffic, different component of vehicles, and natural sources.	Tombia
C	Residential, dump sites , School, commercial,, traffic , different component of vehicles, natural sources	Okutukutu
D	Commercial, traffic, different component of vehicles, dump and natural sources.	Amarata

Table 2: Summary of sequential Extraction Scheme Used

FRACTIONS	EXTRACTANT	TIME(hr)	TEMP oC	DESIGNATION
F1	1g of sediment sample +16ml of 1M $MgCl_2$, pH=7	1	RT	Soluble / Exchangeable
F2	16ml of CH_3COONa/CH_3COOH buffer, pH=5	5	RT	Carbonate bound
F3	20ml of 0.4M NH_2OH. HCl in 25% CH_3COOH	6	96	Fe / Mn-oxide Bound
F4	1.3ml of 0.02M HNO_3+5ml of 30% H_2O_2, pH=2 with HNO_3 2.3ml of 30% H_2O_2, pH = 2 withHNO_3	2	85	Organic matter Bound
	3. 5ml of 3.2M NH_4OAc in 20% HNO_3 followed by dilution to 20ml with de-ionized water	3	85	
F5	5ml HNO_2+ 10ml HF +10ml $HClO_4$			Residual

*Tessier et al., (1979); **Abu-Kukati, 2001 ***RT = room temperature wares used (conical flask, measuring cylinder, volumetric flask, and watch glass) were washed with liquid detergent and rinsed thrice followed by oven drying.

Determination of Metal Speciation in Sediment

For the heavy metal speciation in sediment a five-step sequential extraction procedure was employed in this study. This sequential extraction was based on the principles of (Tessier et al., 1979; Abu-kukati, 2001) procedures. This extraction procedure defines the following five metal speciation regular forms: exchangeable, carbonate-bound, Fe/Mn-oxide bound, organic matter/sulfide bound and residual fraction (Table 2).

RESULTS AND DISCUSSION

Table 3-4 Summaries the concentrations of heavy metals in (range, mean and standard deviation) expressed as milligram / Kilogram (mg/kg) of dried sediments and the operationally defined fractions are represented graphically in Figs. 2-4 The chemical speciation of Pb was majorly associated

Table 3: Concentrations (mg/kg) of heavy metals in various geochemical fractions

PARAMETERS			FRACTIONS		
	exchangeable	**carbonate**	**Fe/Mn oxide**	**organic**	**residual**
Pb					
range	0-5.01	0-22.48	35.56-80.76	0-30.64	0.00-9.7
Min	0.01	0.01	35.56	ND	ND
Max	5.01	22.48	80.76	30.64	9.7
Mean±std	4.66±0.45	13.96±9.83	52.57±19.83	24.00±9.39	6.45±4.45
Mn					
range	7.76-62.32	6.7-27.26	19.58-123.22	1.68-35.82	10.70-66.58
Min	7.76	6.7	19.58	1.68	10.7
Max	62.32	27.26	123.22	35.82	66.58
Mean±std	30.86±23.55	18.96±9.01	60.71±44.26	20.42±17.85	33.52±27.48
Cu					
range	0.08-0.12	0.08-0.18	0.35-0.54	0.20-1.06	0.07-0.40
Min	0.07	0.08	0.35	0.2	0.07
Max	0.12	0.18	0.54	1.06	0.4
Mean±std	0.09±0.04	0.10±0.05	0.47±0.09	0.51±0.38	0.20±0.15
Zn					
range	0.04-0.50	0.60-1.62	2.67-3.99	0.63-3.71	0.44-2.94
Min	0.4	0.6	2.67	0.63	0.44
Max	0.5	1.62	3.99	3.71	2.94
Mean±std	0.24±0.40	0.96±0.45	3.18±0.59	1.84±1.35	1.63±1.02
Cr					
range	0.00-1.84	ND	ND	0	0.00-23
Min	0	ND	ND	0	0
Max	1.84	ND	ND	25.9	23
Mean±std	1.20±0.91	ND	ND	20.24±8.00	22.37±0.90
Cd					
range	ND	ND	ND	ND	ND
Min	ND	ND	ND	ND	ND
Max	ND	ND	ND	ND	ND
Mean±std	ND	ND	ND	ND	ND

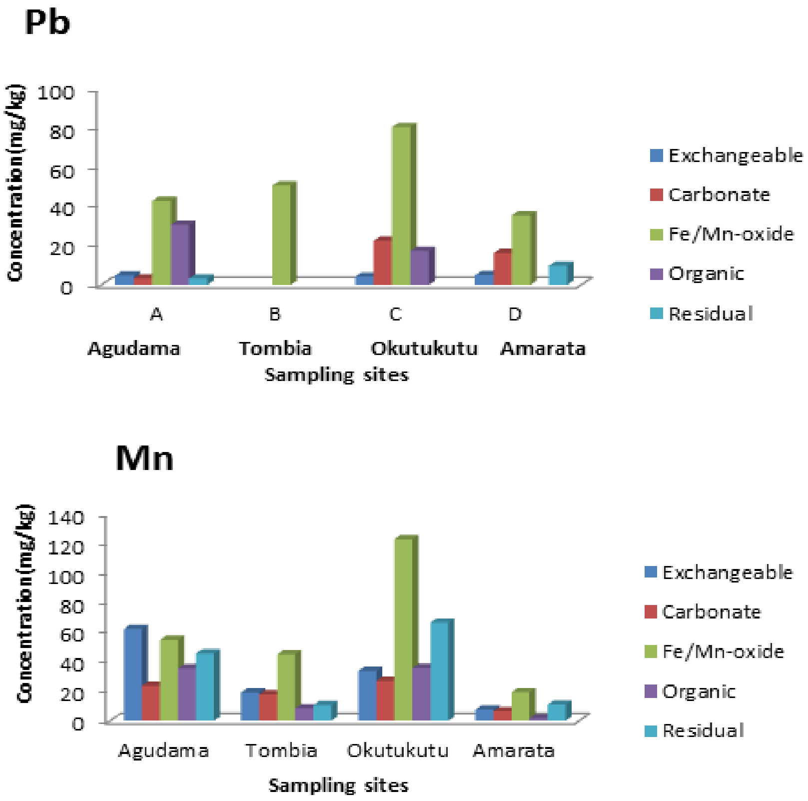

Fig. 2: Speciation pattern of lead and manganese

Table 4: Comparison of heavy metal concentration (mg/kg) in sediment with SQGs some river

	Pb	Mn	Cu	Zn	Cr
sites	mean±std	mean±std	mean±std	mean±std	mean±std
A	16.95±18.62	44.46±15.30	0.40±0.39	2.16±1.42	16.49±12.86
B	51.06±0.01	20.38±14.56	0.20±0.14	1.28±1.19	0.54±0.01
C	31.19±33.94	57.36±39.82	0.30±0.23	1.52±1.47	7.89±9.40
D	16.62±13.44	9.36±6.63	0.23±0.18	1.32±1.09	23.00±0.01
MIN	16.62±13.44	9.36±6.63	0.20±0.14	1.28±1.19	0.54±0.01
MAX	51.06±0.01	57.36±39.82	0.40±0.39	2.16±1.42	23.00±0.01
MEAN	28.96±16.50	32.89±19.08	0.28±0.24	1.57±1.29	11.98±5.57
TEL	35	-	35.7	123	37.3
LEL	31	-	16	120	26
ERL	35	-	70	120	80
TEC	35.8	-	31.6	121	43.4

TEL =Threshold effect level, LEL = Lowest effect level, ERL= Effect range low (Smith et al. 1996), Persaud et al. 1993, (EC and MENVIQ 1992), Long and Morgan 1991; MacDonald et al., 2000) with the Fe/Mn-oxide fraction which ranged from 35.56 -80.76 with a mean of 52.57±19.83 mg/kg. Okutukutu stream sediment had the highest Pb concentration (80.76mg/kg followed closely by Tombia (51.06mg/kg). The next was Agudama (42.90mg/kg) and the lowest concentration of Pb was recorded at Amarata (35.56mg/kg). The concentration level in the Fe/Mn-oxide fraction of the various sites for Pb follows the pattern: Okutukutu >Tombia > Agudama > Amarata.

The Fe/Mn-Oxide fraction represents heavy metals soluble in water as well as those held by electrostatic adsorption (Osakwe, 2010); could be considered relatively stable, but could change with variations in redox conditions of the soil. The amount of metal in this phase indicated the environmental conditions of the soil. The high percentage of lead in this fraction suggests a greater contamination risk for lead (Horsfall and Spiff, 2005; Ramzan et al., 2015).

The data shows that, concentration (mg/kg) of Pb in organic/sulfide fraction ranged from 0 – 30.64 with a mean of 24.00±9.39. Agudama had the highest (30.64mg/kg), closely followed by Okutukutu (17.36mg/kg). The next was Tombia and Amarata which were not detected (ND).

Organic compounds of heavy metals can be directly or indirectly introduced into soil through the formation of complexes and can be taken up by plants. Organic content is associated with the production of gas, and in sandy soil that contains little clay, organic matter and phosphate can leach through the soil and impact ground water (Urunmatsoma and Ikhuoria, 2005; Osakwe, 2010).

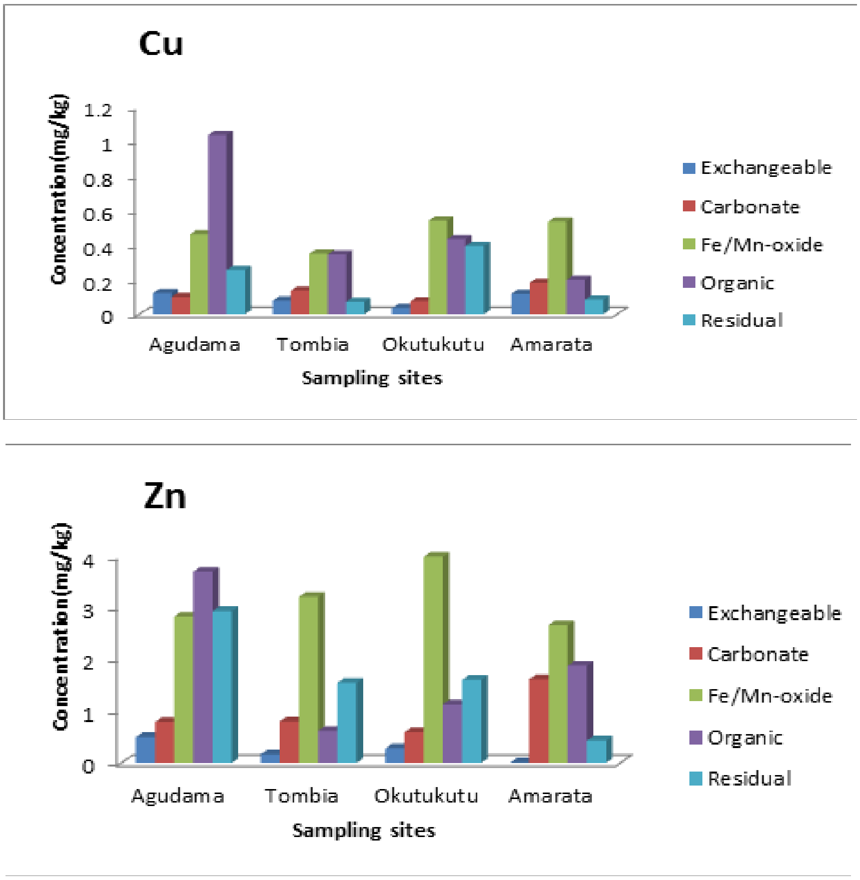

Fig. 3: Speciation pattern of copper and zinc

Organic matter plays an important role in the distribution and dispersion of metals by mechanisms of chelating and cation exchange. This include metals associated through complexation or bioaccumulation process with various kinds of organic materials such as living organisms, detritus or coatings on mineral particles (Tokalioglu et al., 2002). Carboxyl, phenolic, hydroxyl and carbonyl functional groups are assumed to be primarily responsible for metal binding (Horsfall and Spiff, 2005; Ramzan et al., 2015).

Metals complexed with organic matter are generally described by an ion exchange, organo-metallic complexation mechanism. Metal humic complexes are reversible, and metals can be desorbed by salting out or by hydrogen ion competition (Horsfall and Spiff, 2005).

Lead is said to be non-essential major toxic metal with multiple side effects (Klassen. (1996). (Patrick et al., 1977; Klassen, 1996; McBride, 1994; EPA, 2009; Amanda, 2010) who reported that lead is an ubiquitous metal found in all environments, various phases, and all biological systems. At high pH, it is less soluble and complexes with organic matter, sorption to oxides and silicate clays, precipitate as carbonates and hydroxides. It has high affinity for Mn oxides and the least mobile metal known, however, does bio accumulate when complexed to organic matter and tends to accumulate in the roots of plants. Lead and its compounds are known to cause some medical effects such as: cardiotoxicity, neuropathy, encephalopathy, and kidney, vascular, and reproductive effects.

Sia Su, 2008 reported that the presence and potential exposures of the community to groundwater contaminants may contribute to the predilection of human health impacts, from simple poisoning to cancer, heart diseases and teratogenic abnormalities.

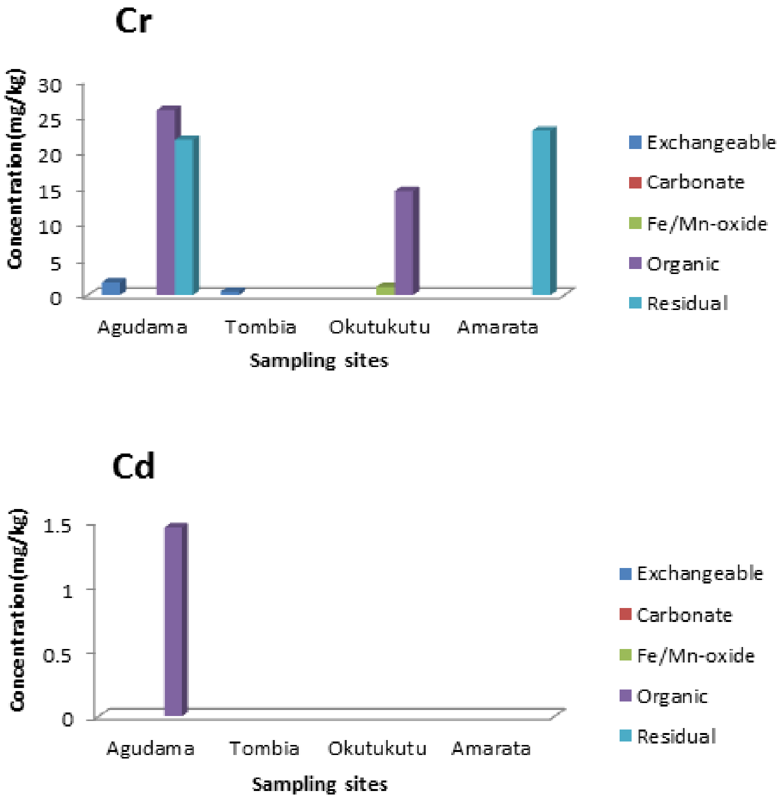

Fig. 4: Speciation pattern of chromium and cadmium

Next in importance for lead content are carbonate fraction, residual fraction and exchangeable fraction in sediment ranged from 0 - 22.48; 0 – 9.7 and 0 – 5.01 with mean values of 13.96±9.80, 6.45±45 and 4.66±0.45 respectively(Table 3-4). The association pattern of lead in the different geochemical fractions was in the order: Fe/Mn oxide > organic > carbonate > residual > exchangeable.

For manganese, the Fe/Mn oxide fraction was the most important fraction which ranged from 19.58 to 123.22 with an average of 60.71±44.26 mg/kg. Okutukutu had the highest (123.22mg/kg), closely followed by Agudama (54.94mg/kg), next was Tombia (45.08mg/kg) and Amarata (19.58mg/kg) respectively.

Next in importance for manganese content was the residual fraction which ranged from 10.70 to 66.58 with a mean of 33.52±27.48 mg/kg. The fraction can be taken as a guide to the degree of pollution of the soil. The smaller the percentages of the metal present in this fraction, the greater the pollution of the area (Horsfall and Spiff, 2005). The residual fraction is considered the most stable, less reactive and less bioavailable since it is occluded within the crystal lattice layer of silicates and well crystallized oxide minerals (Abeh et al., 2007; Schawarzenbach et al., 1993).

Manganese is an essential metal for plants and animals with potential for toxicity. The solubility of Mn is strongly influenced by soil potential, Eh and pH forming soluble hydroxides and carbonates above pH 7. Manganese complexes with organic matter and silicates in soils above pH 6 and usually enters the food chain through foods such as fruits and vegetables. Manganese can be adsorbed onto soil; the extent of adsorption depends on the organic content and cation exchange capacity of the soil.

It can bioaccumulate in lower organisms (e.g., phytoplankton, algae, molluscs and some fish) but not in higher organisms; biomagnification in food chains is not expected to be very significant (Abbasi et al., 1998; Eaton, 2005; WHO, 2004; Akan et al., 2010). It is also being introduced into the environment as an octane booster in gasoline, replacing Pb in the 1980's. Manganese compounds are used in products such as batteries, glass and fireworks, as an oxidant for cleaning, bleaching and disinfection purposes, fertilizers, varnish and fungicides and as livestock feeding supplements. Common effects of excessive Mn are pneumonitis, epithelial necrosis, mononuclear proliferation, central nervous system and liver disorders, and neuropsychiatric disorder (Patrick et al., 1977; Klassen, 1996; McBride, 1994; EPA, 2009).

Other important fractions controlling the mobility and bioavailability of heavy metals in sediment include: exchangeable, carbonate, organic matter and sulfides which ranged from 7.76 - 62.32; 6.70 – 27.26 and 1.68 – 35.82 with mean values of 30.86±23.55, 18.96±9.01 and 20.42±17.85 respectively (Table 3-4). The association pattern of manganese in the different geochemical fractions was in the order: Fe/Mn oxide > residual > exchangeable >organic > carbonate.

The speciation results from the present study found only small amount of copper associated with the five geochemical fractions (Table 3-4). The concentration levels in the fractions followed the order: Organic (0.20-1.06, 0.51±0.38 mg/kg) > Fe/Mn-oxide (0.35-0.54, 0.47±0.09 mg/kg)> residual (0.07-0.40, 0.20±0.15mg/kg) > carbonate (0.08-0.18, 0.13±0.05mg/kg) > exchangeable (0.08-0.12, 0.09±0.04mg/kg). The strong association between soil Cu and the organic matter is also in agreement with the general findings that Cu forms stable complexes with soil humus (Stumm and Morgan, 1981; Chengo et al., 2013).

The residual fraction is a major carrier of metals in most environmental systems and can be taken as a guide to the degree of non-availability of metals (Horsfall and Spiff, 2005). As a result of weathering, a fraction of the trace constituent content is gradually transferred to forms accessible to plants (Hlavay et al., 2004). In all the samples analyzed, Cu was found to be mostly associated with the residual fraction and the results are concomitant with those reported by (Yobouet et al. 2010; Ramzan et al., 2015). In comparison with carbonate minerals, Fe-Mn oxide minerals have relatively large area and surface site density. The Fe-Mn oxide, the reducible phase of the soil under oxidizing conditions is a significant sink for the heavy metals (Forstner and

Wittmann, 1981).

The chemical speciation results from the present study, also found only small amount of zinc associated with the five geochemical fractions and was highest in the Fe/Mn-oxide fraction which ranged from 2.67-3.99 with a mean value of 3.18±0.59mg/kg, while the exchangeable fraction had the lowest which ranged from 0.04-0.50 with a mean value of 0.24±0.35mg/kg (Table 3-4).

The sequence of concentration levels of zinc in the different geochemical fractions is as follows; Fe/Mn oxide (2.67-3.99, 3.18±0.59mg/kg)> organic (0.63-3.71, 1.84±1.35mg/kg) >residual (0.44-2.94, 1.63±1.02ng/kg) > carbonate (0.60-1.62,0.96±0.45mg/kg) > exchangeable (0.04-0.50,0.24±0.35mg/kg).

In comparison with carbonate minerals, Fe-Mn oxide minerals have relatively large area and surface site density (Forstner and Wittmann, 1981). The Fe-Mn oxide, the reducible phase of the soil under oxidizing conditions is a significant sink for the heavy metals. Organic matter plays an important role in the distribution and dispersion of metals by mechanisms of chelating and cation exchange. This includes metals associated through complexation or bioaccumulation process with various kinds of organic materials such as living organisms, detritus or coatings on mineral particles (Tokalioglu et al., 2002; Ramzan et al., 2015). Carboxyl, phenolic, hydroxyl and carbonyl functional groups are assumed to be primarily responsible for metal binding.

Zinc is said to be in the category of essential metals with potential for toxicity. Zinc is used in a number of alloys including brass and bronze, batteries, galvanizing steel and iron products, pesticides, fungicides and pigments.

Excessive intake of Zn may lead to vomiting, dehydration, abdominal pain, nausea, lethargy and Dizziness (ATSDR, 1994). Zinc is an essential element for plants and animals growth but at elevated levels it is toxic to some species of aquatic life (WHO, 2004). Furthermore, it is involved in a variety of enzyme systems which contribute to energy metabolism, transcription and translation. Excessive intake of Zn may lead to vomiting, dehydration, abdominal pain, nausea, lethargy and dizziness (ATSDR, 1994). Zinc is also potentially hazardous and excessive concentrations in soil lead to phytotoxicity as it is a weed killer (Anglin-Brown et al., 1995; Abbasi et al., 1998; WHO, 2004).

Contaminants are bound to various forms of organic matter and these bonds are strong. These contaminants are released when the oxidizing environment changes, degrading the organic matter. Contamination in the Organic fraction is the least biologically available (Tessier et al., 1979).

The chemical speciation of Cr was majorly associated with the organic fraction which ranged from 0 -25.90 with a mean of 20.24±8.00 mg/kg. The sequence of concentration levels of Cr in the different geochemical fractions is as follows; organic (0-25.9, 20.24±8.00mg/kg)> residual (0-23, 22.37±0.90ng/kg) > exchangeable (0-1.84, 1.2±0.91mg/kg) > carbonate (ND) and Fe/Mn-oxide (ND).

Chromium is a major toxic metal with oxidation states ranging from Cr (II) to Cr (VI), however, only the Cr (III), and Cr (VI) states are environmentally available, primarily from the discharge of industrial wastes. The Cr (III) is considered a minor problem, while Cr6+ is very toxic and carcinogenic (ATSDR, 2000; Akan et al., 2010; Amanda, 2010). Chromium (III) had been described as an essential nutrient that helps the body use sugar, protein, and fat (Hati et al., 2005). Some of the medical effects chromium includes eczematous dermatitis, cause cancer of the lungs, nasal cavity and paranasal sinus, cancer of the stomach and larynx (ATSDR, 2000).

The speciation results from the present study found no amount of Cd associated with any of the five geochemical fractions except fraction four (organic) of Agudama (Table 3-4).This could be as result of the non-industrialization of the city. Cadmium is also a major toxic metal with multiple side effects. It's 2+ state sorbs weakly to organic matter, clays, and oxides at pH below 6 and may be released into the environment with a change in ionic composition of the pore waters. It is commonly used in batteries, paints and plastics, and most biological exposure comes from food.

Table 5: % Bioavailability for different heavy metals in water

sample	parameter	Heavy metals					
		Pb	Mn	Cr	Cd	Cu	Zn
Filtered	mean	0.187	0.432	0.210	0.087	0.055	0.342
Unfiltered	mean	0.219	0.494	0.239	0.141	0.173	0.390
% Bioavailability	85.39	87.45	87.87	61.70	37.91	87.69	

Table 6: Mobility factors (%)of the metals in the samples

Loca.	Heavy metals					
	Pb	Mn	Cu	Zn	Cr	Cd
A	9.46	38.74	11.33	12.08	3.72	0.00
B	0.00	36.79	22.08	15.47	1.00	0.00
C	21.35	21.34	7.72	11.63	0.00	0.00
D	31.92	30.90	26.95	24.53	0.00	0.00

Bioavailability

The bioavailability of metals expressed in percentage (%) was calculated as dissolved metal concentration via analysis of filtered water samples divided by the total metal concentration of unfiltered water samples. The term “bioavailability” is meant to denote heavy metals in a water-soluble form that plant and animal communities can readily uptake and assimilate (Kaviraj and Das, 1999; Desta et al., 2012). The bioavailability is mathematically expressed as follows:

$$\% \, Bioavailability = \frac{\text{Dissolved metal concentration}(mg/L)}{\text{Total metal concentration}(mg/L)} X\,100 \quad ...(1)$$

The percentage bioavailability (Table 5) of the metals revealed a maximum and minimum value for Cr (87.87%) and Cu (37.91%) respectively. Mido and Satake, 2003 reported that the bioavailability of the heavy metals depend on the concentration of anions, chelating ligands, pH and Redox status and the presence of absorptive sediments. These findings are in agreement with those reported by Osakwe, 2010; Desta et al., 2012.

Mobility Factor (MF)

In a five-step sequential extraction scheme, the mobility factor was calculated as the concentrations of metal in easily remobilizable fractions (F1 + F2) divided by the combine concentrations in all the five operationally defined geochemical fractions(F1 +F2 + F3 + F4 +F5) (Salbu et al., 1998; Narwal et al, 1999; Kabala and Singh, 2001). The Mobility Factor (MF) is mathematically expressed as follows:

$$MF(\%) = \frac{F1\ X\ F2}{F1\ X\ F2\ X\ F3\ X\ F4\ XF5} X\,100 \quad ...(2)$$

Where, F1 = adsorptive and exchangeable fraction; F2 =carbonate fraction; F3 = Fe-Mn oxide fraction; F4 = organic fraction and F5 = residual fraction. The mobility factors (MF) of the metals for all the sites are presented on Table 6.

The mobility factor (MF) values of the metals in all the sites and profiles follow the order Mn>Cu>Zn>Pb>Cr>Cd. The high present of manganese in the sediment could be attributed to dumping wastes in the streams.

Karczewska 1996; Ma and Rao 1997; Ahumuda et al. 1999; Narwal et al. 1999; Kabala and Singh 2001 who reported a high MF value for heavy metals in soil has been interpreted as evidence of relatively high lability and biological availability.

According to the reports of previous workers Narwal et al., 1999; Kabala and Singh, 2001; Osakwe, 2010; Osakwe et al., 2014 a high mobility factor (MF) value for metal in sediment is an indication of relatively high mobility and biological availability.

CONCLUSION

A five-step sequential extraction method was employed to investigate selected heavy metal in sediments from urban stream stretches of the Yenagoa City, Bayelsa State, Nigeria. The concentrations of the heavy metals in sediment from urban stream stretches were lower than the limits set by SQGs consensus-based TEC (Threshold Effect Concentrations) values. This is of important considering that heavy metals are toxic, persistent and their bioaccumulation leads to serious effect on the ecosystem and human health risk. Pb and Mn in sediment prevail mostly in exchangeable, carbonate and Fe/Mn-oxide fractions. Cu, Zn and Cr were more prevalent in organic and residual fractions, while Cd was below detection limit except for the organic fraction at agudama. Assessment of the sediments using the mobility factor and percentage bioavailability reveals the following sequence: Mn >Cu>Zn >Pb >Cr>Cd and Cr>Zn>Mn>Pb>Cd>Cu respectively. The ecotoxicological sense of heavy metal contamination in sediments was determined using sediment quality guidelines developed for metals in freshwater ecosystems reveals that the studied heavy metals in sediments of the Yenagoa City, urban stream stretches do not exceed consensus-based TEC values which can lead to adverse impact on the ecosystem and health issues. The results further reveal that the heavy metals in sediments of the urban stream stretches are accumulating appreciably. Consequently, therefore, it is expected that regulatory authorities should be encouraged to institute environmentally friendly Frame-work or interventions to maintain the immerse biodiversity, aesthetic value and reduce anthropogenic discharges and indiscriminate dumping of wastes into the urban streams.

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