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Full Length Research Paper

Bioaccumulation of heavy metals in water, sediment and periwinkle (*Tympanotonus fuscatus var radula*) from the Elechi Creek, Niger Delta

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The accumulation of three heavy metals; chromium (Cr), cadmium (Cd) and lead (Pb) in periwinkle (*Tympanotonus fuscatus var radula*; shell and soft tissues), water and sediment collected from four stations along Elechi Creek course was studied. Elechi Creek receives effluents discharges from heavily industrialized and highly populated settlements. The water, sediment and periwinkles were processed and analyzed for heavy metals and the results showed that the sediment concentrated more heavy metals than the water while the periwinkles accumulated more of these metals than the sediment. Cr was the highest concentrated heavy metals in both the normal and depurated periwinkles. The biological concentration factor (BCF) revealed that these periwinkles have high potential to concentrate heavy metals in their shells and soft tissues, and it is directly proportionate to their sizes. However, the observed heavy metals concentrations in these animals are below the recommended limits for human consumption. This study therefore advocates environmental surveillance of this creek in order to achieve good sediment quality and contaminant-free periwinkles for safe human health.

Key word: Bioaccumulation, heavy metals, water, sediment, periwinkle, Elechi Creek.

INTRODUCTION

Elechi Creek is the upper reach of the Bonny Estuary which lies between longitude 7^o 00' to 7^o 15" E and latitude 4^0 25" to 4^0 45' N, and it receives indiscriminate effluents discharges form the heavily industrialized and highly populated Port Harcourt Metropolis. However, several studies have been carried out to understand the physicochemical and biological characteristics of the environment as well as the extent of pollution in this area (RPI, 1985; Ajaji and Osibanjo, 1981; IPS, 1990, 1991a, b; Obire et al., 2003). Other studies describes microbial properties (Ogan, 1988, 1991), phytoplankton (Chindah and Pudo, 1991; RPI, 1985; Nwadiaro and Ezefili, 1987; Davies et al., 2002), macroalgae (Chindah and Amadi, 1993), epipelic algae (Chindah et al., 1993), macroinvertabrates (Ekweozor, 1985; Ombu, 1987; Ekweozor and Snowden, 1987), fisheries study (Wright, 1986; Chindah and Osuamkpe, 1994; Allison et al., 2000) and pollution studies (Chindah and Briade, 2003; Chindah et al., 2003; Chindah et al., 2004; Davies et al., 2004). All these studies provided general baseline information while some attempted to explain the possible effects of industrial discharges on this aquatic environment.

Many aquatic organisms for examples periwinkles have the ability to accumulate and biomagnify contaminants like heavy metals, polycyclic aromatic hydrocarbons and PCB in the environment. The ingestion of these contaminants may affect not only the productivity and reproductive capacibilities of these organisms, but ultimately affect the health of man that depends on these organisms as a major source of protein. The periwinkle,

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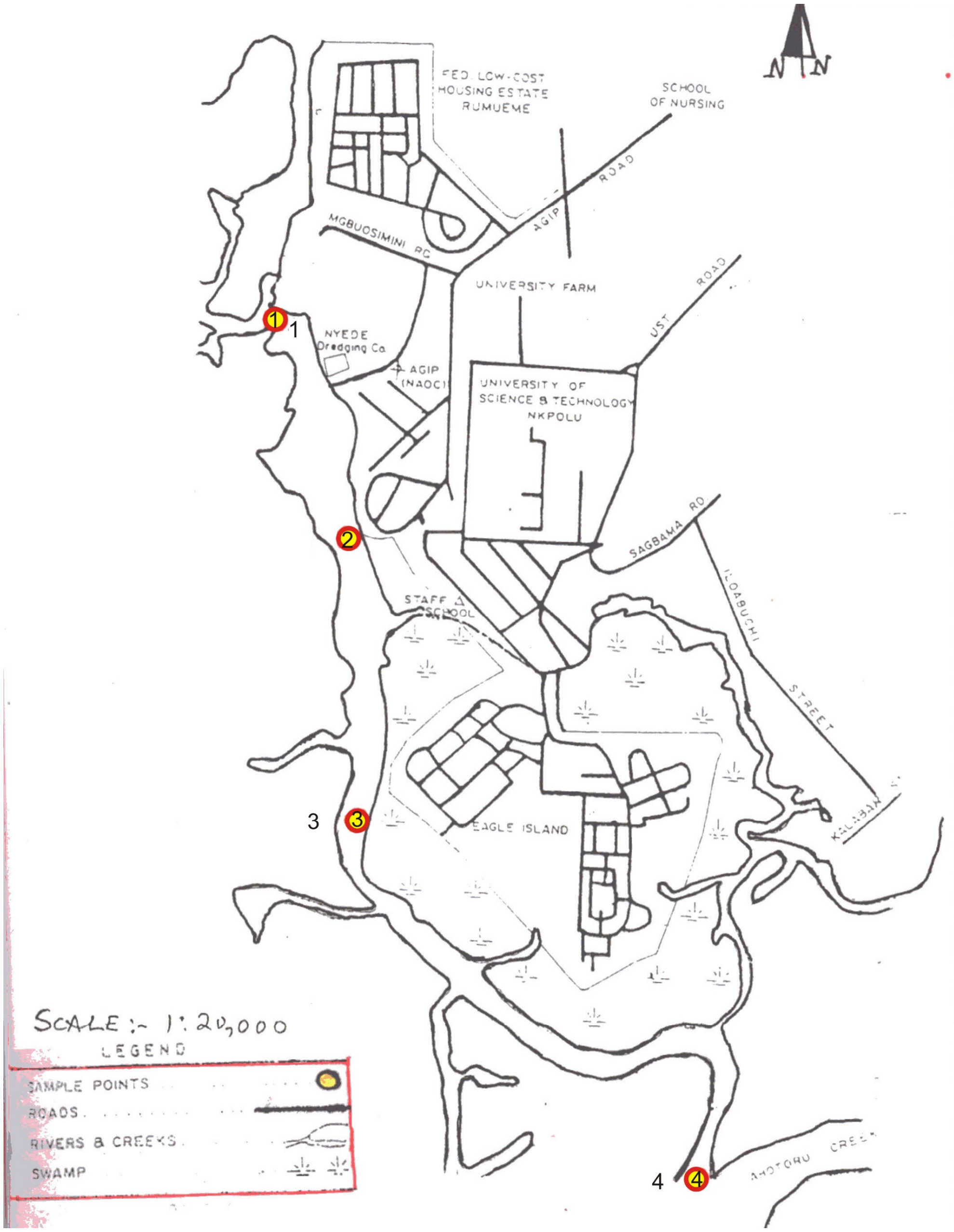

Figure 1: A sketch Map of the study area showing the sampling stations.

Tympanotonus fuscatus var radula, is a mollusk of high economic value in Niger Delta. It is a deposit feeder and bioindicator of heavy metals and hydrocarbon pollutions in the marine environment. It is of vital importance, hence studies are conducted to ascertain the level of concentrations of these metals in this commercial species (Biney, 1991; Okoye, 1991) and determine potentially hazardous levels for human. It is on the basis of this that the present study examines the levels of accumulation of Cr, Pb and Cd in *T. fuscatus*, sediment and water samples in the upper limit of the Bonny Estuary.

MATERIALS AND METHODS

Study Area

The area is a mangrove intertidal wetland within the upper part of Bonny River system adjoining a densely populated municipal environment. The creek is characterized by high sea inflow and low freshwater input from adjoining swamp forest and municipal sewers within the Diobu area of Port Harcourt. The area lies between longitude 7^o 00' to 7^o 15' E and Latitude 4^0 25' to 4^o 45' N. The tidal amplititude is between 1.5 to 2 m in normal tide and water level increases and decreases depending on the lunar cycle (Chindah et al., 2004). At high tides, salinity increases and decreases at low tides and the seasonal salinity variation.

Table 1. Heavy metals concentrations in the water (mg l^{-1}) and sediment (mg kg^{-1}) samples.

Station	Cr		Cd		Pb	
	Water	Sediment	Water	Sediment	Water	Sediment
1	<0.002	0.01’1	<0.001	0.001	< 0.001	0.005
2	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
3	< 0.001	0.008	< 0.001	< 0.001	< 0.001	< 0.004
4	< 0.001	0.006	< 0.001	< 0.001	< 0.001	0.002

Table 2. Heavy metals concentrations in the soft issues and shells of normal and depurated periwinkles (mg kg^{-1} dry weight).

Periwinkles parameter and heavy metals concentrations		Station 1		Station 2		Station 3		Station 4	
		Small	Large	Small	Large	Small	Large	Small	Large
Shell length (mm) means ± SE		20.80 ± 0.89	46.82± 0.82	22.22± 1.00	47.48± 0.81	20.74 ± 0.77	48.2 ± 0.90	21.2 ± 0.75	49.75± 1.01
Number of animal pooled		46	50	47	49	39	49	43	50
Normal soft tissue	Cr	0.017	0.015	0.010	0.019	0.016	0.022	0.014	0.034
	Cd	<0.001	< 0.001	<0.001	0.002	<0.001	0.002	<0.001	0.006
	Pb	0.009	0.010	0.005	0.013	0.008	0.015	0.007	0.020
Normal shell	Cr	0.038	0.016	0.018	0.020	0.009	0.023	0.009	0.020
	Cd	0.006	<0.001	<0.001	0.002	<0.001	0.004	<0.001	0.002
	Pb	0.021	0.010	0.012	0.014	0.004	0.016	0.006	0.013
Depurated soft tissue	Cr	0.019	0.019	0.017	0.021	0.023	0.020	0.016	0.018
	Cd	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001
	Pb	0.009	0.010	0.009	0.008	0.016	0.010	0.008	0.010
Depurated shell	Cr	0.018	0.014	0.021	0.017	0.019	0.015	0.023	0.018
	Cd	0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.002	<0.001
	Pb	0.012	0.008	0.013	0.010	0.012	0.009	0.014	0.010

The bulk of the intertidal area is predominated by mangrove vegetation namely *Rhizophora racemosa, R. mangle, Avicennia Africana, Nypa fruticans, Laguncularia racemosa* and *Achrostichum aureum (*Witcox, 1985). The hydrology of the river is described in detail in NEDECO (1961). The area receives municipal effluents (> 1500 metric ton/day), solid waste (3500 kg/day) oily waste from garages (150 litre/day) in addition to other discharges from sawmills and abattoir.

Sampling

Four sampling stations were established along the creek course with upper most study site at station 1 and downstream limit study site at station 4 creek mouth (Figure 1). The sampling stations were chosen based on ecological settings and human activities in the area.

The top 20 cm of the bottom sediment samples were collected from each sampling station using the Eckman bottom sampler (Topouoglu et al., 2002; ATSM, 1990) and kept in glass bottles (at least 80 g). The sediment samples were later processed following standard methods (ATSM, 1990). Water samples were collected at various stations at a depth of 50 cm below the water surface. They were treated and analyzed for heavy metals using appropriate methods (Lau et al., 1998).

The periwinkle samples were randomly collected by handpicking at river bank/intertidal zone (sediment) from the four (4) stations: Station 1 (uppermost station) is by Ayogologo Abattoir, close to Nyede dreging company; Station 2 is by Agip base landing jetty; Station 3 is situated by Eagle Island waterfront; and Station 4 is by Elechi creek entrance at Abotoru New Calabar River, downstream of Elechi creek, close to shell KI landing jetty. More than two hundred (200) periwinkles were picked and washed immediately with the river water to remove mud and algae. They were kept in labeled plastic containers and packed in iced chest box and transferred to the laboratory for heavy metals analysis. In the laboratory, the specimens were properly washed with distilled water measured and sorted to two size groups of 10 – 30 mm and 40 - 50 mm shell length. The specimens were pooled together according to their measured size group for each station. Each pooled size group was divided into two sets; depurated and not depurated (normal). Depuration was done following the method of Green (1922). Both groups of periwinkles shells and soft tissues (depurated and normal) were analyzed for heavy metals using Buck Scientific Atomic Absorption/ Emission Spectrophoto meter 200A model. The physico-chemical parameters of water (dissolved oxygen, pH and temperature) were measured *in situ* using Horiba model U-10 µ meter.

RESULTS

The results of the levels of concentration of heavy metals in the water, sediments, shells and soft tissues of periwinkles are presented in Tables 1 and 2. The concentration for Cr in water is highest in station 1 (<

Table 3. Biocencentration factor (BCF) for heavy metals in the periwinkle from Elechi Creek.

Metal	BCF for soft tissue		BCF for small	
	Small	Large	Shall	Large
Cr	2.04	3.21	2.64	2.82
Cd	1.00	2.75	2.25	2.25
Pb	2.41	4.83	3.58	4.42

Table 4. Physiochemical parameters measured in the sampling sites.

Stations	Temperature (°C)	Salinity (‰)	pH	DO (mg/l)
1	28.3	14.5	7.2	7.4
2	30.9	16.0	7.3	6.4
3	30.7	19.3	7.4	5.8
4	31.5	21.2	7.4	5.5

0.002 mg/kg) while the concentration (< 0.001 mg/ kg) was the same for stations 2 to 4. The same concentrations (< 0.001mg/ kg) were observed for Cd and Pb in all the stations. However, in the sediments, the concentration of Cr was highest in station 1 and lowest in station 2. The order of heavy metals concentration in sediments in all stations was Cr > Pb > Cd. The sequence of metals in the stations was 1 > 3 > 4 > 2. The sediments accumulated more heavy metals than the water.

The order of heavy metals concentration in the soft tissues and shells of normal large periwinkle was Cr > Pb > Cd. The concentrations of these metals in the soft tissues and shells of normal large periwinkles tended to increase downstream from stations 1 to 3 except in station 4 for shells of periwinkle, where there was decrease. Nevertheless for the depurated large periwinkle soft tissues, the sequences of heavy metals inthe different station were: Cr; 1 < 2 > 3 > 4, Cd; 1 = 2 = 3 = 4 and Pb; 1 > 2 < 3 = 4 while those of depurated large shell were Cr and Pb; 1 < 2 > 3 < 4 and Cd; 1 = 2 = 3 = 4. The orders of heavy metals concentration in the normal small periwinkle soft tissues were Cr and Pb; 1 > 2 < 3 > 4 and Cd; 1 = 2 = 3 = 4. For normal small periwinkle shells, the following sequences were observed Cr; 1 > 2 > 3 = 4, Cd; 1 > 2 = 3 = 4 and Pb; 1 > 2 > 3 < 4. However, the sequences were the same for Cd and Pb (1 = 2 < 3 > 4) but not for Cr (1 > 2 < 3 > 4 in the depurated small perinwinkle soft tissue. Finally the orders of heavy metals accumulation in the depurated small periwinkle shells were the same in all stations (Cr, Cd and Pb; 1 > 2 > 3 < 4).

The normal large periwinkle shell and soft tissues concentrated more heavy metals than the small ones. The levels of concentrations of metals were higher in the normal large periwinkle than the depurated large ones but the opposite was observed in between the normal small and depurated small periwinkle. However, the soft tissues concentrated more heavy metals than the shells in both the normal and depurated periwinkles except in stations 2 and 4 for depurated small periwinkles where the shells concentrated more metals than the soft tissue. Moreso, the concentration of heavy metals were the same for depurated large soft tissue and shell in station 4.

The biological concentration factor (BCF) values increased with the size of the periwinkle. BCF was lowest in the soft tissues of the small periwinkle (1.00) and highest in the soft tissue of the large periwinkle 4.83. The sequence of BCF values for the heavy metals was Pb > Cr > Cd for both small and large periwinkle (soft tissues and shells). The concentrations of Cr, Cd and Pb in soft tissue have positive correlations with the concentrations in the shells but was insignificant at $P<0.05$. The concentrations of metals generally increase with increase in size of periwinkle (soft tissues and shell) but this relationship was insignificant except in Pb for soft tissue ($P<0.005$), (Table 3).

The temperature ranged between 28 and 31.5°C; salinity was between 4.50 to 21.2‰ and pH ranged between 7.2 and 7.4. There was indirect relationship between temperature and dissolved oxygen concentrations (Table 4).

DISCUSSION

The sediment accumulated more heavy metals than the water in this study as have been observed by Bower (1979), Fabris et al. (1994), Lau et al. (1996, 1998, Besada et al. (2001), Chindah and Braide (2003) and Eja et al. (2003). Sediment is the major depository of metals in some cases, holding more than 99 percent of total amount of a metal present in the aquatic system (Odiete, 1999). The observed low concentrations of Cr, Cd and Pb in this present work are consistent with the findings of Obire et al. (2003) who also worked on this creek but contrary to the reports of Chindah and Braide (2003) who observed higher values of Cd and Pb in this aquatic body. This observation is also different from the findings of Lau et al. (1998) in the sediment of Sg Sarawak Kanan, Malaysia and Eja et al. (2003) in great Kwa river Estuary, Calabar.

The concentrations of heavy metals in the normal soft tissues of the sampled snail were lower than those reported by Topouoglu (2002) for sea snail (*Rapana venosa*), mussel (*Mytilus galloprovinialis*) (Besada et al., 2001; Fabris at al., 1994) and for mussel (*Mytilus edulis planulatus*) (Chindah and Braide, 2003). The reduced concentrations of heavy metals in the depurated large periwinkle may be attributed to the ability of these snails to eliminate some accumulated heavy metals when removed from their natural habitat (Odiete, 1999). However, the higher concentration of heavy metals, especially lead, in some depurated small samples may be due to the magnification capabilities of those snails or the depuration time was insufficient. The patterns of heavy metal occurrence (Cr > Pb > Cd) in the normal and depurated soft tissues and shells differ from those of soft tissues of sea snail *Rapana venosa* (Pb > Cr > Cd; Topouoglu at al., 2002). The concentrations of these metals in the shell of these animals were lower than those of mollusk, (*Melanoides tuberculata*) in Sg Sarawak Kanan, Malaysia (Lau at al., 1996). The observed insignificant differences in the accumulation of Cr, Pb and Cd between the small and large periwinkle (soft tissues and shells were also made by Boyden (1977) and Riget et al. (1996) in mollusks, Leung and Furness (1999) on periwinkle (*Littorina littorea*) and Demanous and Brummeth (2002) in fish that bioaccumulation of heavy metals increases with increase in size of the organism. The correlation of heavy metals in the shell and soft tissues of periwinkle (large and small) showed that size is very important in heavy metals accumulation. Boyden (1974, 1997) showed that the levels of heavy metal in mollusk, for example gastropods, were generally size dependent. The observed higher heavy metals concentration in the large periwinkle samples may be attributed to higher metabolic rate of this periwinkle (Nott and Lagstan, 1989; Phillips and Rainbow, 1989; Platz-Osuna and Ruizx Fernandez, 1995).

According to Canterford et al. (1978) it is useful to express results in terms of biological concentration factor (BCF) when comparing the order of uptake of metals. The observed high BCF indicates that periwinkle has a high potential to concentrate heavy metals in their soft tissues and shells (Ademoroti, 1996; Odiete, 1999; Eja et al., 2003). The order of heavy metals BCF in this study (Pb > Cr > Cd) is in agreement with that observed by Eja et al. (2003). It is preferable to use large periwinkles for heavy metals pollution monitoring in the aquatic environment (Lau et al., 1996, 1998). This is proven by the observed higher BCF values in the soft tissues and shells of the large periwinkle.

There is serious heavy metal pollution in this creek and this present study has revealed it. Chindah and Braide (2003) also reported high concentration of iron and copper in three species of fish and sediment from this creek. In addition, Chindah et al. (2004) recorded high concentration of Cr, Cd, V, and Pb in the tissues of shrimps (*Penaeus notialis*). Other studies of Alfred-Ockiya et al. (1997) as well as Ovuru and Alfred-Ockiya (2001) reported the same observations. This creek is receiving organic matter in amount exceeding its natural purification capacity due to high population and industrial growth. In the past natural purification and dilution were usually sufficient (Saad et al., 1994). This study shows that the periwinkle, *T. fuscatus*, has a high potential to concentrate heavy metals though the observed concentrations are below WHO limit. However, indiscriminate effluents discharges should be stopped or effluent must be treated before being released into this creek. Also, there should be continuous environmental pollution monitoring to check heavy metals hazard.

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