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ORIGINAL ARTICLE

Spatial assessment of heavy metal concentrations in giant tiger shrimps (*Penaeus monodon* Fabricius, 1798) in Bodo Creek, Gokana LGA, Rivers State, Nigeria

O.S. Eludoyin, A.N. Balogun, S.O. Otali

Department of Geography and Environmental Management, University of Port Harcourt, Port Harcourt, Nigeria.
E-mail: olatunde.eludoyin@uniport.edu.ng; elutunde@yahoo.com
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This study assessed the heavy metals in shrimps and surface water in Bodo Creek, Gokana LGA, Rivers State, Nigeria. Five composite water samples were collected into the distilled plastic bottles from the upstream, midstream and downstream in relation to a point of discharge of pollutants. Similarly, giant shrimps were collected from the same locations. Laboratory analysis was carried out on Pb, Zn, Cd, Ni, and Fe on water and shrimp samples while pH, salinity, conductivity, temperature and dissolved oxygen (DO) of water samples were determined in situ. The means of heavy metals investigated in surface water and shrimps were explained using descriptive statistics while the significant relationships between the levels of heavy metal concentration of surface water and shrimps was determined by Spearman's rank statistics. Findings reveal that the pH was 6.60 in the upstream, 6.10 in the midstream and 6.30 in the downstream. DO was highest at the midstream (3.10 mg/l) while the conductivity and salinity were highest in the upstream and least in the downstream. Mean Cd, Zn and Ni in the surface water were highest at the midstream with a value of 0.06 mg/l, 4.71 mg/l and 0.35 mg/l respectively while Fe and Pb were highest in the upstream with a value of 1.27 mg/l and 2.40 mg/l. However, mean Ni (3.78 mg/kg), Pb (1.48 mg/kg), Fe (1.48 mg/kg) and Zn (48.89 mg/kg) were highest in the shrimps found in the midstream while mean Cd (2.47 mg/kg) was highest in the downstream. The correlations between the heavy metals in the surface water and shrimps were significant at $p<0.05$. The study recommended that heavy metal concentrations in shrimp caught in Bodo Creek should be properly investigated before consumption to prevent incidences of human health complications.
Keywords: Bodo creek; consumption; heavy metals; human health; nigeria; shrimps; surface water

Introduction

Shrimps are seen as crustaceans of high economic value but the challenge of aquatic ecosystem pollution has been a global concern because of the toxic effects of heavy metals released to the aquatic organisms (Orosaye et al, 2010). Environmental pollution has increased substantially in the last decades due to a great number of industrial, agricultural, commercial and domestic waste, effluents and emissions as well as hazardous substances. Some heavy metals such as Hg, Cr, Cd, Ni, Cu, Pb etc. introduced into environmental water system may pose high toxicities on the aquatic organisms (Wu & Zhao, 2006; Ambreen et al., 2015; El Gendy et al., 2015). Heavy metal occurs naturally in aquatic ecosystem (sea water) in low concentrations and they originate from the earth crust (Alaa & Osman, 2010). Heavy metal pollutions are particularly hazardous contaminants in food and the environment. In general, they are not biodegradable and have long biological half-lives (Heidarieh et al., 2013).

High concentration of heavy metals enters the coastal environment as a result of human activities such as industrial activities, irrigation expansion, increased in urbanization exploration and exploitation of natural resources (Tangkrock-Olan & Cheevaporn, 2003). Heavy metals are metallic chemical elements that have relatively high density and are poisonous or toxic at low concentration (Jarup, 2003). Heavy metals which include mercury (Hg), Copper (Cu), Lead (Pb), Nickel (Ni), Arsenic (As), Zinc (Zn), Manganese (Mn), Cadmium (Cd), Iron (Fe) and Chromium (Cr) have a particular significance in eco-toxicology, since they are highly persistent (Storelli et al, 2005). More importantly, heavy metals like Ni, Cu, Cd, Pb, Mn and Vanadium (V) are associated with crude oil because they parts of the chemical compositions of the crude oil. The major Nigerian crude oil brands such as Bonny light, Forcados brand and Qua Iboe light, Brass River crude oil have the following heavy metals concentrations Ni (4.0 ppm), V (1.0 ppm), Cd (0.1 ppm), Copper (<0.1 ppm), and Pb (<0.1 ppm) (Osuji & Adesiyan, 2005). Thus, the presence of metal pollutant in fresh water is known to disturb the delicate balance of the aquatic ecosystem. The toxic effect of heavy metal on aquatic animals might be both direct (reducing the diversity and abundance of benthic invertebrates and/or indirect (modification of species interaction and reduction in food quality) (Blaylock and Huang, 2000); despite the fact that the production of shrimps increased the gross domestic product of some countries.

Although there is no availability of national food diaries and nutrition data in Nigeria (Orisakwe et al., 2014), sea food generally are known to be contributing to the gross domestic product of individual country. For instance, Chaitanya et al. (2016) reported that India earned $2.84 billion from seafood exports in 2010-2011 commercial year from which frozen shrimp was 36.21 %. Seafood is widely consumed as part of the local diet in Nigeria, due in part to its high protein content, low saturated fats and omega fatty acids which are known to contribute to good health (Kennedy et al., 2009; Orisakwe et al., 2014). However, the toxicity effect of heavy metals in human can result to damage or reduce mental and central nervous functions, cause miscarriage in pregnant women, damage the organs responsible for sperm production in men, lower energy level and damage to blood composition, lung, kidney, liver and other vital organs and it may ultimately cause death (Mudgal et al., 2010). Also long term exposure to these heavy metals may result to show progressing in physical, muscular and neurological degenerative process (Duffus, 2002). Increasing levels of Pb, Cd, and Ni could pose a potential threat to the ecology of the area and the health of the local population (Ginsberg & Toal, 2009; Orisakwe et al. 2014).

Previous studies such as Ololade et al. (2011) and Orisakwe et al (2014) reported high level of Pb, Cd, and Ni in fish, crab and periwinkle in Ondo State, Nigeria. Also, Davies et al. (2006) reported the heavy metal load in water and sediment and bioaccumulation of heavy metals in periwinkle (*Tympanotonus fuscatus*) from Elechi Creek, Niger Delta, Nigeria while Babatunde et al (2015) have reported the bioaccumulation of heavy metals in the Bonny/New Calabar River Estuary in Niger Delta, Nigeria. Umunnakwe and Ogamba (2013) also reported the bioaccumulation of heavy metals in crabs at Bundu-Ama Community of Port Harcourt, Rivers State with Pb and Cd less than 1 mg/kg and 2 mg/kg respectively. Wala et al (2016) also reported heavy metal loads in Ergeria radiata from the Nun River, Niger Delta, Nigeria whereby the Ni and Cd recorded mean concentration values of 0.78±0.32 mg/kg and 0.03±0.01 mg/kg respectively. Similarly, Tiimub & Dzifa-Afua (2013) determined the Fe concentrations in Tilapia and Catfish in Densu River at Weija District in Grater Accra Region of Ghana. Vincent-Akpu et al. (2015) studied the physico-chemical properties and metal contents of water and sediments of Bodo Creek, Niger Delta, Nigeria. None of these studies considered the heavy metals accumulation in the giant tiger shrimp especially in the Niger Delta. Thus, the present study assessed the heavy metal concentrations in giant tiger shrimps (*Penaeus monodon* Fabricius, 1798) in Bodo Creek, Rivers State, Nigeria.

Materials and methods of research

The study was carried out in Bodo Creek which is found in the brackish water environment and situated on the upper reaches of the Andoni-Bonny estuarine system. The creek is locally used for capturing aquatic lives such as fish and shrimps, transportation, cassava fermentation, mangrove fuel-wood production, crude oil exploitation, large scale fish farming and domestic waste disposal (Onwubuta-Enyi et al., 2008). Bodo Creek is potentially attractive for the establishment of industries (Zabbey & Malaquias, 2013), due to the construction of the Bodo. The creek adjoins Bodo community administratively located in the Gokana Local Government area of River State, Nigeria (Figure 1). The study took place in three stations namely upstream of the Bodo Community (longitude 70 16′ 33.10″E and latitude 40 38′ 26.67″N, midstream (i.e. point of discharge and close to Bodo Community) with longitude 70 15′ 17.23″E and latitude 40 37′ 37.66N while Station 3 was located downstream of Bodo Community with longitude 70 14′ 51.90″E and latitude 40 36′ 37.09″N. The study area experiences tropical monsoon climate which is characterized by a humid sub-equatorial long wet season which last from March to October and a short dry season which last from November to February (Eludoyin & Ogbe, 2017). The mean monthly temperature is in the range of 25 °C to 28 °C (Balogun, 2014). The relative humidity throughout the year is high but slightly low in the dry season. The mean annual relative humidity is about 85% (Eludoyin & Ogbe, 2017). The rainfall is seasonal, variable and heavy (Mmom & Fred-Nwagwu, 2013) and mean annual rainfall is about 2,300mm. The prevailing wind is basically south-westerly and north-easterly and the wind speed is between 5 and 17m/s (Utang et al., 2010). The topography of the study area ranges between 16m and 40m above the sea level (Mmom & Fred-Nwagwu, 2013). Generally, the vegetation is made up of fresh water swamp and mangrove which include is Rhizophora racemosa, nypa palm, mangrove sedge, and date palm (Onwugbuta-Enyi et al., 2008). The soils of the area can be categorized as freshwater brown loams and sandy loams (Eludoyin & Ogbe, 2017). The major occupation of the residents of the study area included farming and fishing.

A total of 5 water samples were collected from the upstream, midstream (point of discharge) and downstream with respect to the point of discharge of pollutants along the Bodo Creek as a result of urbanization. The fieldwork took place in December, 2017. The data collection was done in connection with the information sought oil field, flow station, company personnel and residents in the study area. These samples were collected by the use of well-labelled distilled plastic sampling bottles of 1 liter each. The plastic bottles used for water samples collection were cleaned to prevent contamination (El Gendy et al., 2015). The water samples were preserved and stored in a clean ice box in the field at about 4 °C of temperature.

Shrimp species were captured around the same location at the upstream, midstream and downstream of the referenced pollution point using cast nets during the data collection. This study used 5 same sample size of shrimps between 10 g and 15 g. Immediately after sampling, shrimp were stored in a container and preserved in crushed ice and thereafter transferred to the laboratory and frozen -15 °C until analyzed. Samples (whole body) were dried (65 °C for 48 hours) and ground through a 2 mm screen for further investigation. 500 mg of dried shrimp's samples were weighed clean polythene bags using Shrimp Tissue IAEA-407 standard and were heat sealed for irradiation (Heidarieh et al., 2015). The water samples and shrimps were subjected to laboratory analysis on heavy metals (Pb, Zn, Cd, Ni and Fe) using an atomic absorption spectrophotometer (AAS) as described in APHA 3111B and ASTMD 3651 (Fatema et al., 2015). The physical parameters such as pH, salinity, conductivity, temperature and dissolved oxygen (DO) were determined using appropriate measurement tools in situ. pH was measured using calibrated digital pH meter. Salinity and conductivity were measured using calibrated conductivity meter while dissolved oxygen was measured using spectrophotometer method. The heavy metals in shrimp tissues were investigated using the infrared (IR) spectrophotometry - ASTMD 3921 and ASTMD 5765. Descriptive and inferential statistics were employed in this study. The descriptive statistics was used to describe the mean values of the water parameters investigated and the heavy metals in the shrimps. Spearman's rank correlation statistics were used to determine the relationship between the heavy metals in water samples and shrimps in the study area.

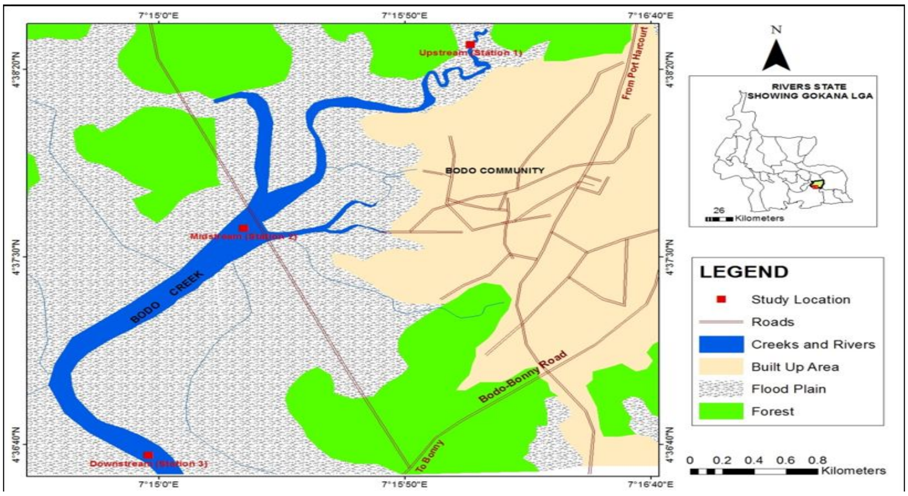

Figure 1. Study locations along Bodo Creek.

Results and discussion

Effects of urbanization on physical properties of surface water

Table 1 and Figure 2 show the analysis of physical parameters of surface water. It is shown that the mean pH in the upstream was 6.60 ranging between 6.30 and 6.70 while in the midstream, the mean value of pH was 6.10 ranging between 6.00 and 6.50 while the mean value of pH in the downstream was 6.30 ranging from 6.20 and 6.80. The analysis thus reveals that the pH of the surface water generally was weakly acidic but it was more acidic at the midstream which was the point of discharge of pollutant. Furthermore, the mean value of DO in the upstream was 1.84 mg/l, while it was 3.10 mg/l and 2.24 mg/l in the midstream and downstream respectively. The mean value of conductivity in the upstream was 25.1 µS/cm, 23.6 µS/cm in the midstream and 18.9 µS/cm in the downstream. The salinity level in the upstream was 12.52 µS/cm while it was 11.8 µS/cm and 9.44 µS/cm in the midstream and downstream respectively. The temperature in the upstream was 31.8 oC, in the midstream was 29.77 °C while in the downstream, the mean value of temperature was 30.43 °C. The analyses generally reveal that conductivity and salinity was higher in the upstream than the midstream and downstream while DO was highest at the midstream. Generally, the pH was lower than the permissible levels except that of the upstream that fell within the WHO/EPA permissible range, suggesting that the pH was acidic. However, the mean DO, conductivity, salinity and temperature of surface water in Bodo Creek was less than the EPA permissible levels.

Table 1. Physical parameters of surface water.

Parameter	Upstream			Midstream			Downstream			Permissible Limits
	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	
pH	6.3	6.7	6.60 ± 0.2	6	6.5	6.10 ± 0.3	6.2	6.8	6.30 ± 0.3	6.0-8.5**
DO (mg/L)	1.6	1.92	1.84 ± 0.1	1.5	3.31	3.10 ± 0.8	1.9	2.67	2.24 ± 0.4	5.0*
Conductivity (µS/cm)	18.5	27.33	25.1 ± 3.4	21.01	25.72	23.6 ± 1.4	17.21	21.54	18.9 ± 1.6	1000*
Salinity (ppt)	9.26	15.31	12.52 ± 1.7	10.21	13.57	11.8 ± 0.9	8.12	11.5	9.44 ± 1.1	≤ 40*
Temperature (°C)	30	31.8	31.8 ± 0.9	28.6	31.12	29.77 ± 1.2	29.8	31.05	30.43 ± 0.6	25*

*EPA (2001) only; **EPA(2001)/WHO(2011).

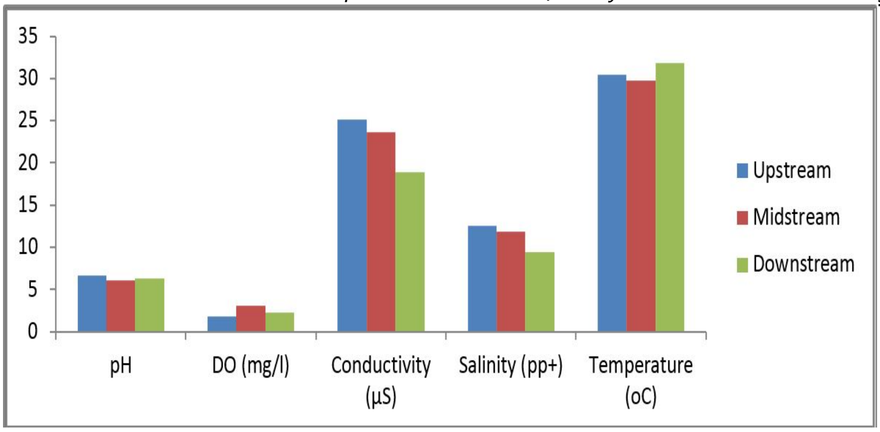

Figure 2. Physical properties of surface water.

Effects of urbanization on heavy metals concentrations in the surface water

Table 2 shows the analyses on the heavy metals concentrations in the surface water and it is revealed that Fe was 1.27 mg/l in the upstream, 1.22 mg/l in the midstream and 0.83 mg/l in the downstream. The mean value of the concentration of Pb in the upstream was 1.27 mg/l, midstream was 2.37 mg/l while it was 2.21 mg/l in the downstream. However, the concentration of Cd was the least among the heavy metals investigated by this study and it shows that in the upstream it was 0.03 mg/l while the concentration in the midstream and downstream was 0.06 mg/l and 0.04 mg/l. It is also shown that the mean value of the concentration of Zn in the upstream, midstream and downstream was 3.61 mg/l, 4.71 mg/l and 4.62 mg/l respectively. The mean value of the concentration of Ni in the surface water reveals was 0.15 mg/l in the upstream, 0.35 mg/l in the midstream and 0.33 mg/l in the downstream. Except Fe and Pb, the concentrations of heavy metals were highest in the midstream and least found in the upstream. Comparing the results of the analyses with the WHO standard, it was discovered that the mean values of Fe, Pb, Cd, Zn and Ni in the upstream, midstream and downstream were greater than the WHO permissible levels while one sample T-test showed that the means Fe, Pb, Cd, Zn and Ni were significantly varied from the WHO permissible levels (Table 2). Similarly, comparing the WHO permissible levels with the mean values of heavy metals in the upstream, midstream and downstream as shown in Table 3; it was revealed that Fe showed significant variation in upstream (p=0.026) and midstream (p=0.000) while Pb showed significant variation in the upstream (0.028). However, Cd concentration was significantly varied from the WHO at the upstream (p=0.017), midstream (p=0.006) and downstream (p=0.009) and at the midstream only, there was a significant variation in Zn (p=0.042) and Ni (p=0.019) (Figure 3).

Table 2. Heavy metals concentrations of surface water.

Parameter	**Upstream**			**Midstream**			**Downstream**			**Permissible Limits**	**General Sample T Test (df=14)**
	Min	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**		
Fe (mg/l)	0.92	1.45	1.27 ± 0.3	1.21	1.23	1.22 ± 0.01	0.45	1.52	0.83 ± 0.6	0.2++	6.877 (0.000)*
Pb (mg/l)	1.9	3.21	2.40 ± 0.7	1.5	4.12	2.37 ± 1.5	1	4.32	2.21 ± 1.8	0.05+	5.589 (0.001)*
Cd (mg/l)	0.03	0.04	0.03 ± 0.001	0.05	0.06	0.06 ± 0.01	0.03	0.04	0.04 ± 0.01	0.005+	9.510 (0.000)*
Zn (mg/l)	3.12	4.51	3.61 ± 0.7	4.21	5.41	4.71 ± 0.6	3.8	5.11	4.62 ± 0.7	3.00++	4.876 (0.001)*
Ni (mg/l)	0.03	0.21	0.15 ± 0.1	0.3	0.43	0.35 ± 0.1	0.22	0.44	0.33 ± 0.1	0.07+++	4.919 (0.001)*

*p-values are significant at 0.05 significant levels; p-values of t-test in the brackets; ++EPA (2001)/WHO (2011); +EPA (2001) only; +++WHO (2011) only.

Table 3. Significant variation of the heavy metals of water from the WHO permissible levels in each study location

Parameters	**Study Locations**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	**Upper**
Fe (mg/l)	Upstream	6.081	4	.026*	1.07433	0.3142	1.8345
	Midstream	153.65	4	.000*	1.02433	0.9956	1.053
	Downstream	1.823	4	0.21	0.63	-0.857	2.117
Pb (mg/l)	Upstream	5.874	4	.028*	2.39333	0.6402	4.1464

	Midstream	2.706	4	0.114	2.36333	-1.3943	6.121
	Downstream	2.072	4	0.174	2.19667	-2.365	6.7584
Cd (mg/l)	Upstream	7.671	4	.017*	0.031	0.0136	0.0484
	Midstream	13.211	4	.006*	0.055	0.0371	0.0729
	Downstream	10.458	4	.009*	0.03433	0.0202	0.0485
Zn (mg/l)	Upstream	1.366	4	0.305	0.61333	-1.3189	2.5456
	Midstream	4.743	4	.042*	1.71	0.1587	3.2613
	Downstream	3.931	4	0.059	1.61667	-0.1529	3.3862
Ni (mg/l)	Upstream	1.352	4	0.309	0.08133	-0.1775	0.3402
	Midstream	7.086	4	.019*	0.28333	0.1113	0.4554
	Downstream	4.088	4	.055*	0.262	-0.0137	0.5377

*p-value is significant at p<0.05.

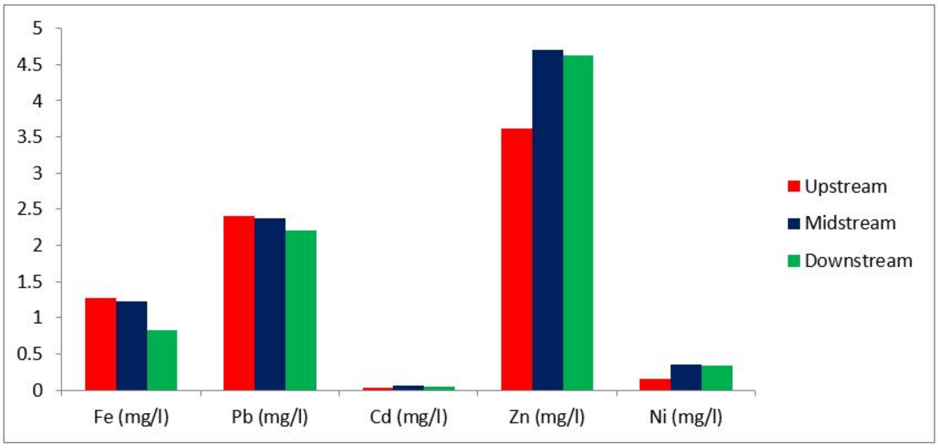

Figure 3. Heavy metal concentrations in surface water.

Effects of urbanization on heavy metals concentrations in the shrimps

Table 4 presents the heavy metal concentrations in the shrimps found in Bodo Creek. It is shown that the mean value of Cd in the shrimp found in the upstream was 2.38 mg/kg and it was 2.45 mg/kg for the shrimps found in the midstream while it was 2.47 mg/kg in the shrimps found in the downstream. However, the concentration Ni in the tissues of shrimps was 3.73 mg/kg for the shrimps in the upstream, while it was 3.78 mg/kg and 3.71 mg/kg in the shrimps found in the midstream and downstream. Pb concentration in the shrimps in the upstream, midstream and downstream was 1.46 mg/kg, 1.48 mg/kg, 1.44 mg/kg respectively while the Fe concentration in the shrimps found in the upstream, midstream and downstream was 48.83 mg/kg, 48.89 mg/kg and 48.97 mg/kg respectively. Fe concentration was the highest in the shrimps among the heavy metals investigated. The mean value of the concentration of Zn in the shrimps in the upstream was 2.62 mg/kg, 2.65 mg/kg in the shrimps found in the midstream and 2.61 mg/kg in the shrimps found in the downstream. The analysis is also shown in Figure 4. The analysis reveals that except Cd, the concentrations of heavy metals in the shrimps at the midstream were the highest. Comparing the concentrations of the heavy metals in the shrimp with the international standards, it is discovered that the concentrations Fe and Zn were below the WHO (1989) and FAO/WHO (1984) standards respectively. On the other hand, the concentrations of Cd and Pb were higher than the FAO/WHO (1984) standard and Ni concentration was also lower than the WHO (1985) standard (Table 5).

Table 4. Heavy metals concentrations in the shrimps.

Parameter	**Upstream**			**Midstream**			**Downstream**			**International Standards**
	Min	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	
Cd (mg/kg)	1.25	3	2.38 ± 0.9	1.3	3.2	2.45 ± 0.9	1.42	3.5	2.47 ± 1.0	0.5*
Ni (mg/kg)	2.5	4.95	3.73 ± 1.2	2.6	4.91	3.78 ± 1.1	2.5	4.93	3.71 ± 1.2	0.5-0.6***
Pb (mg/kg)	1.5	2.11	1.46 ± 0.6	1.06	2.12	1.48 ± 0.5	1.01	2.1	1.44 ± 0.6	0.5*
Fe (mg/kg)	40.3	60.3	48.83 ± 10.3	40.5	60.8	48.89 ± 10.6	40.2	61.2	48.97 ± 10.9	100**
Zn (mg/kg)	2.34	2.99	2.62 ± 0.3	2.38	2.94	2.65 ± 0.2	2.35	2.95	2.61 ± 0.3	40*

*FAO/WHO (1984), El-Moselhy et al. (2014); **WHO (1989), Mohktar, (2009); ***WHO (1985), Hashim et al. (2014).

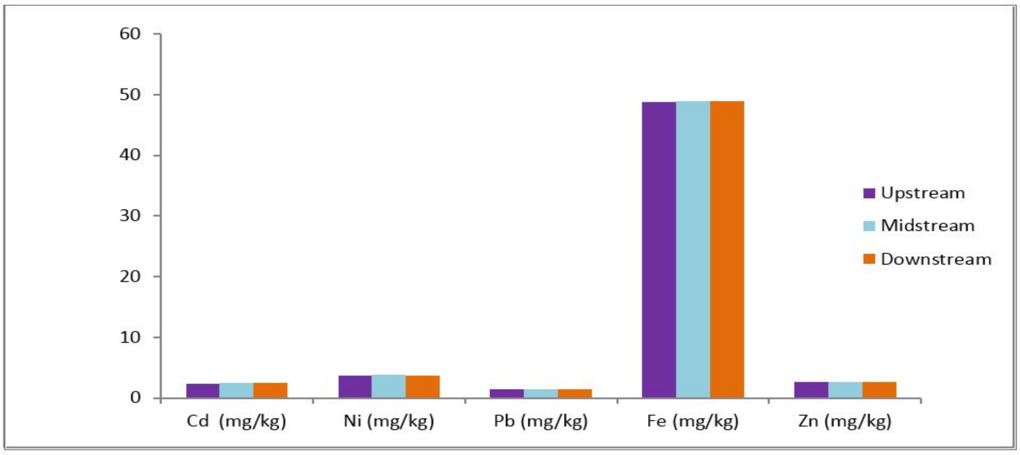

Figure 4. Heavy metal concentrations in Shrimps.

Relationship in heavy metals between surface water and shrimp tissues

The correlation coefficients of the relationship between the heavy metals concentrations in the surface water and shrimps for Fe, Pb, Cd, Zn and Ni was 0.87, 0.92, 0.78, 0.88 and 0.75 respectively at the $p<0.05$ significant levels (Table 5). This suggests that heavy metals present in the shrimps in Bodo Creek were significantly influenced by the concentrations of heavy metals in the surface water.

Table 5. Correlations between heavy metals of surface water and shrimps.

Heavy metals	Correlation coefficient	p-value
Fe	0.87*	0.002
Pb	0.92*	0.001
Cd	0.78*	0.002
Zn	0.88*	0.007
Ni	0.75*	0.004

*Significant at $p<0.05$.

Discussion

Findings showed that the salinity of surface water in Bodo Creek ranged from 8.12 ppt in the downstream to 15.31 ppt in the upstream while DO ranged from 1.50 mg/l to 3.31 mg/l. These results are lower than that of Onwugbuta-Enyi et al, (2008) who reported salinity levels between 11.6 ppt and 16.1 ppt and DO ranging from 7.7 mg/l to 8.2 mg/l in Bodo Creek. The mean DO was highest in the midstream while the least was observed in the upstream. Conversely, the mean temperature was least in the midstream and highest in the upstream. The behaviour of DO may be linked to the temperature level in that environment. Already, it was established that DO concentrations fluctuate with water temperature seasonally and daily. DO is necessary in aquatic systems for the survival and growth of many aquatic organisms as it assesses the health of surface-water bodies. The Cd levels were low in the surface water samples. This is in consonance with previous studies in the Niger Delta such as Vincent-Akpu et al. (2015), Babatunde et al. (2015) and Wala et al. (2016).

Heavy metals concentration in Bodo Creek was very high in relation to the EPA/WHO standards for aquaculture water quality. This means that the river water was not portable and its heavy metal concentration is beyond the approved and acceptable limit, hence this may pose threat to human lives in the surrounding communities. Similarly, the concentration of heavy metals in the shrimps is an indication that surrounding surface water has been polluted. It is revealed that the concentrations of heavy metals in the shrimps were higher than the international standard limit. The findings was similar to Singh (1988) and Rojas de Astudillo (2002) which reported that land species crustaceans and mollusks found near coastal villages of Tobago exceeded heavy metal permissible limits for human consumption. On the other hand, the present study is not in agreement with the findings of Balfour et al (2012) who reported that the metal concentrations of the Penaeus shrimp species sampled in 2009 in Trinidad were well below the maximum admissible limits for human consumption according to international and local standards. The concentrations of Cd, Cr, Cu, Zn and Hg in the local shrimp (Penaeus spp.) reported in various shrimp species from India (Guhathakurta & Kaviraj, 2000), China (Wu & Yang, 2011) and Egypt (Soliman, 2006) are similar to the findings in the present study as their concentrations exceeded the maximum admissible limits for human consumption when compared to international and local standards.

The concentrations of Pb and Cd in the shrimps were significantly higher than the permissible levels. This shows that the health of the people that are readily exposed to consumption of the shrimps may be affected. The accumulation of Pb in food chains can give rise to health effects such as disruption of biosynthesis of haemoglobin and anaemia, decline in fertility, brain and kidney damage (Umunnakwe & Ogamba, 2013). In fact, Pb is a confirmed carcinogen (Martin and Griswold, 2009; Babatunde et al, 2015). In aquatic ecosystem, Cd can bio-accumulate in mussels, oysters, shrimps, lobsters and fish. High Cd accumulation in shrimps in Bodo Creek may be attributed to the fact that freshwater organisms are less resistant to Cd

poisoning than the salt water organism (Umunnakwe & Ogamba, 2013). In addition, Eneji et al. (2011) and Babatunde et al. (2015) viewed that the rate of bioaccumulation of heavy metals in aquatic organisms depends on the ability of the organisms to digest the metals, the concentration of such metal in the river, the feeding habits of the organism, age and lipid content in the tissue of the organism.
The significant influence of heavy metals in the shrimp by the concentrations of the heavy metals in the surface water shows that heavy metals are actually absorbed by shrimps and this could be dangerous for the consumers of such contaminated shrimps. Vannoort & Thomson (2006) noted that long term and high dose exposure to cadmium can cause kidney failure, softening of bones and prostate cancer while McMurtrie & Kennedy (2012) reported that Pb can build up in the body and affects the nervous system, reproductive system, kidneys and learning difficulties in children or babies.
Furthermore, the higher concentration of heavy metals in shrimps in the midstream may be a reflection of their time spent around this area in search for food like phytoplankton or waste discharged into the river. McMurtrie & Kennedy (2012) reported that feeding habitats and life history patterns could influence heavy metal levels in shellfish and shrimp and as a result if the shrimp is consumed, it could cause vomiting, diarrhoea, and abdominal pain. The higher concentrations of heavy metals at the midstream is an indication of the pollution caused by human activities especially industrialization as this point is known as the point of discharge of the wastes from the industries and more importantly oil pollution. According to McMurtrie & Kennedy (2012), human activities from industry and run-off from urban and agricultural landuse increase the concentrations of heavy metals in the environment, potentially to levels which could have adverse effects on humans and animals. High Fe concentration in shrimp is similar to the findings of Heidarieh et al. (2013) whereby the Fe concentration was 288 mg/kg and that of Tiimub and Dzifa-Afua (2013) whose study revealed a high Fe concentration (53 mg/L) in the Tilapia. The high Fe concentration may be due to the potential ability of shrimp to accumulate heavy metals in their muscle (Heidarieh et al., 2013). Lower concentration of Cd was discovered in the water samples in Bodo Creek among other heavy metals investigated. According to McMurtrie & Kennedy (2012), Cd occurs naturally in low levels in the environment. On the other hand, Cd concentrations in the tissue of shrimps were higher in Bodo Creek. This is in agreement with the findings of Gray et al. (2005) who claimed that the Cd in shellfish can be high.

Conclusions and recommendations

The study has assessed the status of heavy metals in shrimps and surface water in Bodo Creek and it can be concluded that the concentrations of Cd, Zn and Ni were highest in the surface water while Pb, Zn, Ni and Fe were highest in the shrimps at the point of discharge. The levels of Pb, Cd and Ni in shrimps were higher than the international standards. The study recommended that shrimp caught in Bodo Creek should be investigated thoroughly before being consumed; laws and regulations should be enforced to protect aquatic lives; environmental education should be given in form of campaign and creating awareness on heavy metal concentrations in Bodo Creek; and further studies are necessary to evaluate the effects of organs, sex, size and season on heavy metal concentrations in shrimp.

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