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Cadmium (Cd) and Lead (Pb) in *Penaeus notialis* purchased from Creek Road Market, Port Harcourt, Nigeria: Risk Assessment of Cd from Consumption of *P. notialis*

Ugbomeh Adaobi Patricia and Jaja Boma
Applied and Environmental Biology Department, Rivers State University of Science and Technology, Nkpolu-Oroworukwo, PMB 5080, Port Harcourt

Abstract: Cadmium (Cd) and Lead (Pb) concentrations were estimated in the abdomenal muscle (edible portion) and cephalothorax of the pink shrimp *Penaeus notialis*. The shrimps were purchased from the Creek road market, the most populated fish market in Port Harcourt, Nigeria. Morphometric measurement (total lenght in cm and weight in g) of six shrimps was made. The carapace and hard covering of the abdomen was removed and the fleshy parts as well as the cephalothorax were analyzed for Cd and Pb by flame atomic absorption spectrophotometric (AAS model GBC AvantaPm AAS). The abdomenal concentrations of Cd ranged from 0.06 to 0.30 mg/kg and 0.41 to 0.98 mg/kg for Pb. In the cephalothorax Cd concentrations ranged from 0.16 to 1.25 mg/kg, while Pb concentrations were 0.78 to 1.95 mg/kg. These concentrations were higher than the WHO and FAO permissible limit of 0.1 µg/g for Cd and 0.2 µg/g for Pb. The concentration of Pb was significantly higher than the concentration of Cd in both the cephalothorax and abdomen of the shrimp and concentrations in the cephalothorax were significantly higher than in the abdomen. A risk assessment and hazard quotient was estimated for Cd for children, teenagers, women of child bearing age and adults.

Keywords: Cadmium, hazard quotient, lead, *Penaeus notialis,* pink shrimp, risk assessment

INTRODUCTION

Aquatic invertebrates take up and accumulate trace heavy metals whether essential or non-essential, all of which have the potential to cause toxic effects. Decapod crustaceans have the ability to metabolically regulate essential metals like zinc, copper and manganese (Rainbow, 1995) and in contrast tend to be effective as bio accumulators of non-essential metals such as lead and cadmium, reflecting environmental levels and serve as bio-indicators of these metals (Rainbow, 1990).

Toxicity however ensues when the rate of metal uptake from all sources exceeds the combined rates of detoxification and excretion (if present) of the metal concerned. Glanze (1996) have listed the heavy metals of human health concern as antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium and zinc. Toxicity can result from any of these metals but the commonly encountered toxic metals are lead, arsenic, mercury, cadmium, iron, zinc and chromium.

Cadmium is a major metal pollutant and causes a range of pathological alterations (Zheng *et al*., 2009). It derives its toxicological properties from its chemical similarity to Zinc which is an essential micronutrient for plants, animals and humans. They are bio persistent and once absorbed by an organism, remains resident for many years before it is eventually excreted. In humans, long term exposure to Cd is associated with renal dysfunction and high exposure can lead to obstructive lung disease. Also Cd may produce bone defects in humans and animals.

Lead is a highly toxic heavy metal which occurs naturally in parts of the environment but is now ubiquitous because of human activities (Pain *et al*., 1995). Therefore all animals are exposed to a certain amount of Pb in the environment (especially in food and water), but such background level exposure does not result in Pb poisoning. There have been incidents of Pb poisoning in birds and other animals living or feeding near point sources of Pb contamination (Bull *et al*., 1983). Lead has also been found to accumulate preferentially in oyster shells than in the tissues (Dambo and Ekweozor, 2000). Concentrations of Pb and Zn have been found to vary (from about 9 and 13 µg/g in uncontaminated areas to about 230 and 290 µg/g in a contaminated environment) in calcitic shells (Dossis and Warren, 1980). Lead, at certain contact degrees, is a poisonous substance to animals as well as for human beings. It damages the nervous system and causes brain disorders. Excessive lead also causes blood disorders in mammals. Like the element mercury, lead

Corresponding Author: Ugbomeh Adaobi Patricia, Applied and Environmental Biology Department, Rivers State University of Science and Technology, Nkpolu-Oroworukwo, PMB 5080, Port Harcourt, Tel.: 002348033104090

is a neurotoxin that accumulates both in soft tissues and the bones (WHO Foods).

Shrimps are consumed by artisanal fishermen, their families as well as people from other works of life either as fresh or smoked dry, largely because of the perceived and documented nutritional benefits of eating shrimp and the availability. At 6 g/ounce, shrimp is an excellent source of protein. In fact, among all WHO Foods, shrimp ranks as the 4^{th} best source of high-quality protein (WHO Foods). The protein richness of shrimp is one of the reasons this shellfish is relied on in so many different culinary traditions.

Penaeus notialis of family penaeidae is a common catch in the estaurine waters of the Bonny river and its tributaries The research aims to ascertain the concentration of Cd and Pb in *P. notialis* in a local market, determine the concentration pattern of cadmium and lead in *P. notialis* by determining the concentrations in the abdomen and in the head and estimate the risk assessment of this shrimp for fisher men and attendant buyers of the product from the Borikiri market.

MATERIALS AND METHODS

The Pink shrimp (*P. notialis*) was purchased at the Creek Road market on a tributary of Bonny river at Port- Harcourt, Rivers State, Nigeria in August 2012. Twenty samples were collected and from these six were selected for estimation of Cd and Pb concentrations. Some morphometric measurements were taken, abdomen was separated from the cephalothorax and dried to a constant weight. Samples were prepared according methods by APHA (1998) and analyzed by flame atomic absorption spectrophotometric (AAS model GBC Avanta Pm AAS).

Statistical analyses were carried out using Microsoft office Excel 2010. ANOVA was used to determine significant variations in the concentrations of Cd and Pb at a 5% level of significance.

The average daily intake dose of exposed individuals was calculated and compared with a Reference Dose (RfD) obtained from IRIS (2012). Pb has no RfD but that of Cd is 1×10^{-3} mg/kg/day based on a chronic intake that would result in a kidney concentration of 200 µg/g wet weight.

Risk assessment for Cd was estimated by calculating the Average Daily Dose (ADD) and Hazard Quotient (HQ) for children, teenagers, women of chid bearing age and adults using the equation:

$$ADD = C_{shrimp} \times IR_{shrimp} \times EF \times ED/BW \times AT$$ (Yan, 2001)

where,

- ADD : Average Daily Dose (ingestion of contaminated shrimp, mg/kg/day)
- C_{shrimp} : Concentration of contaminants in shrimp (mg/kg fish)
- IR_{shrimp} : Per capita intake rate of shrimp (kg fish/meal)
- EF : Exposure frequency (meals/day)
- ED : Exposure duration (days)
- BW : Body weight (kg)
- AT : Averaging time (days)

Depending on different age and gender, 4 subpopulation groups were considered, including children from 6-11 years old, youth from 12-18 years old, women of childbearing age and normal adults.

Input parameters were RfD of Cd, body weight of consumer, per capita intake of 4oz (0.113 g) of shrimp for less than 15 years and 8oz (0.226 g) of shrimp for adults, 95% CI of mean, EF of 1 meal a day, ED of 3 meals a week and average time of 1 week (7 days). Then the hazard quotient was calculated by:

$$\text{Hazard quotient} = ADD/RfD$$

If the hazard quotient is greater than 1, it means the population has excess non-carcinogenic health risk from the specified pathway and exposure frequency of the shrimp. If the hazard is less or equal to 1 means the study population does not have excess non-carcinogenic health risk from the specified pathway and exposure frequency of the shrimp.

Furthermore the number of allowable meals per month was estimated from:

$$CR_{lim} = RfD \times BW/C_{shrimp}$$

where,

- CR_{lim} : Maximum allowable shrimp consumption rate (kg/d)
- RfD : Reference dose (mg/kg-day)
- BW : Consumer body weight (kg)
- C_{shrimp} : Measured concentration of contaminants in pink shrimp (mg/kg shrimp)

This daily consumption limits in kilograms was converted to meal consumption limits over a given time period (month) as a function of meal size:

$$CR_{mm} = CR_{lim} \times AT/IR_{shrimp}$$

where,

- CR_{mm} : Maximum allowable shrimp consumption rate (meals/month)
- CR_{lim} : Maximum allowable shrimp consumption rate (kg/d)
- AT : Average time (30 days/month)
- IR_{shrimp} : Per capita intake rate of shrimp (kg shrimp/meal)

RESULTS AND DISCUSSION

The weight of shrimp ranged from 5.30 to 8.20 g. The concentration of Pb in the cephalothorax ranged from 0.78-1.95 mg/kg with a mean and SD of 1.34+/-0.43 and for the abdomen 0.41-0.98 with mean of 0.66+/-0.20. Cd concentration in the cephalothorax ranged from 0.16-0.28 mg/kg with a mean of 0.22+/-0.04 and 0.06-0.30 with mean of 0.12+/-0.09 in the abdomen. The WHO permissible limits for these metals is 0.1 µg/g for Cd and 0.2 µg/g for Pb. The concentrations were all higher than the permissible limit.

In Fig. 1, Pb concentrations were higher in the abdomen and the cephalothorax than the Cd concentrations and these were significant at $p = 0.0001$ and $p = 7.98\times10^{-5}$. The concentrations of Cd and Pb were higher in the cephalothorax than in the abdomen. These were significantly different at $p = 0.006$ ($F = 12.22$) for Pb and $p = 0.023$ ($F = 7.19$) for Cd. The higher concentrations in the cephalothorax is because the gills, hepato-pancreas and the antennal glands are the most vulnerable of the organ systems to the toxic effects of contaminations (Bryan, 1979) and these are located in the head region of the shrimp. This is because:

- The gills are one of the entry points for harmful substances.
- The hepatopancreas serves as the main organ for absorption, storage and secretion and could be damaged when toxicants are stored in it while.
- The antennal gland is where excretion takes place making it even more vulnerable.

The lead and cadmium levels in pink shrimp bought in Creek Road market are significantly high, local fishermen and their families are exposed to lead and cadmium through ingestion of pink shrimp. Based on this finding, it was necessary to assess the risk of non-carcinogenic health effects from lead and cadmium that the target group is exposed to. The population group of concern is adult subsistence fishermen and their families who regularly eat shrimp caught from the creek. The primary exposure pathway is ingestion of shrimp. The basic demographic parameters' values were selected from Exposure Factor Handbook (USEPA 1997), assuming all the groups eat 1 meal/day and 3 meals of shrimp every week.

A hazard quotient is the ratio of a single contaminant exposure level over a specified time period to a reference dose for that contaminant derived from a similar exposure period. It indicates hazard or risk from exposure to that substance. This was estimated for Cd with a reference dose of 1×10^{-3}. A sensitivity analysis for each subgroup was done, meaning that the range of Average Daily Dose (ADD) and the range of Hazard Quotients for each specified subgroup based on the 95% CI of mean cadmium in the shrimp bought from Creek Road market was calculated.

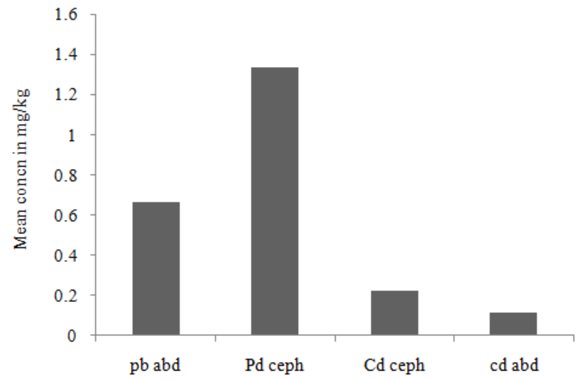

Fig. 1: Mean concentration of Cd in the cephalothorax and abdomen of *P. notialis*

The values for the different age groups are presented in Table 1.

By calculation, the hazard quotients for all subgroups ranged from 1.6-3.39 with the highest hazard quotient for children of less than 5 years. This also means all the subgroups are at great risk of non-carcinogenic health effects by ingestion of shrimp bought from Creek Road market as all HQ values were greater than 1. For each group, the range of hazard quotients are based on the 95% confidence interval of measured Cd concentrations in shrimp from Creek Road market. Even with the lowest observed concentration in the range, all the hazards were still significant. Expressed as the maximum allowable fish consumption limits, as in Table 2 the children below 5 years old are at risk from eating more than 34 meals of 0.113 kg of shrimp from the Creek Road market per month. For women of childbearing age, it is not advisable that they eat more than 71 times of the shrimp meal of 0.227 kg/month. These consumption limits allows for one meal a day for children and up to two meals a day for the older members of the fisherman's family.

Cadmium is a highly toxic non-essential heavy metal and it does not have a role in biological processes in living organisms. Thus even in low concentration, cadmium could be harmful to living organisms (Burden *et al*., 1998). Agricultural activities are likely to add important amounts of Cd to the natural levels. Fertilizers are important sources of Cd based agrochemicals which are widely used in intensive agriculture (Alloway, 1990).

Cadmium is bio-accumulative, that means it is persistent and increase with time since it is non-biodegradable. Cadmium wastes washed into aquatic bodies accumulate in aquatic biomass; they are concentrated and pass up to the food chain. Cadmium is

Table 1: Estimated average daily dose and hazard quotient of Cd in abdomen of *P. notialis*

The ADD and risk for each subgroup	ADD (range, mg/kg-day)	RfD (mg/kg-day)	Hazard quotients (range)
1-5 year	3.28×10^{-3} - 3.39×10^{-3}	10^{-3}	3.28 - 3.39
6-11 year	1.86×10^{-3} - 1.92×10^{-3}	10^{-3}	1.86 - 1.92
12-18	2.33×10^{-3} - 2.41×10^{-3}	10^{-3}	2.33 - 2.41
19-24	2.03×10^{-3} - 2.11×10^{-3}	10^{-3}	2.03 - 2.11
Women of childbearing age	1.75×10^{-3} - 1.81×10^{-3}	10^{-3}	1.75 - 1.81
Adults	1.60×10^{-3} - 1.65×10^{-3}	10^{-3}	1.60 - 1.65

Table 2: Monthly fish consumption limits for non-carcinogenic health endpoints (Cd)

Study group	Fish meals/month (risk-based consumption limit)	Shrimp tissue concentrations (upper 95% CI of mean Cd level) (mg/kg, wet weight)
1-5 year	33.5	0.119
6-11 year	67	0.119
12-18 year	53	0.119
19- 24 year	61	0.119
Women of childbearing age	71	0.119
Adults	78	0.119

toxic even if absorption by ingestion is low, chronic exposure to high levels of cadmium in food has caused bone disorders, including osteoporosis and osteomalacia. Long-term ingestion, by a Japanese population, of water and food contaminated with Cd was associated with a crippling condition, (itai-itai) (ouch-ouch) disease. The affliction is characterized by pain in the back and joints, osteomalacia (adult rickets), bone fractures and occasional renal failure and most often affects women with multiple risk factors such as multiparity and poor nutrition. Other consequences of Cd exposure are: anemia, yellow discoloration of the teeth, rhinitis, occasional ulceration of the nasal septum, damage to the olfactory nerve and anosmia (Gustav, 1994; McKinney and Rogers, 1992; Nweodozie, 1998; Ademoroti, 1996; Elson and Haas, 2003).

Based on the findings of this study, one would advise the use of these shrimp for consumption be within the calculated monthly allowance to reduce the risk of chronic contamination. In other words, the metals will pose health hazard to the communities around the river once these limits are exceeded since they depend on these shrimps as a source of protein in their soups.

The concentration of the metals in the shrimp indicates a polluted environment and this is of interest. The source of contamination should be established in further studies so that the hazard can be eliminated.

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