Chapter

Assessment of Metal Accumulation and Bioaccumulation Factor of Some Trace and Heavy Metals in Freshwater Prawn and Crab

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Abstract

Globally, freshwater decapods have been one of the major food delicacies because of their rich deposits of minerals. High metals are usually accumulated in the body tissues of these organisms because of their lifestyle. Metal accumulation in freshwater decapods has been acclaimed and perceived to cause serious health concerns when transferred to humans along the food chain. A recent study has shown that freshwater biota, prawn (Macrobrachium rosenbergii), showed significant differences (p < 0.05) in Mn, Cu, Pb and Cr and no significant difference (p > 0.05) in Fe, Zn and Cd. In contrast, the freshwater biota, crab (Sudanonautes africanus), showed significant differences (p < 0.05) in Fe, Zn and Mn and no significant differences (p > 0.05) in Pb, Cr and Cd. A high accumulation of Fe in the whole tissues of Macrobrachium rosenbergii and Sudanonautes africanus was also established. This is because Fe in the Nigerian soil and sediment is naturally very high beyond slated thresholds and tend to accumulate and transcend or magnify in benthic. It was noticed that Zn (2.68) and Cr (4.52) had the highest bioaccumulation factors in prawn and crab, respectively. Chromium has been observed to be carcinogenic. The consumption of Cr in the muscles of crab might constitute probable serious health risk.

Keywords: accumulation, biomagnification, decapods, risk, carcinogenicity

1. Introduction

Globally, freshwater decapods have been one of the major food delicacies because of their rich deposits of minerals, metals; calcium (Ca), iron (Fe), zinc (Zn) and copper (Cu), Nickel (Ni), Vanadium (V) and Cadmium (Cd) as well as nutrients; protein, fibers and cellulose. High levels of mineral contents like metals are usually accumulated in the body tissues of these organisms because of their lifestyle. This has necessitated the increased rate of human consumption in recent times [1].
It has been documented that freshwater crab (*Sudanonautes africanus*) and prawn (*Macrobrachium rosenbergii*) have high deposits of Fe, Zn and Mn, with few traces of Cu, Pb, Cr, Cd, Ni and V [1–4].

Metal accumulation in freshwater decapods has been acclaimed and perceived to cause serious health concerns when transferred to humans along the food chain. Environmental valuation of the noxiousness of metals in the freshwater *Sudanonautes africanus* and *Macrobrachium rosenbergii* had been shown to have probable human health hazard effect concomitant by way of ingestion [1].

Health risks associated with heavy metals such as renal failure, skeletal deformation, and hepatic failure have been linked to their non-decomposable and persistence nature in the visceral organ-parts of humans [5]. This can lead to severe maladies like dysentery, stomach aches, head-tremor, anemia, paralysis, nausea, paroxysm, melancholy and even respiratory disorders [6], which can be either acute or chronic forms; neuron toxicity, oncogenic, genetic alteration or teratogenicity [7].

High levels of bio-accumulated heavy metals in freshwater decapods have been identified in these ranks; Fe > Zn > Mn > Cu > Pb > Cr [1] as interconnected with their sediment background levels [8].

2. Methodology

2.1 Sampling technique

Samples of freshwater prawns and crabs (*Macrobrachium rosenbergii* and *Sudanonautes africanus*) were captured and collected monthly from March 2015 to August 2016 at designated stations by some fishermen, using local-hand nets enticed with ox-heart, set at the river bank of each station 24 hours before capturing. The prawns and crabs were collected and kept in different labeled plastic rubbers according to the stations, filled with the river water and immediately taken to the laboratory for heavy metal analysis and identifications.

2.2 Extraction and determination of heavy metals in freshwater decapods

Employing the methods of [1], the freshwater biota was oven dried at 105°C. About 2 g of a dried up standardized sample of each tissue were digested and sample was made up to about 50 ml of purified water. Samples of the biota were analyzed for iron, manganese, zinc, copper, chromium, cadmium, nickel, lead, and vanadium with an AAS (atomic absorption spectrophotometer; SOLAAR 969AA UNICAM, Spectronic Unicam, Cambridge, UK) [1].

2.3 Data analysis

Simple descriptive analysis, ANOVA (Analysis of variance), was employed using SPSS version 20.0.

To determine the accumulation rate of heavy metals in the freshwater biota, the bio-indices; bioaccumulation factor was employed with Micro Excel version 2013. Bioaccumulation factor (BAF) is the concentration of metals in sediment or water over the concentration of metals in the biota in mg kg\(^{-1}\) [8]. This can be represented in the equation below:

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BAF = \frac{\text{concentration of metals in sediment/water (mg/kg)}}{\text{concentration of metals in Crab/prawn (mg/kg)}}
\]
3. Assessment of metal contents in freshwater decapods

The assessment of metal contents in freshwater decapods is suitable for both water and terrestrial life forms. This is based on their significance as water indicators of pollutants via monitoring in spatial or temporal, in order to quantify their ecological role in the ecosystem. Even though the dangers of water pollution by metals are fully acknowledged, it is still a subject of discussing in line with the over increasing anthropogenic activities [9] and as well as the lithogenic activities [1].

Freshwater prawn and shrimp (Macroinvertebrates) are commonly recommended as fauna-indicators for evaluating the fluctuation of aquatic disorders in the region of probable pollution [3]. In general, decapods are of certain prominence for bio-monitoring survey [10], as the bedrock species in most aquatic systems [11], as well as the most tolerated species against water pollution. This shows their pollution status as regards to the buildup of the corresponding components of metals in their muscles [12].

3.1 Accumulation of metals in *Sudanonautes africanus* and *Macrobrachium rosenbergii*

Metal contamination in freshwater ecosystem is of utmost worry everywhere in the biosphere [13–15]. This might be as a result of their persistence noxious special effects and accumulation features in the aquatic system and fauna respectively [16–22].

Metals go in into freshwater ecosystem via lithogenic and human activities [18, 22–24]. Benthic region is a key sink and a basis for metal pollution [25]. Built-up substances such as metals can be a sign of macrobenthic fauna-accumulation severity, ill health or death as the case may arise [24]. Certain residential chemicals in the sediment can exterminate benthic macroinvertebrates, thus plummeting the food chain structure [26].

However, a recent study has shown that freshwater biota; prawn (*Macrobrachium rosenbergii*) showed significant differences (p < 0.05) in Mn, Cu, Pb and Cr and no significant difference (p > 0.05) in Fe, Zn and Cd. No observable p-values were noticed for Ni and V respectively (Table 1). In contrast, the freshwater biota; crab (*Sudanonautes africanus*) showed significant differences (p < 0.05) in Fe, Zn and Mn and no significant difference (p > 0.05) was observed in Pb, Cr and Cd. There was also no observed p-values in Ni and V (Table 2) [28]. It was noticed that the ranks of heavy metals and their spatial variability in the shrimps and crabs were Fe > Zn > Cu > Pb = Cd > Cr = Ni = V and Fe > Zn > Mn > Cu > Pb > Cr = Cd > Ni = V respectively.

3.2 Bioaccumulation

The food chain structure has served as a pointer where metals are streamed along. Freshwater ecosystem pollution by metals, especially the heavy ones is on the increase daily around the world, causing several problems globally. Consequent of the buildup effect of certain heavy metals, particularly via the food chain, their bio-availability needs to be examined. This can be done via investigation of metal contents in biota in order to gather and predict its bioavailability and subsequent accumulation in the organism(s).

Generally, freshwater decapods freely accumulate metals in their muscles in order to meet their basic metabolic needs. This makes them appropriate as bio-indicators of metals in the ecosystem. For example, freshwater *Sudanonautes africanus* and *Macrobrachium rosenbergii* accumulate high levels of Fe, Zn and Mn in their muscles [28] based on the facts that these metals play vital role in the respiratory pigment.
| Parameters | Units | Station 1 | Station 2 | Station 3 | Station 4 | p-values | Significant | [27] limits |
|-----------|-------|----------|----------|----------|----------|----------|-------------|-------------|
| Fe        | mg kg\(^{-1}\) | 120.99 ± 43.95 | 150.45 ± 71.66 | 148.48 ± 86.88 | 119.16 ± 49.36 | 0.25 | p > 0.05 | 100 |
| Zn        | mg kg\(^{-1}\) | 45.82 ± 22.46 | 52.13 ± 23.26 | 57.79 ± 21.14 | 53.06 ± 18.55 | 0.32 | p > 0.05 | 100 |
| Mn        | mg kg\(^{-1}\) | 1.61 ± 1.41 | 1.94 ± 1.16 | 2.08 ± 1.68 | 1.13 ± 0.46 | 0.04 | p < 0.05 | 1.0 |
| Cu        | mg kg\(^{-1}\) | 0.39 ± 0.32 | 0.73 ± 0.48 | 0.72 ± 0.57 | 0.66 ± 0.32 | 0.04 | p < 0.05 | 30 |
| Pb        | mg kg\(^{-1}\) | 0.01 ± 0.01 | 0.02 ± 0.02 | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.02 | p < 0.05 | 0.5 |
| Cr        | mg kg\(^{-1}\) | 0.00 ± 0.00 | 0.01 ± 0.02 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.05 | p < 0.05 | NS |
| Cd        | mg kg\(^{-1}\) | 0.01 ± 0.02 | 0.02 ± 0.02 | 0.02 ± 0.02 | 0.01 ± 0.01 | 0.62 | p > 0.05 | 0.5 |
| Ni        | mg kg\(^{-1}\) | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 | — | NS |
| V         | mg kg\(^{-1}\) | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 | — | NS |

Most of the parameters were measured in mg/kg; p < 0.05, significant difference; p > 0.05, no significant difference. NS, not specified; FAO, Food and Agriculture Organization; WHO, World Health Organization.

Table 1. Summary of the accumulation of heavy metals in prawns from Ossimo River collected from designated stations from March 2015 to August 2016.
| Parameters | Units | Station 1 | Station 2 | Station 3 | Station 4 | p-values | Significance | [27] limits |
|-----------|-------|-----------|-----------|-----------|-----------|----------|-------------|------------|
|           |       | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD |          |             |            |
| Fe        | mg kg⁻¹ | 154.55 ± 41.40 | 203.42 ± 76.29 | 167.86 ± 118.00 | 170.28 ± 113.14 | 0.02     | p < 0.05    | 100        |
| Zn        | mg kg⁻¹ | 66.59 ± 21.15 | 92.99 ± 31.40 | 66.80 ± 51.76 | 69.73 ± 50.92 | 0.02     | p < 0.05    | 100        |
| Mn        | mg kg⁻¹ | 1.98 ± 1.60 | 3.68 ± 2.59 | 3.31 ± 2.95 | 3.57 ± 3.11 | 0.02     | p < 0.05    | 1.0        |
| Cu        | mg kg⁻¹ | 0.64 ± 0.27 | 1.13 ± 0.74 | 0.88 ± 0.78 | 0.95 ± 0.81 | 0.03     | p < 0.05    | 30         |
| Pb        | mg kg⁻¹ | 0.01 ± 0.02 | 0.03 ± 0.04 | 0.03 ± 0.04 | 0.04 ± 0.04 | 0.19     | p > 0.05    | 0.5        |
| Cr        | mg kg⁻¹ | 0.01 ± 0.01 | 0.02 ± 0.02 | 0.02 ± 0.02 | 0.02 ± 0.03 | 0.34     | p > 0.05    | NS         |
| Cd        | mg kg⁻¹ | 0.00 ± 0.01 | 0.02 ± 0.03 | 0.02 ± 0.03 | 0.02 ± 0.03 | 0.23     | p > 0.05    | 0.5        |
| Ni        | mg kg⁻¹ | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00     | —           | NS         |
| V         | mg kg⁻¹ | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00     | —           | NS         |

Most of the parameters were measured in mg/kg; p < 0.05, significant difference; p > 0.05, no significant difference. NS, not specified; FAO, Food and Agriculture Organization; WHO, World Health Organization.

Table 2.
Summary of the accumulation of heavy metals in crab from Ossorno River collected from designated stations from March 2015 to August 2016.
hemocyanin [29] and metalloenzymes [30] respectively. An appreciable increase in the values of Mn in the whole tissue of freshwater decapods has been associated with a combination of factors such as co-factor [1, 30–32]. More so, high concentration of iron in the sediment and decapods can possibly be related to its presence in cytochromes and proteins [28, 32].

A high accumulation of Fe in the whole tissues of Macrobachium rosenbergii and Sudanonauetes africanus has been established by [28]. This is because Fe in the Nigerian soil and sediment is naturally very high beyond slated thresholds and tends to accumulate and transcend or magnify in benthic macroinvertebrates [24, 33–35].

Freshwater fauna are well known to be discriminatory in metal accumulation [36]. Antón et al. and Hopkin [37, 38], stated that decapods regulate their net assimilation of metals, which need about 0.07 mg kg\(^{-1}\) of Zn and 0.08 mg kg\(^{-1}\) of Cu to trigger the enzymes and respiratory proteins. The high levels of heavy metals in aquatic biotas are of particular interest because of the potential risk to humans who consume them [1, 36]. The effects of metals in the surroundings, rest on to a great magnitude on whether they exist in forms that can be assimilated by plants or animals [36]. Some freshwater decapods are bottom feeders and are generally expected to concentrate more metals than surface feeders like shrimp. The accumulation of metals in their muscles may be either dosage or time-reliant. This may therefore be contemplative of the amount of metals in the ecosystem [37–41].

### 3.3 Bioaccumulation factor: designated trace and heavy metals and impact in freshwater Macrobachium rosenbergii and Sudanonauetes africanus

Table 3 shows the computed bioaccumulation factor for the different trace and heavy metals in the whole body tissue of freshwater prawn and crab. It was observed that the concentration of the BAFs of heavy metals of prawn as compared with that of crab was distinct with varied increase in values greater than 1 (BAFs > 1) Fe (2.68) in prawn and Fe, Zn, Mn, Cu, Pb and Cr (1.30, 1.45, 1.77, 1.41, 1.81, and 4.52) in crab as related to their sediment concentrations. It was noticed that Cr had the highest value of accumulation in crab.

| Trace and heavy metal in mgkg\(^{-1}\) | Mean Trace and heavy metal in Sediment | Mean Trace and heavy metal in Shrimps | Mean Trace and heavy metal in Crabs | BAF in Shrimps | BAF in Crabs |
|--------------------------------------|--------------------------------------|-------------------------------------|-------------------------------------|----------------|----------------|
| Fe                                   | 249.11                               | 134.77                              | 175.27                              | 0.54           | 1.30           |
| Zn                                   | 19.46                                | 52.20                               | 75.46                               | 2.68           | 1.45           |
| Mn                                   | 36.53                                | 1.69                                | 2.99                                | 0.05           | 1.77           |
| Cu                                   | 8.07                                 | 0.63                                | 0.88                                | 0.08           | 1.41           |
| Pb                                   | 3.48                                 | 0.01                                | 0.02                                | 0.00           | 1.81           |
| Cr                                   | 4.05                                 | 0.00                                | 0.01                                | 0.00           | 4.52           |
| Cd                                   | 3.93                                 | 0.01                                | 0.01                                | 0.00           | 1.06           |
| Ni                                   | 1.98                                 | 0.00                                | 0.00                                | 0.00           | 0.00           |
| V                                    | 1.72                                 | 0.00                                | 0.00                                | 0.00           | 0.00           |

NB: Values in red; means BAF > 1, an indication of increase level beyond threshold. Black bolded values; means BAF < 1, an indication of safe limit.

**Table 3.** Results of bioaccumulation factors (BAFs) of trace and heavy metals in freshwater prawn (Macrobachium rosenbergii) and crab (Sudanonauetes africanus) in Ossimo River.
3.3.1 Iron (Fe)

Iron, is the richest element in the Earth’s crust [42]. The two oxidation states of Fe; ferrous (Fe$^{2+}$), and ferric (Fe$^{3+}$) account for their Fenton chemical reactions in aquatic fauna via combination with their macromolecules (proteins, nucleic acids, lipids and carbohydrates) [43]. On the other hand, ferric iron is virtually insoluble in aqueous solution and can bioaccumulate in freshwater fauna (decapods) in their tissues [44] and even biomagnified along the food chain thereby impeding the health status of humans.

Iron is very vital to quite a lot of life processes; manufacturing of DNA, the respiratory electron transport chain, as well as oxygen storage and transport. However, level of Fe beyond the threshold in fauna muscles can result to conjunctivitis, choroids, and retinitis [45] pneumoconiosis, called siderosis [46] and the risk of pulmonary cancer when ingested or inhaled by humans [43].

3.3.2 Zinc (Zn)

Zinc is one of the essential trace metals in nature. Aquatic fauna depends on it for their survival. Zinc is made up of about 200 metalloenzymes and other metabolic components guaranteeing permanency of the DNA and its assemblies; nuclear membranes, nucleolus and protein structures (ribosomes) [41]. Excessive consumption of Zn can result to a diverse compulsive health impact on humans [47].

The composition of zinc found in the tissue of decapods has been investigated to be intrinsically high which will possibly biomagnify in tissues at much higher levels [48–52]. Possible impact of Zn toxicity in freshwater decapods is in the gills, and abdominal muscle which has been confirmed in juvenile of decapods [53, 54]. This might be basically linked to the comparatively greater and more pervious body nature of the juveniles [41].

3.3.3 Manganese (Mn)

This is a crucial trace metal which can be seriously noxious upon persistent contact through ingestion above threshold limits. The basic dietary requirements of Mn are fulfilled through food intake [55–57], but with little noxious effects from air and water. This is a great concern to individuals who will consume freshwater of Macrobrachium rosenbergii and Sudanonautes africanus with elevated amounts of Mn accumulated in them.

Possible conditions linked to Mn toxicity are schizophrenia, dreariness, weak brute force, head tremor and sleeplessness [58, 59]. Chronic impacts of Mn are hepatopancreas, lung, liver and vascular instabilities, deteriorations in body fluid pressure, failure in growth of fauna fetuses and brain impairment.

3.3.4 Copper (Cu)

Like manganese, copper is found naturally in the surroundings and also crucial for normal growth and metabolic rate of all fauna [60] especially the aquatic ones. Copper contributes immensely to the cellular metalloprotein-hemocyanin in freshwater decapods [49, 61]. However, fairly low copper contents are found in the muscles of freshwater Sudanonautes africanus and Macrobrachium rosenbergii [28].

Freshwater Sudanonautes africanus and Macrobrachium rosenbergii cannot be compared to their counterpart; crayfish, which is very valuable for evaluating bioavailability of Cu in water environments [62, 63].
3.3.5 Lead (Pb)

This element is neither crucial nor valuable to aquatic fauna and causes series of health conditions in the biota [40, 60] and subsequently probable risk impact to man via the food chain [1]. Pb can be introduced into a freshwater ecosystem via lithogenic form; re-suspension of the bottom sediment by benthic dwellers [1, 24] or via anthropogenic inputs; fertilizers and pesticides.

The amount of lead accumulated in freshwater Sudanonautes africanus and Macrobrachium rosenbergii has been investigated to be fairly below the benchmark limits of [27]. Previous studies have stated that the amount of Pb found in muscles of decapods were also in line of the benchmark limit [54, 64–67]. Contrary, [68] observed a high concentration (0.15 mg l⁻¹) of Pb in the gonads of the freshwater crab, Potamonautes perlatus.

At low concentrations, Pb may result to a variety of health effects, including behavioral problems and learning disabilities [58]. Lead affects the central and peripheral nervous systems, eventually causing neurological and behavioral disorders in patients [69]. Lead has been found to be carcinogenic and also a probable enzyme stimulating effect [70], which interferes with fertility and causes renal damage.

3.3.6 Chromium (Cr)

This is a crucial element that has high noxious level [71]. Chromium has been found to be very high in the muscles of certain decapods [41, 54–67, 72]. However, study on freshwater Sudanonautes africanus and Macrobrachium rosenbergii revealed fairly low amount of Cr in their whole tissue [28].

3.3.7 Cadmium (Cd)

This is not an essential element and has high potential for teratogenicity, cancer-causing, and high latency for kidney toxicity at the chronic stage if ingested via food [72, 73].

Bioaccumulation of residue Cd in aquatic ecosystems and decapods whole tissue have been described to have a positive relationship consequent on the biota closeness to point source [9, 74–78].

3.3.8 Nickel (Ni) and vanadium (V)

Nickel and vanadium are universal elements recognized for their noxiousness, persistence, and likeness for bio-accumulation [60]. However, they were below detectable limits (BDL) in Sudanonautes africanus and Macrobrachium rosenbergii in this study [28]. This might be as a result of the geo-formation of the ecosystem and lack of the use of Ni and V related materials around the study terrain.

4. Conclusions

The assessment of metal accumulation and bioaccumulation factor of some trace and heavy metals in freshwater prawn and crab (Sudanonautes africanus and Macrobrachium rosenbergii) have shown that the metal accumulation were in this ranks: Fe > Zn > Cu > Pb = Cd > Cr = Ni = V and Fe > Zn > Mn > Cu > Pb > Cr = Cd > Ni = V. The BAFs values obtained were observed to be greater than 1 (BAFs > 1) for Fe (2.68) in prawn and also for Fe, Zn, Mn, Cu, Pb and Cr (1.30, 1.45, 1.77, 1.41, 1.81, and 4.52) in crab as related to their sediment concentrations. It was noticed
that Zn and Cr had the highest bioaccumulation factors in prawn and crab respectively. Chromium has been observed to be carcinogenic. Consumption of Cr in the muscles of crab might constitute probable serious health risk.

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Conflict of interest

We declare no conflict of interest.

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