Evaluation of heavy metals concentration in some mollusc species and human health risk in selected communities of Bakor sub-tribe, Ogoja, Nigeria

Chris A. Diminyi
Department of Hospitality and Tourism Management,
University of Calabar, Nigeria. gagadiminyi@gmail.com

Abstract
The assessment of certain metals in the tissues of gastropods sourced from selected communities in Ogoja local government area was conducted between August and October 2024. Selected heavy metals, including As, Pb, Hg, Cd, Ni, and Zn, were analyzed using an Atomic Absorption Spectrophotometer. The analysis of heavy metal concentrations in *A. marginata* indicated that Zinc levels were the highest throughout the period. Similarly, *V. contectus* also exhibited the highest Zinc levels, with measurements of 3.1840 ± 0.24936 mg/kg in August and 3.3540 ± 0.24327 mg/kg in October. Statistical analysis demonstrated a significant difference ($P < 0.05$) between Zn and Ni compared to other metals across the species. The observed trend in mean heavy metal concentrations for *A. marginata* over the months was Zn > Ni > Cd > Pb > Hg > As. In contrast, *V. contectus* exhibited a different trend, with mean concentrations of Zn > Ni > Cd > Pb > As > Hg. It was also observed that the concentration of heavy metals in the aquatic snail *V. contectus* surpassed that of the land snail *A. marginata*. Consumers of gastropods, particularly *A. marginata* and *V. contectus* in Ogoja, should be informed through public awareness campaigns about the risks associated with consuming contaminated food due to the ongoing and indiscriminate disposal of waste in both aquatic and terrestrial environments.

Keywords: *Archachatina marginata*, *Viviparus contectus,* Lead (Pb), mercury (Hg), cadmium (Cd), zinc (Zn).

Introduction
Heavy metals are high-density chemical elements with minimal concentration of toxicity but are persistent in environmental contamination. They include Zinc, Lead, Nickel, and Mercury among other elements which are essential in maintaining body metabolism, but are toxic at higher concentrations. They get into the environment naturally or by human activities and become harmful to human health as their concentration form poisonous soluble compounds (Chen, Cai, Cao, Liu, Liang, Hu, Yin, Li, Shi, 2022). Heavy metals are enduring environmental pollutants, originating from natural processes and human activities. Certain heavy metals can become toxic due to the formation of harmful soluble compounds. Elevated levels of these metals pose significant risks, as they disrupt ecosystems through bioaccumulation in living organisms, leading to toxic effects and potentially resulting in mortality among various species (Bat, Oztekın, Arıcı, & Sahın 2021; Mowang, Ndome, Naku, Ayim, Elvis & Ayame, 2017). Heavy metals can infiltrate water sources through industrial and consumer waste, as well as from acidic rain that leaches metals into streams, lakes, rivers, and groundwater (Mowang et al., 2017).

Gastropods are a significant taxonomic class within the phylum Mollusca, representing the most diverse group with an estimated 60,000 to 80,000 species of snails and slugs currently living. They inhabit various environments, including terrestrial, marine, and freshwater ecosystems, and can vary in size from microscopic forms to larger specimens. Among these, marine gastropods constitute the largest species group found in the shallow seas (Nour, Ramadan, Shammari, Tawfik 2022), although only a few are considered suitable for human consumption. Common edible species such as Giant land snail (*Archchatina marginata*) and Lister's river snail (*Viviparus contectus*) can be found in forest and swampy areas in Ogoja. These organisms are primarily sedentary and sessile filter-feeders, displaying a wide geographical distribution that renders them vulnerable to changes in their environmental conditions. Mungla, Facknath, and Lalljee (2022) indicate that gastropods exhibit a heightened vulnerability to the accumulation of heavy metals, primarily through dietary intake and environmental absorption, which can sometimes result in health risks for consumers. Research shows that gastropods can accumulate heavy metals in their tissues at levels significantly exceeding those found in their surrounding environment Mungla et al., 2022).

Snails primarily derive nutrients from herbs and vegetables, which inherently tend to absorb toxic substances, including heavy metals, that can be transferred through the food chain. The primary sources of heavy metals in herbs, vegetables, and crops are their growth media—such as soil, air, and nutrient solutions—through which these metals are absorbed by the roots or leaves (Singh and Gupta 2021). Consequently, snails that feed on these plants accumulate heavy metals in their bodies. Also, mud, humus, sand particles, and sediments are often contaminated with various hazardous substances, including heavy metals. Heavy metals are recognized as persistent environmental pollutants, raising significant public concern due to their long-lasting presence in the environment and their potential to bioaccumulate through the food chain (Eniola and Folake 2020). The acceptable tolerable weekly intake of mercury is established at 5µg/kg of body weight, corresponding to 300µg of mercury per week for an individual weighing 60kg (Edet and Edet, 2014). The European Commission has established a limit of 0.2 ppm or 2mg/kg for canned fish (EC, 2002), while the permissible limit for cadmium in shellfish is set at 2mg/kg. Although Copper, Zinc, and Iron are essential cellular components for organisms, they can become toxic under certain conditions and at elevated concentrations. (Rahman, Islam, Moniruzzaman, Sultana & Begum 2024, Osuna-Mascaro, Cruz-Bustos, Marie, Checa and Marin, 2016).

Extensive research on mollusks (Pund and Kurhe, 2023; Çulha, Karaduman, & Çulha, 2022; Ak, Cankiriligil, Türker, & Sever, 2021; Petruzzelli, Pedron, Rosellini, 2020) highlights not only their remarkable ability to bioaccumulate both organic and inorganic pollutants but also their prevalence in coastal ecosystems. It has been estimated that over 90% of human exposure to various contaminants occurs through dietary sources, primarily seafood and meat (Ndome, Mowang, Okorafor, & Etiese 2014). The utilization of gastropods as bioindicators for heavy metal contamination has been extensively documented, owing to their ecological and biological traits that facilitate effective monitoring. Molluscan shells offer several advantages for monitoring metal pollution in marine environments compared to soft tissues (Bitlis, 2019; Swaleh, Ruwa, Wainaina, Ojwang, Shikuku and Maghanga, 2016). Shells are easier to store and manage, and they demonstrate sensitivity to environmental heavy metals over extended periods. As shell growth is incremental, they can indicate contamination over specific timeframes, unlike soft tissues, which tend to accumulate metals and reflect chemical exposure throughout the organism's lifespan. Although previous research has established a link between heavy metal concentrations in organisms and their surrounding sediment and water, but there is no research on heavy metal concentrations in edible gastropods, specifically *Archachatina marginata* and *Viviparus contectus*, and their health risk in Ogoja. This gap in knowledge serves as the primary impetus for the present study, which aims to assess the concentration and health risks associated with heavy metals such as Arsenic (As), Lead (Pb), Mercury (Hg), Cadmium (Cd), Nickel (Ni), and Zinc (Zn) in these species, thereby ensuring food safety for selected communities in the Ogoja Local Government Area of Cross River State, Nigeria.

Empirical review

Sami, Ibrahim, and Mohammad (2020) carried out a study to assess how size classes influence the removal of heavy metals (Cu, Fe, Pb, Co, Ni, and Zn) in certain commercial bivalves, specifically *Ruditapes decussatus*, *Venerupis pullastra*, and *Paphia undulata*. The researchers identified negative correlations between the sizes of the examined species and the levels of all heavy metals, with the exception of Cu, which exhibited a positive correlation with size in *V. pullastra.* The concentrations of heavy metals (Cu, Fe, Pb, Co, and Zn) in the bivalves were found to be greater than those present in the surrounding water and sediment. Notably, the highest depuration rates for all species were observed in the smaller size classes of clams.

Çulha, Karaduman, and Çulha (2022) conducted a study on the accumulation of heavy metals in molluscs associated with *Cystoseira barbata* in the Black Sea region of Türkiye. Their research focused on the levels of heavy metal accumulation in various mollusc species linked to this macroalga. The study analyzed the accumulation of ten heavy metals (Cd, Cu, Zn, Ni, As, Pb, Sn, Mn, Fe, Se) in five mollusc species: *Mytilus galloprovincialis*, *Tricolia pullus pullus*, *Bittium reticulatum*, *Tritia neritea*, and *Rissoa splendida*, as well as in *Cystoseira barbata*. The determination of heavy metal concentrations was performed using Inductively Coupled Plasma – Mass Spectrometry (ICP-MS). The order of heavy metal accumulation in the species was found to be Fe > Ni > Mn > Zn > As > Cu > Cd > Se > Pb > Sn. The level of arsenic accumulation in C. barbata was evaluated against the quality standards for edible algae sold in France. Concentrations of Cd, Ni, As, and Zn in various mollusc species exceeded both national and international safety limits. Additionally, the total metal accumulation for each species was assessed using the Metal Pollution Index (MPI), with the ranking as follows: *C. barbata* > *B. reticulatum* > *R. splendida* > *T. neritea* > *T. pullus pullus* > *M. galloprovincialis*, indicating that *C. barbata* exhibited the highest metal accumulation. The significant levels of metal pollution detected in the study area suggest that the aquatic environment is contaminated from multiple sources.

Farrell, Baker, Webster, Jansson, Szabo, and Zammit (2018) conducted an evaluation of potential heavy metal contaminants in bivalve shellfish sourced from aquaculture zones along the New South Wales coast in Australia. Their findings indicated that the levels of inorganic arsenic, cadmium, lead, and mercury were low and remained within the maximum limits set by the Australia New Zealand Food Standards Code. Since there are no established maximum limits for copper, selenium, and zinc, the researchers referred to accepted international dietary guidelines for comparison. The dietary exposure assessments for these elements revealed that the shellfish from the studied aquaculture areas do not pose a food safety risk. However, ongoing monitoring is crucial due to the increasing pressures on Australia's coastal resources.

Vukašinović-Pešić, Blagojević, Vukanović, Savić, & Pešić (2017) conducted a study on the concentrations of heavy metals in various tissues of the freshwater snail Viviparus mamillatus (Küster, 1852) sourced from both lacustrine and riverine habitats in Montenegro. The primary aim of their research was to examine the distribution of heavy metals, specifically Cd, Cu, Pb, Fe, and Zn, within the different tissues of *V. mamillatus*. The study found significant variations in the concentrations of all analyzed metals across the snail's tissues, with the exception of lead (Pb). Correlation analysis indicated that the head with tentacles could serve as effective biomonitoring agents for cadmium (Cd), zinc (Zn), and iron (Fe), while the mantle was suitable for monitoring Cd and Zn, and the foot was indicative of environmental Fe levels. Additionally, the findings suggested that the accumulation of metals in *V. mamillatus* could negatively influence its growth rate, as significant negative correlations were observed between Pb, Cd, Cu, and Zn levels in various tissues and allometric parameters. These results underscore the potential of *V. mamillatus* as a bioindicator for monitoring environmental conditions.

Tanhan, Lansubsakul, Phaochoosak, Sirinupong, Yeesin, and Imsilp (2022) conducted a study on the seasonal bioaccumulation of nine heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and

Zn) in 14 seafood species of commercial significance, which included four fish, five molluscs, and five crustaceans. Samples were gathered from Pattani Bay in Pattani province, Thailand, during the dry season in July 2020 and the wet season in February 2021. The edible samples underwent analysis for heavy metal concentrations utilizing a flame atomic absorption spectrophotometer. The findings indicated that the bioaccumulation of heavy metals followed a decreasing trend in the order of molluscs > crustaceans > fish. An assessment of potential human health risks linked to the consumption of heavy metal-contaminated seafood was performed. The study evaluated non-carcinogenic and carcinogenic risks using parameters such as the target hazard quotient (THQ), total hazard index (HI), and target cancer risk (TR). The average ranges recorded for THQs (7.79×10^{-8}–8.97×10^{-3}), HIs (4.30×10^{-5}–1.55×10^{-2}), and TRs (2.70×10^{-9}–1.34×10^{-5}) were noted among the seafood species examined. The results indicated that there were no significant non-carcinogenic or carcinogenic health risks associated with the consumption of these 14 seafood types.

Edet and Edet (2014) examined the concentrations of heavy metals, including mercury (Hg), lead (Pb), cadmium (Cd), iron (Fe), copper (Cu), and zinc (Zn), across four species of gastropods in Itu River. Their findings indicated that Hg and Pb were undetectable (<0.0001 ppm) in both periods and across all species. While Zn, Fe, Cu, and Cd were present in all species, their levels remained below the maximum permissible limits set by international standards, confirming that all four seafood types are safe for consumption. Ibrahim and El-Regal (2014) investigated the correlation between size and heavy metal concentration, finding that the largest gastropod specimens (measuring 65-70 mm) exhibited the highest levels of heavy metals, including Cr, Cu, Fe, Pb, and Zn. Cubadda et al. (2011) identified a positive relationship between the size of limpets and snails and their heavy metal concentrations, indicating that larger individuals tend to accumulate more heavy metals.

Zheng, Wang, Zhang, Zheng, and Zheng (2008) examined the bioaccumulation of total methylmercury in arthropods. In this research, it was found that the total mercury concentrations in the tissues of *Locusta migratoria manilensis* and *Acrida chinensis* ranged from 0.013 to 0.154 mg/kg and 0.009 to 0.138 mg/kg, respectively. The levels of methylmercury in these species were recorded at 0.001 to 0.012 mg/kg for *Locusta migratoria manilensis* and 0.001 to 0.006 mg/kg for *Acrida chinensis*. Notably, the total mercury concentrations in these primary consumers were lower than those found in their food sources, while the secondary consumer, *Paratenodera sinensis*, exhibited higher mercury accumulation. For *Locusta migratoria manilensis*, total mercury levels showed an inverse relationship with body length, whereas *Acrida chinensis* displayed an initial increase followed by a decrease in total mercury concentrations as body length increased. In terms of methylmercury, concentrations were directly proportional to body length for both species. Additionally, total mercury levels varied across different body segments of the arthropods, following the order: abdomen > thorax > head.

Methodology

Description of study area

The study was conducted in Ogoja Local Government Area of Cross River State, Nigeria. between latitude 6^0 30' N and longitude 8^0 40' E (Fig.1).

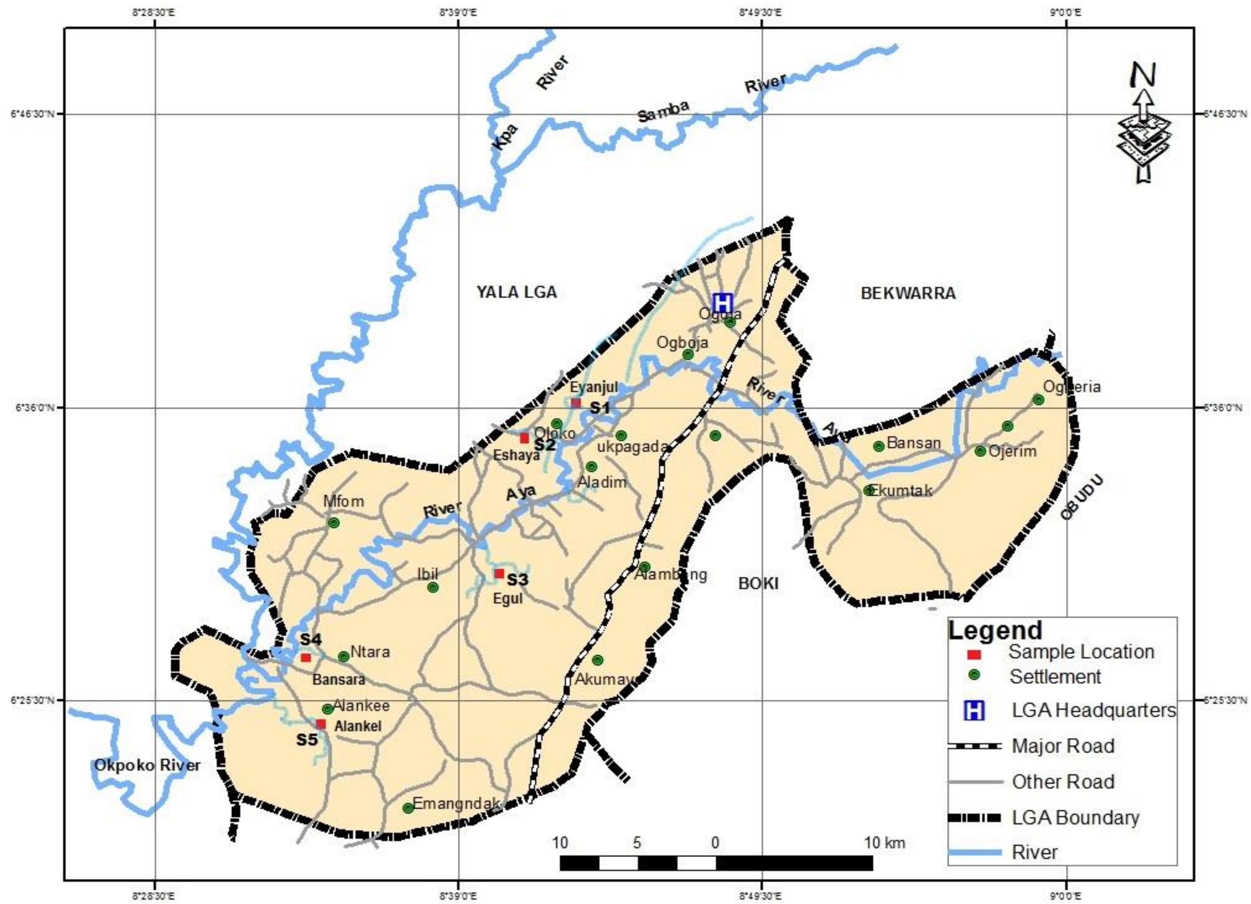


Fig.1: Map of Ogoja showing the study area.

Samples collection

Samples of *Archachatina marginata* and v*iviparus contectus* was purchased from local farmers at Eyanjul, Oloko, Egul, Bansara, and Alankel communities in Ekajuk clan. These communities were chosen because they produce and consume these species of gastropods in large quantity. The periwinkle samples were measured in cups while the snail samples were in heaps of different sizes.

Preservation and transportation of samples to the laboratory

The different samples were put separately in pre-cleaned polyethylene containers and stored in a cooler containing ice blocks to prevent changes in chemical composition of the gastropods and then transported to the laboratory for analysis.

Preparation of gastropod samples for heavy metal analysis

Fifteen (15) fresh specimens each of *Archchatina marginata* and *Viviparus contectus* were selected according to the taxonomic criteria established by Bouchet and Pocroi (2005). The samples underwent a thorough cleaning process using fresh water to eliminate any debris attached to the gastropods, and soft tissue was carefully removed from the shells using a pin. Subsequently, the tissues were dried in an oven at 90°C and grounded into a fine powder with a clean, dry mortar and pestle. The powdered samples were then passed through a 2mm sieve and dried again in the oven to achieve a fine ash-like consistency before being allowed to cool. For each sample, 5g was measured, moistened with a few drops of distilled water, and treated with 10ml of HCl. The resulting mixtures were filtered into a cylinder and diluted to a final volume of 20 ml with distilled water. The digested samples were subsequently analyzed for heavy metal content using an Atomic Absorption Spectrophotometer (AAS).

Statistical analysis

Data obtained was subjected to descriptive statistics. The values computed and recorded as mean standard deviation and presented in tables and charts. Also, data obtained was subjected to analysis of variance for test of significance at 0.05 probability level.

Results

Variations in the levels of heavy metals in tissues of Gastropods in the months of August – October, 2019.

Variations in the levels of heavy metals in tissues of A. marginata in the month of August.

In August, the following concentrations of heavy metals were observed: Arsenic (As) had a mean and standard deviation of 0.000 ± 0.000 mg/kg. Lead (Pb) levels varied from 0 to 0.02 mg/kg, with a mean of 0.004 ± 0.0089 mg/kg. Mercury (Hg) was found in a range from 0.0 to 0.01 mg/kg, yielding a mean and standard deviation of 0.020 ± 0.0045 mg/kg. Additionally, Cadmium (Cd) levels ranged from 0.011 to 0.022 mg/kg, with a mean of 0.0170 ± 0.0055 mg/kg. Nickel (Ni) concentrations varied between 0.22 and 0.56 mg/kg, resulting in a mean of 0.464 ± 0.1433 mg/kg. Lastly, Zinc (Zn) levels ranged from 2.05 mg/kg to 3.64 mg/kg, with a mean and standard deviation of 2.6480 ± 0.4431 mg/kg, as illustrated in Fig. 2.

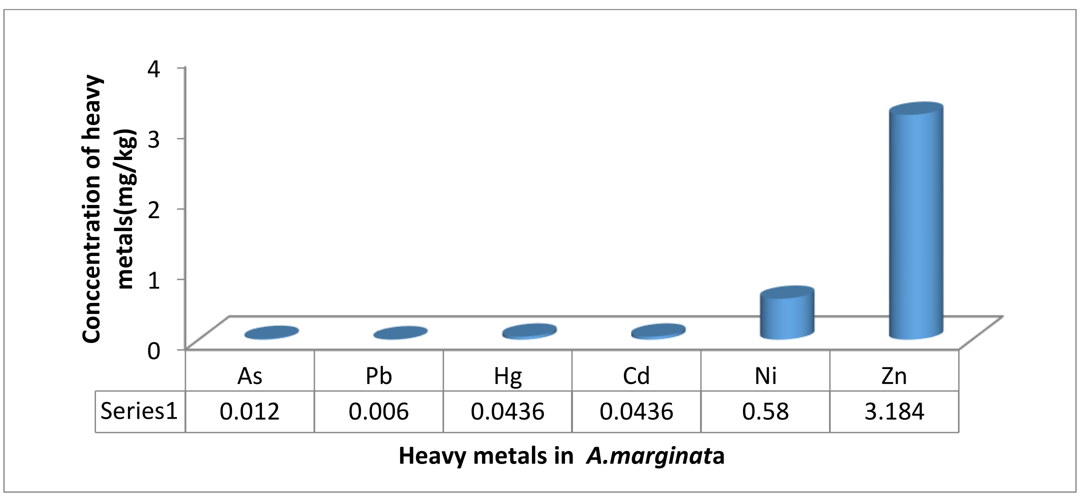


Fig.2: Levels of heavy metals in tissues of *A. marginata* in August.

Variations in the levels of heavy metals in tissues of A. marginata in the month of September.

In September, the mean and standard deviation for Arsenic (As), Lead (Pb), and Mercury (Hg) were both recorded at zero (0) mg/kg. Cadmium levels varied between 0.022 and 0.041 mg/kg, with a mean of 0.0296 and a standard deviation of 0.000744 mg/kg. Nickel concentrations ranged from 0.30 to 0.74 mg/kg, yielding a mean of 0.4480 and a standard deviation of 0.2596 mg/kg. Zinc (Zn) levels were observed between 2.66 and 4.00 mg/kg, with a mean of 3.1820 and a standard deviation of 0.49631 mg/kg, as illustrated in Fig. 3.

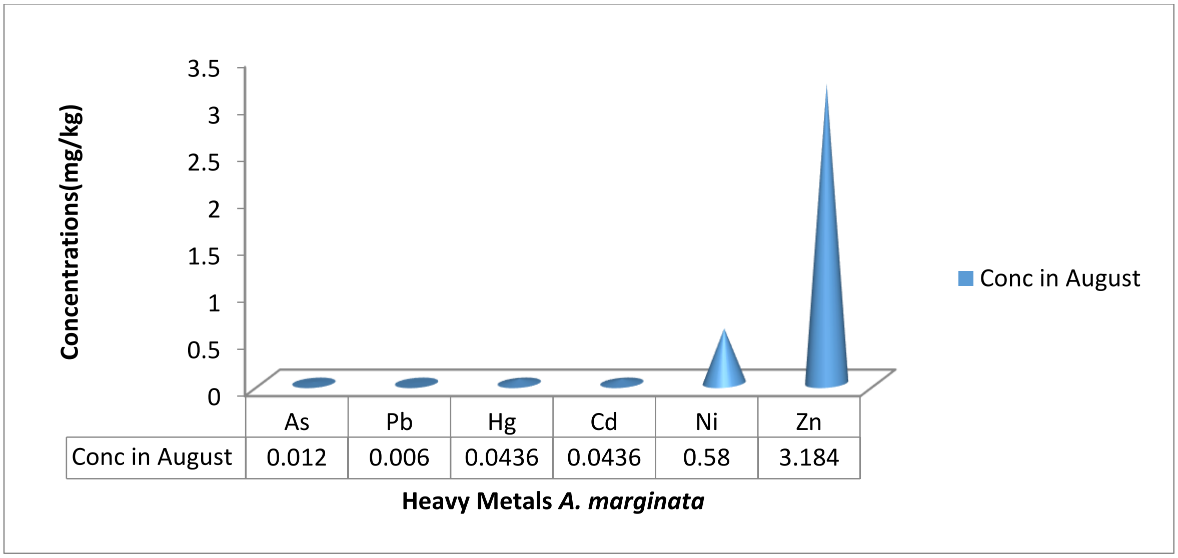


Fig.3: Levels of heavy metals in tissues of *A. marginata* in September.

Variations in the levels of heavy metals in tissues of A. marginata in the month of October

In October, the analysis of Arsenic (As) showed a mean and standard deviation of 0.000 ± 0.000 mg/kg. Lead (Pb) levels varied from 0 to 0.01 mg/kg, with a mean and standard deviation of 0.004 ± 0.006 mg/kg. Mercury (Hg) was recorded at zero (0), with a mean and standard deviation of 0.00 ± 0.00 mg/kg. Similarly, Cadmium (Cd), Nickel (Ni), and Zinc (Zn) exhibited the following results: Cadmium levels ranged from 0.012 to 0.024 mg/kg, with a mean and standard deviation of 0.026 ± 0.0104 mg/kg; Nickel levels varied between 0.10 and 0.81 mg/kg, with a mean and standard deviation of 0.514 ± 0.2654 mg/kg; and Zinc levels ranged from 2.46 mg/kg to 3.26 mg/kg, with a mean and standard deviation of 2.942 ± 0.2928 mg/kg, respectively (see Fig. 4).

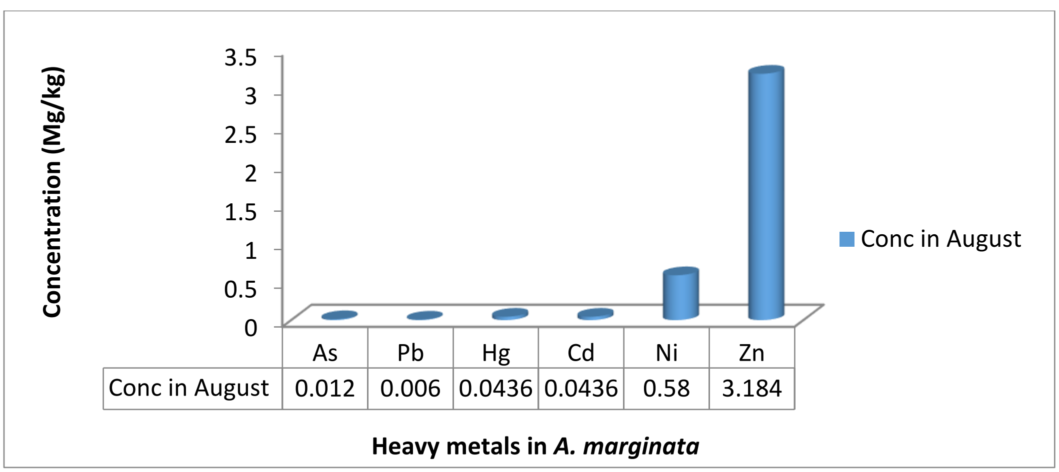
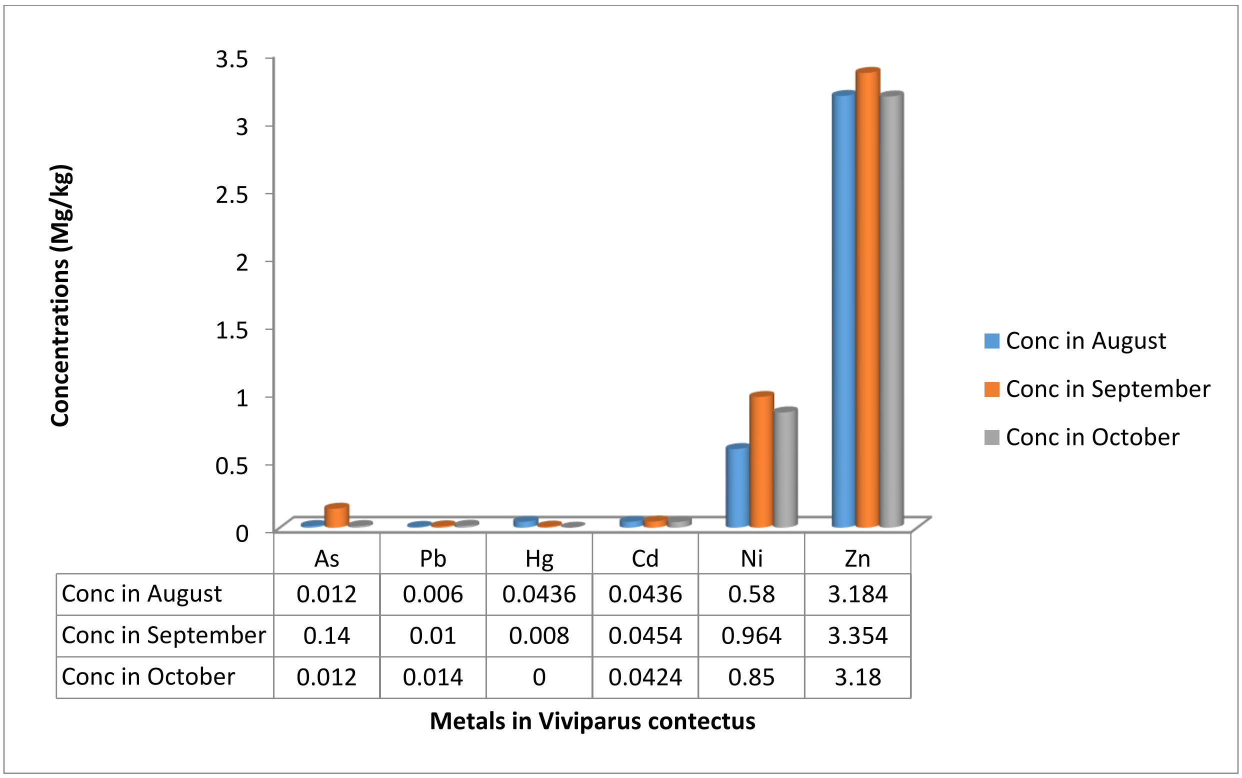


Fig.4: Levels of heavy metals in tissues of *A. marginata* in October.

Variations in the levels of Heavymetals in tissues of A. marginata in the month of August to October.

In August, Arsenic (As) exhibited a concentration range of 0.1 to 0.02 mg/kg, with a mean of 0.012 ± 0.005 mg/kg. Lead (Pb) showed a range from 0.01 to 0.03 mg/kg, resulting in a mean of 0.006 ± 0.0055 mg/kg. Conversely, Mercury (Hg) was recorded between 0.0 and 0.1 mg/kg, with a mean deviation of 0.0436 ± 0.00913 mg/kg. Additionally, Cadmium (Cd), Nickel (Ni), and Zinc (Zn) had ranges of 0.030 to 0.53 mg/kg, 0.20 to 0.85 mg/kg, and 2.81 to 3.33 mg/kg, respectively, with means and standard deviations of 0.0436 ± 0.00913 mg/kg, 0.5800 ± 0.23622 mg/kg, and 3.1840 ± 0.24936 mg/kg, as illustrated in Fig 4. In September, Arsenic (As) recorded a range of 0.01 to 0.03 mg/kg, with a mean deviation of 0.140 ± 0.0114 mg/kg. Lead and Mercury were observed within the ranges of 0.0 to 0.02 mg/kg, with mean deviations of 0.010 ± 0.010 mg/kg and 0.0080 ± 0.00837 mg/kg, respectively. Furthermore, Cadmium, Nickel, and Zinc showed ranges of 0.034 to 0.061 mg/kg, 0.75 to 1.46 mg/kg, and 3.09 to 3.66 mg/kg, respectively, as depicted in Fig 4. In October, Arsenic (As), Lead (Pb), and Mercury (Hg) were recorded within the ranges of 0.01 to 0.03 mg/kg, 0.01 to 0.03 mg/kg, and 0 mg/kg, respectively. The mean and standard deviations for these were 0.0120 ± 0.01095 mg/kg, 0.014 ± 0.1140 mg/kg, and 0.0 ± 0.0 mg/kg, respectively. Cadmium (Cd), Nickel (Ni), and Zinc (Zn) exhibited concentration values ranging from 0.030 to 0.076 mg/kg, 0.43 to 1.43 mg/kg, and 2.51 to 3.56 mg/kg, respectively, as illustrated in Fig. 5.



	As	Pb	Hg	Cd	Ni	Zn
Conc in August	0.012	0.006	0.0436	0.0436	0.58	3.184
Conc in September	0.14	0.01	0.008	0.0454	0.964	3.354
Conc in October	0.012	0.014	0	0.0424	0.85	3.18

Fig.5: Levels of heavy metals in tissues of *V. contectus* from August to October.

Discussion of result

Concentration of heavy metals in A. marginata from August to October, 2024.

Analysis of heavy metal concentrations in *A. marginata* from major markets in Ogoja between August and October 2023 indicates that Zinc levels were consistently the highest throughout this period. This elevated concentration of Zinc may be attributed to its essential functions within the body. Zinc is crucial for the proper functioning of the immune system and is involved in various biological processes, including cell division, growth, wound healing, and carbohydrate metabolism. Additionally, it is important for maintaining the senses of smell and taste. Adequate Zinc intake is particularly vital during pregnancy, infancy, and childhood for optimal growth and development. Furthermore, Zinc plays a significant role in enhancing insulin activity. The presence of free zinc ions in solution poses significant toxicity risks to bacteria, plants, invertebrates, and even vertebrate. Statistical analysis indicates a notable difference ($P < 0.05$) when comparing zinc to other metals, while no significant variation ($P > 0.05$) is observed across different months. The zinc concentration found in the tissues of A. marginata remained below the permissible limits set by the WHO. This finding aligns with the research conducted by Edet and Edet (2014), that mercury (Hg) and lead (Pb) were not present (<0.0001 ppm) in either of the study periods or the species analyzed. Lead is known to accumulate in the body and can adversely impact the nervous system, kidneys, and reproductive health. Zinc (Zn), iron (Fe), copper (Cu), and cadmium (Cd) were found in all species, but their concentrations remained below the maximum allowable limits set by international standards. Sediments serve as sensitive indicators for tracking contaminants in aquatic ecosystems (Sami et al., 2020). These ecosystems are often contaminated with various hazardous and toxic substances, including heavy metals

Nickel levels were found to be lower than those of Zinc, yet still exceeded the levels of Cadmium. Statistical analysis indicated a significant difference ($P<0.05$) between Nickel and the other metals examined. However, no significant variation ($P>0.05$) in Nickel levels was observed across different months. While the body requires Nickel, it is only in trace amounts. The Nickel concentration in the tissues of *A. marginata* was below the permissible limits set by the WHO. Nickel is a prevalent trace element found in various multivitamins and is utilized to enhance iron absorption, combat iron deficiency anemia, and support bone health in cases of osteoporosis. This aligns with the findings of Tanhan et al. (2022), who documented heavy metal concentrations in mollusks from the southern Atlantic coast of Spain. Their study revealed that the concentrations of Cr, Cu, Pb, Zn, As, and Hg in *D. trunculus* were significantly higher ($p < 0.05$) compared to *C. gallina*; however, *C. gallina* exhibited higher levels of Ni and Cd. The observed Nickel concentration in this study may be influenced by variations in human activities in the respective areas.

Arsenic (As) was consistently undetected throughout the months of the study. Recognized as one of the ten chemicals of significant public health concern by the World Health Organization, arsenic is linked to the onset of various health issues, including diabetes, cancer, vascular diseases, and lung diseases. The Food and Drug Administration has indicated that prolonged exposure to elevated arsenic levels correlates with increased incidences of skin, bladder, and lung cancers, as well as heart disease. During the period of our investigation, this heavy metal was not found in the tissues of *A. marginata*. More so, lead and mercury were not detected in September and October, indicating no significant differences ($P>0.05$) between the months. A minor concentration of mercury was observed in August, but it remained below the permissible limit set by WHO for mercury in biological tissues.

Concentration of heavy metals in Viviparus contectus from August to October, 2024.

Analysis of heavy metal concentrations in *V. contectus* from various communities within the period indicates that Zinc levels were consistently the highest throughout these months. This elevated concentration of Zinc may be attributed to its essential functions within the body. Zinc is crucial for the proper functioning of the immune system and is involved in processes such as cell division, growth, wound healing, and carbohydrate metabolism. Additionally, it is important for maintaining the senses of smell and taste. Adequate Zinc intake is particularly critical during pregnancy, infancy, and childhood for proper growth and development. Furthermore, Zinc enhances insulin activity. However, it is important to note that free zinc ions in solution can be highly toxic to various organisms, including bacteria, plants, invertebrates, and even vertebrate fish (Rout et al., 2003). The statistical analysis indicates a notable difference ($P < 0.05$) between Zinc and other metals, while no significant variation ($P > 0.05$) was observed across different months. The concentration of Zinc in the tissues of *V. contectus* was found to be below the permissible limits set by WHO. This finding aligns with the study conducted by Edet and Edet (2014), were they found out that that Hg and Pb were not detected (<0.0001 ppm) in either of the study periods or species analyzed. Zn, Fe, Cu, and Cd were present in all species but remained below the maximum allowable limits established by international guidelines. Sediments serve as sensitive indicators for tracking contaminants in aquatic ecosystems. These ecosystems are reported to be contaminated with various hazardous and toxic substances, including heavy metals (Bat et al. 2021; Mowan et al., 2017).

Nickel levels were found to be lower than those of Zinc, yet still exceeded the concentrations of Cadmium, Mercury, Lead, and Arsenic. Statistical analysis indicated a significant difference ($P<0.05$) between Nickel and the other metals examined. However, no significant variation ($P>0.05$) in Nickel levels was observed across different months. The human body requires Nickel, albeit in minimal quantities. The Nickel concentration in the tissues of *V. contectus* was below the permissible limits set by the WHO. Nickel is a prevalent trace element found in various multivitamins and is utilized to enhance iron absorption, combat iron deficiency anemia, and support bone health in cases of osteoporosis. This finding aligns with the work of Usero et al. (2005) and Sami et al. (2020) where they revealed that the concentrations of Cr, Cu, Pb, Zn, As, and Hg in *D. trunculus* were significantly higher ($p < 0.05$) compared to *C. gallina*; however, *C. gallina* exhibited higher levels of Ni and Cd. The observed Nickel concentration in this study may be influenced by variations in human activities in the respective regions.

Arsenic (As) was identified over several months, raising significant concerns due to its classification as one of the ten chemicals of major public health concern by the World Health Organization. This heavy metal is linked to the potential development of serious health issues, including diabetes, cancer, vascular diseases, and lung diseases. The Food and Drug Administration has indicated that prolonged exposure to elevated arsenic levels correlates with increased incidences of skin, bladder, and lung cancers, as well as heart disease. The presence of arsenic in *T. fuscatus* suggests that freshwater benthic organisms tend to bioaccumulate heavy metals more than terrestrial gastropods, Ibrahim and El-Regal (2014). Bat et al. 2021) noted that gastropods are particularly vulnerable to heavy metal accumulation through dietary intake and environmental absorption, which can pose health risks to consumers. It is well-documented that gastropods can accumulate heavy metals in their tissues at concentrations significantly higher than those found in their surrounding environment.

Lead and mercury were detected from August to October, but no significant differences were observed between the months ($P > 0.05$). However, there was a statistically significant difference in the levels of lead and mercury ($P < 0.05$). The concentrations of mercury and lead found in the tissues of organisms were below the permissible limits set by the WHO. One method to assess the environmental impact of mercury emissions in the Pantanal is through the study of bioaccumulation. In this context, total mercury levels were measured in 188 gastropods from three distinct species across seven sampling locations during both dry and wet seasons. The increase in mercury concentrations among the snails was primarily observed in the gold mining region and nearby sedimentation zones. The highest mercury levels were recorded at the Tanque dos Padres site, with *Pomacea scalaris* individuals exhibiting concentrations of 2.04 µg g-1. In contrast, mollusks collected from the Araras/Piuval Bay complex, identified as a mercury retention area, displayed significant mercury levels, reaching up to 1.12 µg g-1.

Conclusion

The assessment of certain metals in the tissues of gastropods within the Ogoja local government area was conducted from August to October 2024. Selected heavy metals, including arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), nickel (Ni), and zinc (Zn), were analyzed using an Atomic Absorption Spectrophotometer. The results indicated that the mean concentrations of Zn, Ni, and Cd in the gastropod samples were significantly elevated, yet remained within the acceptable limits set by the World Health Organization for food safety. Conversely, the mean concentrations of As, Pb, and Hg were found to be low, which raises concerns regarding their potential impact. These findings suggest that anthropogenic activities may be contributing to the presence of these metals in the ecosystem of Cross River State. Prolonged accumulation of these substances could lead to bioaccumulation and increased bio-concentration of heavy metals in the benthic organisms of the ecosystem. Such accumulation poses a risk to the ecosystem and aquatic life in the river, with the potential to enter the food chain if not addressed. The findings from this study support the notion that heavy metals can accumulate in the tissues of living organisms, indicating that these tissues can serve as indicators of heavy metal pollution in both terrestrial and aquatic environments. The average concentrations of heavy metals in *A. marginata* over the months were observed in the following order: Zn > Ni > Cd > Pb > Hg > As. In contrast, the average concentrations in *V. contectus* were ranked as follows: Zn > Ni > Cd > Pb > As > Hg. Notably, the concentration of heavy metals in the aquatic snail (*V. contectus*) was higher than that found in the land snail (*A. marginata*).

References

Ak, I., Cankiriligil, E. C., Türker, G., & Sever, O. (2021). Assessment of light intensity and salinity regimes on the element levels of brown macroalgae, Treptacantha barbata: Application of response surface methodology (RSM). *Food Science and Technology*, 41(4), 944-952.

Bat, L., Oztekın, A., Arıcı, E., & Sahın, F. (2021). Mytilus galloprovincialis and metal contaminants: health risk assessment from Sinop coasts. *The Korean Journal of Food & Health Convergence*, 7(4), 13-21.

Bitlis, B. (2019). Mollusk fauna associated with (Stockhouse) *C. Agardh*, 1820 in the Sea of Marmara (Turkey). *Oceanological and Hydrobiological Studies*, 48(2), 174-183.

Chen, L., Cai, X., Cao, M., Liu, H., Liang, Y., Hu, L., Yin, Y., Li, Y., & Shi, J. (2022). Long-term investigation of heavy metal variations in mollusks along the Chinese Bohai Sea. *Ecotoxicology and Environmental Safety,* 236 (2022), 1-9

Cubadda, F., Conti, M. E. and Campanella, L. (2011). Size dependent concentrations of trace metals in four Mediterranean gastropods. *Chemophere*, 45:561-559.

Çulha, S. T., Karaduman, F. R., & Çulha, M. (2022). Heavy metal accumulation in molluscs associated with Cystoseira barbata in the Black Sea (Türkiye). *Sustainable Aquatic Research*, 1(3), 76-89.

Çulha, S. T., Karaduman, F. R., & Çulha, M. (2022). Heavy metal accumulation in molluscs associated with Cystoseira barbata in the Black Sea. *Sustainable Aquatic Research*, 1(3), 183-200.

Edet, U. O. and Edet, B. O. (2014). Heavy metal contamination profile of four selected sea foods Harvested in Cross River in the Niger Delta Region of Nigeria, *International Journal of Innovation and Applied Studies* 8 (4), 1831-1835.

Eniola, E. B., and Folake, O. Z. (2020). Proximate analysis and heavy metals in molluscs, tympanotonus Fuscatus (linnaeus, 1758) and pachymelina aurita (müller, 1774) from the Riparian area of Lagos lagoon, South - western Nigeria. *Applied tropical agriculture,* 25(1), 169 – 177.

Farrell, H., Baker, P., Webster, G., Jansson, E., Szabo, E., & Zammit, A. (2018). An Assessment of Potential Heavy Metal Contaminants in Bivalve Shellfish from Aquaculture Zones along the Coast of New South Wales, Australia. *Food Protection Trends*, 38, (1), 18–26.

Farrell, H., Baker, P., Webster, G., Jansson, E., Szabo, E., & Zammit, A. (2018). An Assessment of Potential Heavy Metal Contaminants in Bivalve Shellfish from Aquaculture Zones along the Coast of New South Wales, Australia. *Food Protection Trends*, 38(1),18–26

Ibrahim, N. K. and El-Regal, A. M. (2014). Heavy metals accumulation in marine edible mollusks, Timsah Lake, Suez Canal, Egypt, ARPN *Journal of Science Technology*, 4:282-288.

Mowang, A.D., Ndome, C. B., Naku, J. B., Ayim, Elvis, M. E., Ayame, G. M. (2017). Concentrations of Heavy Metals In Fresh Cow Milk (Nunu) And Nigeria Dwarf Goat Milk In Ogoja, Nigeria. *International Journal of Innovative Research and Advanced Studies*. 4(10):54-58.

Osuna-Mascaro, A., Cruz-Bustos, T., Marie, B., Checa, A. G., & Marin, F. (2016). Heavy metals in mollusk shell: a quick method for their detection. *Key engineering materials*, 672, 340-345

Petruzzelli, G., Pedron, F., & Rosellini, I. (2020). Bioavailability and bioaccessibility in soil: a short review and a case study. *AIMS Environmental Science*, 7(2): 208-225.

Pund, A., & Kurhe, A. (2023). A review on heavy metals impact and marine molluscs. *International journal of multidisciplinary research and growth evaluation*, 4(3), 535-538.

Rahman, M. M., Islam, S., Moniruzzaman, M., Sultana, N., & Begum, M. (2024). Assessment of molluscan diversity and their responses to heavy metal deposition in a river ecosystem of Bangladesh. *Journal of Entomology and Zoology Studies*, 12(3), 54-61.

Sami, M., Ibrahim, N. K., & Mohammad, D. A. (2020). Impact of the size of commercial bivalves on bioaccumulation and depuration of heavy metals. *Egyptian Journal of Aquatic Biology & Fisheries,* 24(7), 553 – 573.

Singh, P. P., and Gupta, S. M. (2021). Molluscs as biomonitors of heavy metal pollution: a review. *Journal of advanced scientific research*, 12 (2), 35-42

Swaleh, M. M., Ruwa, R., Wainaina, M. N., Ojwang, L. M., Shikuku, S. L., & Maghanga, J. K. (2016). Heavy Metals Bioaccumulation in Edible Marine Bivalve Mollusks of Tudor Creek Mombasa Kenya. *Journal of Environmental Science, Toxicology and Food Technology,* 10(8), 43-52.

Tanhan P, Lansubsakul N, Phaochoosak N, Sirinupong P, Yeesin P, Imsilp K. Human Health Risk Assessment of Heavy Metal Concentration in Seafood Collected from Pattani Bay, Thailand. *Toxics*, 11(1),18. doi: 10.3390/toxics11010018.

Vukašinović-Pešić, V., Blagojević, N., Vukanović, S., Savić, A., & Pešić, V. (2017). Heavy Metal Concentrations in Different Tissues of the Snail Viviparus mamillatus (Küster, 1852) from Lacustrine and Riverine Environments in Montenegro. *Turkish Journal of Fisheries and Aquatic Sciences*, 17: 557-563.

Zheng, D. M; Wang Q. C; Zhang Z.S; Zheng N; Zheng X. W (2008). Bioaccumulation of total and methylmercury by Arthropods. *Bulletin of Environmental contamination and Toxicology.* 81(1) :95-100.