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Study of Heavy Metal Bioaccumulation in Commonly Consumed Prawns of Genus *Penaeus* and the Associated Human Health Risks

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ABSTRACT

Heavy metals are inherent in the aquatic environment, arising through natural processes as well as through human actions such as mining, industrial practices, unscientific use of fertilisers, discharge of municipal sewage sludge, etc. Aquatic organisms can be subjected to contamination with heavy metals occurring in both surface water and sediments of their respective ecosystems Metals such as Copper, Zinc, Lead, Cadmium can affect human beings and aquatic organisms, as they can find their way through the food chain and are biomagnified from one trophic level to another. Shellfish have high commercial value as people cherish the shellfish almost throughout the world. The objective of this study is to monitor the metal concentrations present in the tissue of the muscle of the most preferred edible and commercially viable species of prawns namely, *Penaeus monodon* and *Penaeus indicus*, collected from the lower part of the Hooghly estuarine system. In the case of zinc, the concentration values found in the shellfish were mostly below the recommended level defined by WHO and FAO. The other heavy metals, i.e. Cu, Pb and Cd, showed mostly higher levels than that recommended. The value of Cu (up to 86.67 mg/kg) and Pb (up to 42.1 mg/kg) in the prawns exhibited higher concentrations. Heavy metals accumulated in the muscle tissue of prawns as Zinc > Copper > Lead > Cadmium in most of the cases. This study is crucial from the human wellbeing viewpoint and also represents how the aquatic bodies are contaminated by heavy metals which make their way to the most profitable and edible shellfish of the Hooghly estuarine system.

Keywords: *Heavy Metals; Muscle Tissue; Prawns; Shellfish*

Introduction

Heavy metals are inherent in the aquatic environment, arising through natural processes as well as through human actions such as mining, industrial practices, unscientific use of fertilisers, discharge of municipal sewage sludge, etc. Aquatic organisms can be subjected to contamination with heavy metals from their respective ecosystems (Hossain, Ahmed & Sarker, 2018).

India is a country of great rivers. The Ganga is one of the most significant rivers of India. In West Bengal, it is known as the Hooghly River, which after traversing a considerable distance finally reaches the Bay of Bengal. Many religious practices and anthropogenic activities take place at the banks of the river. Recently, there has been an increasing public health risk associated with the concentration of the heavy metals found in the environment. The lower part of the Hooghly estuary receives effluents from miscellaneous industries such as paper, pharmaceuticals, textiles, leather, jute, chemicals, etc. These factories or industries serve as the sources of metal pollution in the aquatic ecosystem (Mondal *et al.*, 2021). As these metals are concentrated in the shellfish bodies, assessment of heavy metal concentration is required to determine the health of the water body. Essential heavy metals such as Zinc and Copper are less harmful at lower concentrations. Cadmium and Lead are the non-essential metals which can be extremely toxic even at smaller concentrations.

Shellfish have high commercial value as people cherish the shellfish almost throughout the world. They act as a source of minerals, as well as proteins. The shellfish do not migrate often. Therefore, they can be a key indicator for identifying pollution (van Oosterom *et al.*, 2010). However, the shellfish's accumulation of heavy metals depends upon the category of metal and the kind of tissue of the shellfish. The objective of this study is to monitor the metal concentrations present in the tissue of the muscle of the most preferred edible and commercially viable species of prawns namely, *Penaeus monodon* and *Penaeus indicus*. The accumulation of the heavy metals under the study in the shellfish muscle has been explored considering the literature available and the work done by the author.

Methodology

Collection of Primary Data

Study Area

Sampling site namely, Diamond Harbour in the lower Gangetic delta, was selected (Figure 1) to collect the shellfishes (in this case, two species of *Penaeus*) inhabiting the zone.

Figure 1: Study Site Selected for Collection of Primary Data

The sampling site was in the vicinity of Hooghly estuary at 22º11´4.2´´N Latitude 88º11´22.2´´E Longitude. Diamond Harbour is a busy area nearer to the Haldia Port cum Industrial complex.

Collection of Secondary Data

This was obtained through a literature survey of almost the same aquatic system.

Collection of specimens

Two species of prawns namely *Penaeus monodon* and *Penaeus indicus* were collected randomly from the markets and fishermen. The samples were preserved in crushed ice. For further analysis, the samples were brought to the laboratory. Sorting of similarly sized specimens of each species was done for analysing the heavy metal content in the muscle tissue of prawns.

Evaluation of Heavy Metal Content

At first, dry ashing of the muscle tissues of prawns under study was done. Using a microwave digester, the dried samples were digested in nitric acid. Then it was transferred to a volumetric flask of 50 ml. Using demineralised water, the solution was made up to the marking line of the volumetric flask. It was then filtered using Whatman filter paper. For heavy metal analysis this filtrate was used as the sample solution. Measurement of the absorbance of the samples (Zn, Cu, Pb and Cd) was done by an atomic absorption spectrophotometer (Model Perkin Elmer Type 2380) and expressed as ppm (mg/kg dry wt. basis).

Results and Discussion

Description of the species under study:

Penaeus monodon, commonly known as the giant tiger prawn/ Asian tiger shrimp/ black tiger shrimp, is a marine crustacean that is widely reared for food.

Description

Morphological characteristics

Penaeus monodon are usually dark coloured with a transversely banded abdomen with black and white marks. Females are generally 25–30 cm long, while males are slightly smaller, 20–25 cm long. Pleopods are biramous (Figure 2).

Distribution

It is found in the Indo-Pacific region, coastal areas of Africa, Arabian Peninsula, Southeast Asia, the western Pacific Ocean and northern Australia.

Ecology

P. monodon can inhabit a multitude of environments. *P. monodon* burrow into the substrate during daytime and feed at night on molluscs, polychaetes, smaller crustaceans, and algae as well as detritus (Chimsung, 2014; Burford *et al*., 2020). However, on farms, the shrimps are also given a compound diet. The optimal temperature required for their growth is between 28nd 33°C and the salinity around 15-25 g/L (Shekhar *et al*., 2014).

Figure 2: Tiger Prawns -Penaeus Monodon Displayed in a Supermarket

Penaeus indicus

The Indian prawn (*Fenneropenaeus indicus*, formerly *Penaeus indicus*) is used for human consumption and is an important commercial species of marine fishery.

Description

Morphological characteristics

Body is yellowish white or greyish green with a body length of 23 cm (females) and 17 cm (males) with a smooth carapace. Rostrum is slender, long and slightly curved at the tip and bears teeth (Figure 3).

Distribution

Its natural distribution is in India, China, Malaysia, Indonesia, Thailand, Vietnam, Africa and northern Australia.

Ecology

They prefer sandy substrates at depths of 2–90 metres. They require high salinity, about 20–30 ppt. The lethal temperature is above 34°C (Pillay, 1990). They feed several times at night and search the bottom for food like algal mats, smaller crustaceans, slow-moving organisms, molluscs, etc.

Figure 3: Penaeus Indicus

The results of the heavy metal concentrations of the shellfish are shown in Table 1. The maximum recommended limits of heavy metals for human consumption as defined by WHO and FAO (World Health Organisation, 1976) for shellfish are 100, 30, 2, and 1 mg/kg for Zn, Cu, Pb and Cd, respectively. In the case of zinc, the concentration in all the samples analysed showed a lower value than the recommended level, as shown in table 1. The other heavy metals, i.e. Cu, Pb and Cd, showed mostly higher levels than that recommended. Cu (up to 86.67 mg/kg) and Pb (up to 42.1 mg/kg) in the prawns showed relatively higher concentrations, as summarised in table 1. Heavy metals cumulated in the muscle tissue of prawns as Zinc > Copper > Lead >Cadmium in most of the cases.

Table 1: Contamination Level of Heavy Metals in the Prawn Species-penaeus Monodon and Penaeus Indicus Collected From Different Localities of Lower Gangetic Delta (in mg/kg)

Species	Heavy metal concentration				Studied by	Locality
	Zn	Cu	Pb	Cd		
Penaeus monodon	99.8±2.30	71.18± 1.12	4.18± 0.38	2.3± 0.55	Present study	Diamond Harbour, lower Gangetic delta
Penaeus indicus	95.5±2.41	62.99±1.16	3.76±0.43	1.89± 0.62	Present study	Diamond Harbour, lower Gangetic delta
Penaeus monodon	7.3–4809.5	---	22.9–42.1	0.11– 3.2	Guhathakurta and Kaviraj, 2000	Sunderban mangrove system, India.
Penaeus monodon	78.88 ±1.22	59.18 ±1.13	9.18 ±0.68	--	Mitra and Zaman, 2012	Nayachar island, Hooghly estuary
Penaeus indicus	124.03±1.25	86.67±0.70	11.10±0.30		Bhattacharyya *et al*., 2013	Sagar South, Western sector of Indian Sunderbans.

The concentrations of Zn and Cu usually remain higher than the other trace elements or heavy metals because they are essential elements that are needed by the organisms for various metabolic actions. A study conducted by Biswas, Bandyopadhyay and Chatterjee (2013) in oysters regarding the concentrations of heavy metals showed that in the bodies of the shellfish, Zn, Cu or Fe may build up preferentially in comparison to the other heavy metals.

The higher concentration of zinc in the shrimps is probably related to the increased bioavailability of this element in the aquatic environment. Also, Zinc plays an enzymatic role as a regulator of several enzymes. According to do Amaral *et al*. (2005), due to the high affinity of zinc for metallothionein, it has a low excretion rate and tends to accumulate inside the body. Thus, its congregation is higher in all the tissues compared to the other metals. In the present study in the Diamond Harbour region of the Gangetic plain, the sources of Zn are the industrial units such as galvanising, paint factories and pharmaceuticals, originating from the Haldia industrial sector.

Although the crustaceans can excrete toxic elements (Simkiss & Taylor, 1995), the concentrations of Cu were greater than the threshold value of Cu in most of the studies indicated in table 1. In the study site, the major sources of Cu are the bottom paints designed for underwater surfaces in the different fishing vessels and trawlers. However, industrial discharges are also there in addition.

Pb is one of the extremely toxic heavy metals that has deleterious effects on human health even at a very low concentration. Pb may accumulate throughout the body in brain, liver, bones, kidneys and in due course may accumulate in teeth and bones also (Jaishankar *et al*., 2014). Pb navigates in the water body via the effluents of various factories of paints, oil distilleries, battery production units, etc. Lead-containing antifouling paints are used by the fishermen to prevent the growth of barnacles or other marine organisms at the bottom of the fishing boats and also trawlers. Leaching of toxic metals from these paints into the water is noxious to the aquatic organisms. Although Lead may also enter the water body from both land-based sources and the aerosphere.

Cadmium (Cd) is also very harmful if its level in man exceeds the permissible limit. Electroplating, Batteries, welding, etc., act as sources of cadmium (Roy *et al*., 2022). As these kinds of heavy metals are not biodegradable, they accumulate in the water, mainly settling at the undermost water, and form different complex compounds reacting with different organic and inorganic materials. Heavy metals or trace elements are not biodegradable and are snowballed in the human bodies, leading to undesirable effects such as slow maturation, renal disease, and carcinogenesis, and may be lethal also (Paul, 2017). Heavy metals exceeding threshold limits in the aquatic ecosystem are threatening to mankind and other aquatic organisms also.

Shellfish are one of the most competent hydrographic animals to accumulate heavy metals. This is because they live in the sediment or bottom of the water, operate very slowly, take their food by filtering water, and their food is detritus at the undermost portion of the aquatic body. So the possibility of these metals entering their bodies is enormous.

As per the study conducted by Tahity *et al.* (2022), concentrations of metals also vary between organs, which may be due to the different physiological functions of the different organs.

This study is crucial from the human wellbeing viewpoint and also represents how the aquatic bodies are contaminated by heavy metals which make their way to the most profitable and edible shellfish of the Gangetic delta. It is a cause of concern that food ingredients that contain heavy metals, even if in a small amount, if consumed continuously, will accumulate in the human body and tend to be harmful (Biswas *et al*., 2021; Siahaan, Silalahi & Lubis, 2022).

Conclusion

Biomonitoring of heavy metals in the muscle tissue of the shellfish can serve as an effective index of water body fouling. It may be noted that prawns or shrimps are commonly edible and very preferred seafood in India and also throughout the world. The prawns *P. monodon* and *P. indicus* are available almost everywhere in the markets. Most heavy metals were detected with a concentration tendency exceeding the recommended level. So proper planning to check these contaminations and monitoring of these edible species is highly needed. Such biomonitoring studies should be done regularly for the safe food supply to mankind.

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