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Assessing potential health risks of heavy metal contamination in common carp (*Cyprinus carpio*) and redbelly tilapia (*Coptodon zillii*) from the Shatt al-Arab River, Basrah, Iraq

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ABSTRACT

This study aimed to assess the concentrations of selected trace elements in the edible tissues of two fish species available in the Shatt al-Arab River in Basrah Province, southern Iraq. Common carp (*Cyprinus carpio*) and redbelly tilapia (*Coptodon zillii*) were purchased from a fisherman who sells fish daily on the Shatt al-Arab riverbank. Using an X-ray fluorescence spectrophotometer, the concentrations of Ba, Cu, Mo, Pb, Zn, Co, Cr, Ni, V, Sr, Zr, and Ce were determined. Ba, Cu, Mo, Pb, and Zr were not detected in any of the samples analyzed. Except for zinc, the levels of the remaining elements were higher than the permitted limits set by international standards; there were no significant differences ($p>0.05$) between the two fish species. The results suggest that consuming large quantities of these fish may pose health concerns for humans. In addition, this study provides useful information on the levels of some trace elements in the mentioned fish species, which can be used as a reference for future studies.

KEYWORDS: Trace elements, Fish tissues, Monitoring, X-ray fluorescence

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1. Introduction

More than three million people live in Basrah and depend on the Shatt al-Arab River for their freshwater needs including drinking water, domestic use, agricultural, industrial, health, and recreational activities. The river is also important for fishing and fish farming (Ahmed, 2022). However, a recent study by Mahdi et al., (2023) highlighted the degradation of the water quality in Shatt al-Arab due to the continuous discharge of industrial waste, oil effluents, and sewage from urban areas. Trace metals are a common pollutant in the aquatic environment and are considered a significant threat due to their toxicity and ability to bioaccumulate in the food chain (Ahmed et al., 2015; Wu et al., 2016). The freshwater quality deterioration ultimately affects economic activity and human welfare. The study of Yüksel et al., (2021) investigated the impact of a garbage disposal facility (GDF) near Çavuşlu Stream in Giresun, Turkey on the water quality and associated human health risks. An ICP-MS technique was used to quantify levels of toxic metals (As, Pb, Cd, Hg, Sb, Al, Ni) as well as essential elements (Se, Cu, Fe, Mg, Mn, Zn, Co) in water samples from four stations along the stream and tap water sourced from it. The results suggest the GDF is decreasing water quality in the stream and may be responsible for the elevated cancer risk. Al-Darraji et al., (2023) measured the concentration of heavy metals (lead, cadmium, copper, and iron) in three stations along the Shatt al-Arab River. The study revealed that the recorded levels of the measured elements, except for cadmium, exceeded the Iraqi standard limits. In addition, the study suggested that trace element pollution in the Shatt al-Arab river could be attributed to agricultural discharges and industrial activities. Another study reported that the sediments of Shatt al-Arab are contaminated with different elements such as Zn, Ni, Cu, Mo, Cu, and Fe (Allafta and Opp, 2020). It has been proposed that some aquatic plants described as "Hyperaccumulators" owing to their ability to absorb and accumulate trace elements in their tissues at high levels, and thereby may impact the ecosystem and potentially harm humans and animals (Anna et al., 2023). Fish can absorb trace elements directly from the surrounding environment through their gills and skin or via contaminated food and sediment (Emon et al., 2023). In addition, fish can bioaccumulate trace elements and toxic materials from their aquatic habitat and are therefore used as biomarkers for environmental pollution (Albuquerque et al., 2021). The accumulation of trace metals in the fish body can result in negative effects such as irritation of the gastrointestinal mucosa, nephritis, necrosis and, neurological and behavioral disorders (Agbugui et al., 2023). The accumulation of trace elements in the edible tissues of fish poses a significant threat to public health (Ahmed, 2021; Al-Sarraj et al., 2022). Töre et al., (2021) analyzed metal concentrations in the tissues of six fish species from the Tigris River in Turkey. The results showed varying degrees of accumulation across different metals and species. The study concluded that the occasional consumption of these fish is safe based on target hazard quotients/ hazard index. However, it noted potential long-term carcinogenic risks from certain metals meriting further monitoring. For that reason, it is critical to monitor the concentration of trace elements in fish meat and compare it with the international accepted limits.

X-ray fluorescence is a fast and economical analytical technique that can determine the chemical composition of a wide variety of materials and environmental samples (solids, liquids, and powders). XRF can be used to identify up to 30 elements at the same time in concentration ranges from 100 wt% to sub-ppm levels (Beckhoff et al., 2006). In this regard, Bilo et al., (2015) used XRF to study Pb and Zn accumulation in zebrafish embryos. Similarly, Limburg et al., (2007) used the X-ray fluorescence technique to investigate the trace element distribution in fish otolith (earstones), while Ahmed (2021) used the XRF Spectro to qualitatively and quantitatively determine the metals present in the edible tissues of *C. carpio.*

The current study aims to assess the ability of two fish species, common carp (*C. carpio*) and redbelly tilapia (*C. zillii*), to accumulate trace elements in their edible parts and to ensure the safety of consuming these fish by humans.

2. Material and Methods

2.1. Study Area

The Shatt al-Arab River originates from the confluence of the Euphrates and Tigris rivers in al-Qurnah, southern Iraq. The river flows southeastward for approximately 193 kilometers, forming part of the boundary between Iraq and Iran, before draining into the Arabian Gulf.

In this study, common carp (*C. carpio*) and redbelly tilapia (*C. zillii*) samples were collected from the Shatt al-Arab River (Hamadan village in the Abul-Khaseeb district) in collaboration with a fisherman who catches fish daily on the riverbank (Figure 1).

Thirty specimens of each species, common carp (*C. carpio*) and redbelly tilapia (*C. zillii*), of approximately similar weights and lengths were purchased from a fisherman who sells fish daily on the riverbank in Basrah province, southern Iraq. The samples were placed in a refrigerated box with ice and promptly transferred to the laboratory of the Marine Science Centre, University of Basrah, Iraq. The data related to the length and weight of individual fish were recorded. The edible sections of fish tissues were removed from the dorsal part of the body and chopped into tiny pieces. The samples were dried in an oven at 65°C for 24 hours before homogenizing in a porcelain mortar, as described previously by Ahmed (2021). Briefly, 0.5 g of each sample's powdered fish was weighed and mixed with three drops of organic binder before being pressed into pellets ready for metal analysis. The metals (Ba, Cu, Mo, Pb, Zn, Co, Cr, Ni, V, Sr, Zr, and Ce) in the tissue samples were determined qualitatively and quantitatively using an X-ray fluorescence spectrometer (Shimadzu, Japan).

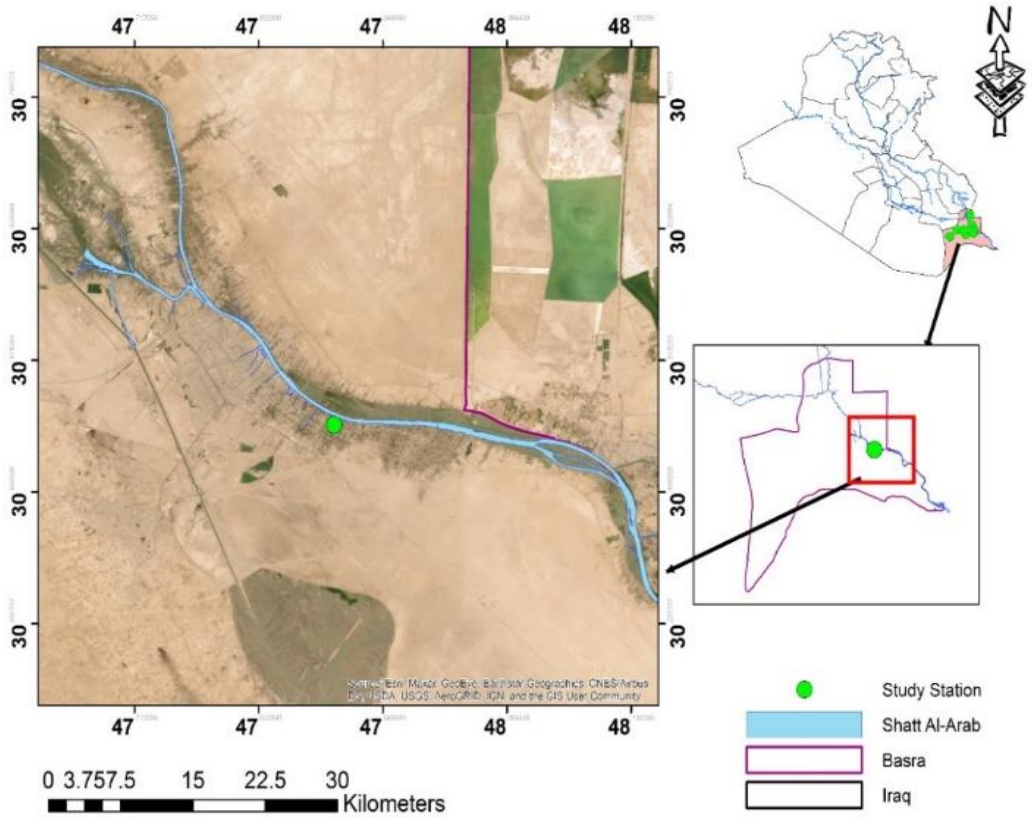

Figure 1. The map shows the location of the fishing nets installation.

2.2. Statistical Analysis

Excel software was used for statistical analysis (min, max, mean, and standard deviation). The two-sample t-test for independent samples was employed to compare the means of two groups to determine if there was a significant difference between them. All data are presented as the mean ± standard deviation (SD).

3. Results

The length of carp samples ranged between 24.5-27.0 cm and 20-23 cm for tilapia. The weight of Carp and tilapia samples ranged from 237.9 to 345 g and 177 to 303 g, respectively, as presented in Table 1.

Ba, Cu, Mo, Pb, and Zr were not found in the analyzed samples. Table 2 presents the concentrations of Zn, Co, Cr, Ni, V, Sr, and Ce in the selected species. All data are provided as means ± standard deviations. Within the same parameter, mean values with various superscripts are significantly different ($p < 0.05$).

The results indicated that the trace element concentrations in Table 1 exceeded the allowable limit, with no significant differences ($p > 0.05$) between the two fish species except for Zn.

Table 1. The average weight and length of the fish used in the current study.

Species	Average weight (g)	Average length (cm)
Carp	276.9 g; SD = 34.07	25.55 cm; SD = 1.04
Tilapia	222.5 g; SD = 33.51	21.75 cm; SD = 0.98

SD: is standard division

Table 2. Content of heavy metals (mg/kg dry weight) in the edible parts of the tested samples compared with standard limits.

	Carp (mg/kg)			Tilapia (mg/kg)			Legislation limits			
Element	**Min**	**Max**	**Mean ±SD**	**Min**	**Max**	**Mean ±SD**	**WHO, 1985**	**FAO/WHO, 1979**	**FAO/WHO, 2004**	**NRC, 1989**
Zn	28.07	63.00	^{a}50±11.5	16.3	31.8	^{b}20.8±5.77			50.00	
Co	6.00	33.01	14.83±9.39	6.00	15.03	11±3.35				0.01
Cr	5.01	23.00	13±6.25	4.02	17.25	9.83±6.08	0.15		1.00	
Ni	13.00	38.02	23.5±10.62	19.10	40.05	28.5±10.4	0.60			
V	12.01	14.04	13.33±0.81	10.04	16.00	12.83±2.04		0.5		
Sr	17.02	29.01	24.67±4.13	16.10	32.01	22±5.83	No information available			
Ce	24.04	51.00	32.83±11.39	10.07	32.00	23.17±7.41	No information available			

Different letters (a and b) indicate statistically significant differences ($p < 0.05$)

4. Discussion

Fish are a valuable source of essential micronutrients for normal growth and development. However, these micronutrients can become toxic at high levels for humans and animals. This study evaluated the levels of specific heavy metals in the edible parts of two fish species collected from the Shatt al-Arab River in Basrah, southern Iraq. The river has been affected by many human activities, and fishing is still widespread, potentially putting the local population at risk for health issues caused by consuming contaminated fish.

Zn is a cofactor of major proteins and an immunomodulatory agent, that plays an essential role in the growth of living organisms (Hussain et al., 2022). However, exposure to high levels of Zn could produce an alternation in the blood profile of freshwater fish (Gupta et al., 2023). Talal et al., (2020) reported that the maximum concentration of Zn in Shatt al-Arab water (1.116 mg/l) was found in the Abul-Khaseeb district, while the highest concentration of Zn in fish (69.5 mg/kg) was found in tilapia from the same region. In the current study, the concentration of Zn in carp tissues (52±11.5) slightly exceeded the permissible limit (50 mg/kg) set by the FAO/WHO (2004). On the other hand, the concentration of Zn was much lower in tilapia tissues (21 ±5.77 mg/kg), with a significant difference ($P<0.05$) between the two fish species. The ability of fish to absorb trace metals from contaminated food and water is affected by their metabolic capacity (Satheeshkumar et al., 2011).

Chromium concentrations in Shatt al-Arab sediment ranged from 738 to 883 mg/kg during the wet and dry seasons, respectively (Allafta and Opp, 2020). A small amount of Cr has been suggested to enhance the growth performance of fish and feed conversion ratio. However, high levels could negatively affect the general fish health (Ahmed et al., 2013). The concentration of Cr in the edible tissues of both species in the current investigation was much greater than the regulatory limits established by the FAO/WHO (2004). According to Rahman et al., (2009) and Ali et al., (2010), the presence of benthic invertebrates, detritus, and mud throughout the year in the digestive tract of carp suggests that the species eats at the bottom of the water body, which is already contaminated with trace elements (Moyel et al., 2015). Similarly, tilapia can consume a wide range of feed ingredients, including raw materials, smaller fish, algae, debris, aquatic plants, and invertebrates, which may carry trace elements to higher levels in the food chain (Ganie et al., 2013). Cobalt (Co) is an integral component of cobalamin or vitamin B12 in animals and is critical for ovulation in fish (Gautam et al., 2018; Banerjee and Bhattacharyam, 2021). However, Co is toxic to living organisms at higher levels (Nagpal, 2004). The concentration of Co (10 mg/kg) in Shatt al-Arab surface sediment was measured recently by Allafta and Opp (2020). The mean Co concentrations in carp and tilapia in the current study were 12±9.39 and 11±3.35, respectively, with no significant differences ($p>0.05$) between the two fish species. The recorded values in the current study were above the acceptable limit of the NRC (1989), which is (0.01 mg/kg dry weight). High levels of cobalt reach the ecosystem with industrial discharges, agricultural waste, and domestic sewage. Cobalt is included in the composition of agricultural fertilizers due to its effective role in stimulating plant growth (Hu et al., 2021). Further, cobalt plays an important role in various fields, such as the oil industry, used as a coloring agent for glass and ceramics, catalysts and alloys for the mechanical industries (Nagpal, 2004; Hu et al., 2021).

Nickle in environmental samples is attributed to industrial and agricultural activities (Al-Sarraj, 2021; Al-Asadi et al., 2020). Al-Asadi et al., (2020) reported that Shatt al-

Arab sediment is contaminated with high levels of toxic metals including Ni. Another study reported that Shatt al-Arab water is polluted with Ni and the concentrations ranged between 79.82 and 144.01 µg/l (Moyle et al., 2015). In the current study, the concentration of Ni in carp (24.8±11.8 mg/kg) and tilapia (29.8±9.8 mg/kg) exceeded the allowed limit of WHO (1985), with no significant differences ($p > 0.05$) between the two fish groups. Excess nickel intake may cause disturbance of the proper composition of intestinal microflora, especially in people diagnosed with systemic nickel allergy syndrome (Świerc et al., 2022).

Heavy metals, such as vanadium, are non-biodegradable and persistent in the environment, posing environmental and human risks owing to their potential toxicity (Tulcan et al., 2021). Animal studies with a high-vanadium-content diet showed a significant increase in metal retention in various tissues (Treviño et al., 2019). The concentrations of vanadium in the current study were 13.50 and 12.38 mg/kg for carp and tilapia, respectively. However, there is no specific standard regulation for the permissible level of vanadium in fish flesh and there is no precise data from previous studies about the levels of vanadium in Shatt al-Arab water.

The current investigation found that carp and tilapia had mean concentrations of Sr of 25.5±4.13 and 22±5.83 mg/kg, respectively, with no significant differences. Sr is a naturally occurring element that is recommended for treating osteoporosis (Alexandersen et al., 2011; Rossi et al., 2014). Several studies have focused on the benefits of Sr for humans in promoting cartilage matrix secretion, stimulating human osteoblast proliferation, and enhancing bone mineralization (Dermience et al., 2015; Cabrera et al., 1999). However, consuming high levels of Sr could lead to possible health hazards (Langley et al., 2009).

In the current study, Ce concentrations were 37.0±12.1 and 23.4±8.29 mg/kg for carp and tilapia, respectively. There were no significant differences ($p > 0.05$) between the two fish species. Ce is a rare earth element widely used in agriculture (Dahle and Arai, 2015). Regarding current knowledge, no information is available on the maximum Sr and Ce concentrations in fish samples. Further, there is no data available on Sr and Ce concentrations in Shatt al-Arab water and sediment.

5. Conclusion

The results of the current study showed that consuming carp and tilapia fish from the Shatt al-Arab River could endanger the lives of consumers. Hence, it is critical to monitor the concentrations of these elements in fish from this area. Mitigating pollution issues in Shatt al-Arab requires an effective strategy, including applying environmental protection laws, adopting waste management methods, and raising public awareness about the dangers of ecosystem pollution.

It is worth noting that previous studies and specialized international organizations did not provide specific maximum limits for the elements mentioned in fish meat, which were included in the current study. The presence of these elements in high concentrations calls for more studies on the health effects of the presence of these substances in the daily meals preferred by the residents of Basrah province.

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