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Bioaccumulation of some heavy metals in three fish species in the Euphrates River waters in Nasiriyah, Iraq

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Abstract
Heavy metals are a major cause of pollution in the Euphrates River in Nasiriyah. The current study included determining the level of pollution and assessing the risks of heavy metals accumulating in the muscles of three fish species (*Cyprinus carpio*, *Barbus canis* and *Acanthopagrus latus*) consumed by the city's population. The bioaccumulation rate of heavy metals in these three fish species, their transfer through the food chain, and their access to humans were measured. Three study stations were identified within Nasiriyah city on the Euphrates River (Al-Batha'a, Nasiriyah Center, and Souq Al-Shuyukh). Thirty-six water samples were collected from the Euphrates River and 360 fish samples from the three species were collected quarterly during the study period (October 2023 to September 2024) to measure heavy metals. The results of the heavy elements used in the study (copper, cadmium and lead) showed a great convergence in their values and it was found that there were no significant differences between them (P>0.05), while a great variation was observed in the values of the concentrations of the studied heavy metals in fish, if their values rose in the spring and summer more than in the winter and autumn, and the results of this study indicated that the concentrations of heavy metals were higher in fish than in water, and this is considered environmental evidence of pollution of the Euphrates River.

Keywords: Euphrates River, heavy metals, water pollution, bioaccumulation, aquatic environment

Introduction
Heavy metals are one of the pollutants that enter the freshwater environment, causing an imbalance in the ecological balance, which has direct or indirect effects on humans (Ateshan *et al.*, 2020) [1]. The pollution of the aquatic environment with heavy metals results from various human uses of water, including industrial, commercial, and agricultural uses. Numerous studies have also indicated that rivers are exposed to heavy metal pollution from various sources, such as household waste, mining activities, and agricultural activities, including the addition of fertilizers and pesticides, which affects the balance in the aquatic ecosystem (Ateshan *et al.*, 2019) [2].

Therefore, heavy metals are the most dangerous pollutants of the aquatic environment, as their use is widespread in various industries, which discharge their polluted water without any treatment. These materials accumulate in water sources, causing the most dangerous types of pollution with these elements, including lead, copper, mercury, cadmium, and others (Li *et al.*, 2020; Yang *et al.*, 2022) [3, 4].

Fish is one of the most important and widely distributed basic food sources in various parts of the world. It is an economic resource, inexpensive and of high nutritional value, due to its richness in proteins necessary for humans. It is easy to digest and low in calories and saturated fatty acids, unlike red meat. According to the American Heart Association (AHA), it is recommended to eat fish twice a week for adults who do not have a history of heart attacks or strokes (Javed *et al.*, 2016) [5]. Fish are widely used to assess the health of aquatic systems. They are the ideal model for detecting contamination at low concentrations of metals in water, as they are highly sensitive to the presence of contamination. Fish also have the ability to accumulate at higher concentrations than in water and sediments due to their feeding on algae and microorganisms, in addition to organic matter present in the aquatic environment (Wang *et al.*, 2022) [6]. Heavy metals enter aquatic food chains, especially fish, either directly through food or indirectly through the gills (Garai, *et al.*, 2021; Ateshan and Misnan, 2025a) [7, 8]. The toxic effects of heavy metals are transmitted from one organism to

another through feeding through the food chain, and then these elements reach the human consumer who is at the top of the food pyramid (Ateshan *et al.*, 2019; Oros, *et al.*, 2025) [2, 9].

Health risks of heavy metals to humans

Heavy metals cause food poisoning and permanent disabilities in humans. They can also cause cancer, genetic mutations, and sometimes death. Heavy metal poisoning occurs when they enter the body as biochemical compounds or accumulate inside it in quantities higher than the permissible limits over a short period of time, or in low concentrations over long periods of time.

Cadmium is a highly toxic heavy metal. Exposure to it causes anemia, tooth discoloration, damage to the olfactory nerve, ulceration of the nasal septum, and loss of the sense of smell in aquatic organisms (Ateshan *et al.*, 2020; Charkiewicz, *et al.*, 2023) [1, 10]. Copper is an essential element for the body. It helps in metabolic processes (Ha *et al.*, 2019; Chen *et al.*, 2020) [11, 12], is a cofactor for many reactions that occur inside cells, affects the breathing process, and causes swelling and paleness of the gills (Kumar *et al.*, 2025) [13].

Lead is concentrated in the muscle tissues of fish and aquatic organisms, and lead toxicity occurs relatively less than copper and cadmium, but it leads, even at low doses dissolved in water, to acute respiratory infections in fish. Its presence in high concentrations in water may lead to the death of mollusks and crustaceans. Cadmium salts are more toxic to fish and other aquatic organisms than the pure element, at lower concentrations (Azar and Vajargah, 2023; Ateshan and Misnan, 2025b) [14, 15]. Therefore, many studies have indicated the possibility of using marine and freshwater fish as a biological indicator or guide to pollution of the aquatic environment with heavy elements and to obtain clear information about the extent of pollution in river water (Jasim *et al.*, 2021; Aziz, *et al.*, 2023) [16, 17]. Studying pollutants in fish provides clear information about the extent of pollution in river water. Fish have been adopted as a biological indicator of pollution. This has prompted human health authorities in various countries to set standards and maximum permissible limits for these pollutants (Al Sailawi *et al.*, 2020; Azemi *et al.*, 2021; Ayejoto & Egbueri, 2024) [18, 19, 20]. The following table shows the maximum permissible levels for these elements in both water and fish. It is worth noting that these percentages are approximate and represent the highest permissible concentrations of these elements, exceeding which is evidence of water pollution. The study of the bioaccumulation of heavy metals in various organs and tissues of fish is of great importance in determining the extent of their exposure to pollutants during their lifetime. It is used as a biological indicator to determine the extent of pollution in the aquatic environment in which they live, as well as the effect of heavy metals on their value, reproduction, and growth (Ateshan and Saxena, 2015; Zaghloul *et al.*, 2020) [21, 22]. Given the Euphrates River in Nasiriyah exposure to various pollutants, including heavy metals that tend to accumulate in aquatic organisms, it has become necessary to conduct research to improve assessment programs regarding the harmful environmental impacts of human activities on the aquatic environment. This research is being conducted using fish as biological indicators. Three species of fish found in the Euphrates River, which are the most widely consumed by humans in Nasiriyah and have diverse diets, were selected to study the bioaccumulation of some heavy metals in the muscles of these fish, using them as biological indicators of Euphrates River pollution in the city.

Research Objectives

The objectives of the research were as follows

1. To determine the level of pollution with some heavy elements (such as Cu, Cd, and Pb) in the waters of the Euphrates River in the city of Nasiriyah.
2. To measure the rate of accumulation of heavy metals in the muscles of some fish species (the edible part) caught from it.

Materials and Methods

1. Study area

This study covered various areas of the city of Nasiriyah in Thi Qar Governorate, along the Euphrates River, with diverse human activities. The river is extremely important to the city's residents, who depend on it primarily and entirely. It irrigates crops and provides water for industry and power plants. Three stations along the Euphrates River were selected in the city (Al-Batha'a, Nasiriyah Center, and Souq Al-Shuyukh), as shown in the attached map:

2. Research methods

Living material (fish species studied)

Three important fish species were selected for this study, differing in their feeding patterns, biological characteristics, and habitats. Samples were collected seasonally from October 2023 to April 2024 to investigate the bioaccumulation of some heavy metals in fish muscles, which are used as good biological indicators for assessing the aquatic environment with heavy metals.

Local fish species

1. *Cyprinus carpio*
2. *Barbus canis*
3. *Acanthopagrus latus*

3. Field work

Water sample collection and analysis

36 water samples were collected from the three study stations, at a rate of one sample per month, starting from October 2023 until September 2024. Water samples were taken at a depth of 1 m and against the direction of the current, using 1-liter polyethylene plastic containers.

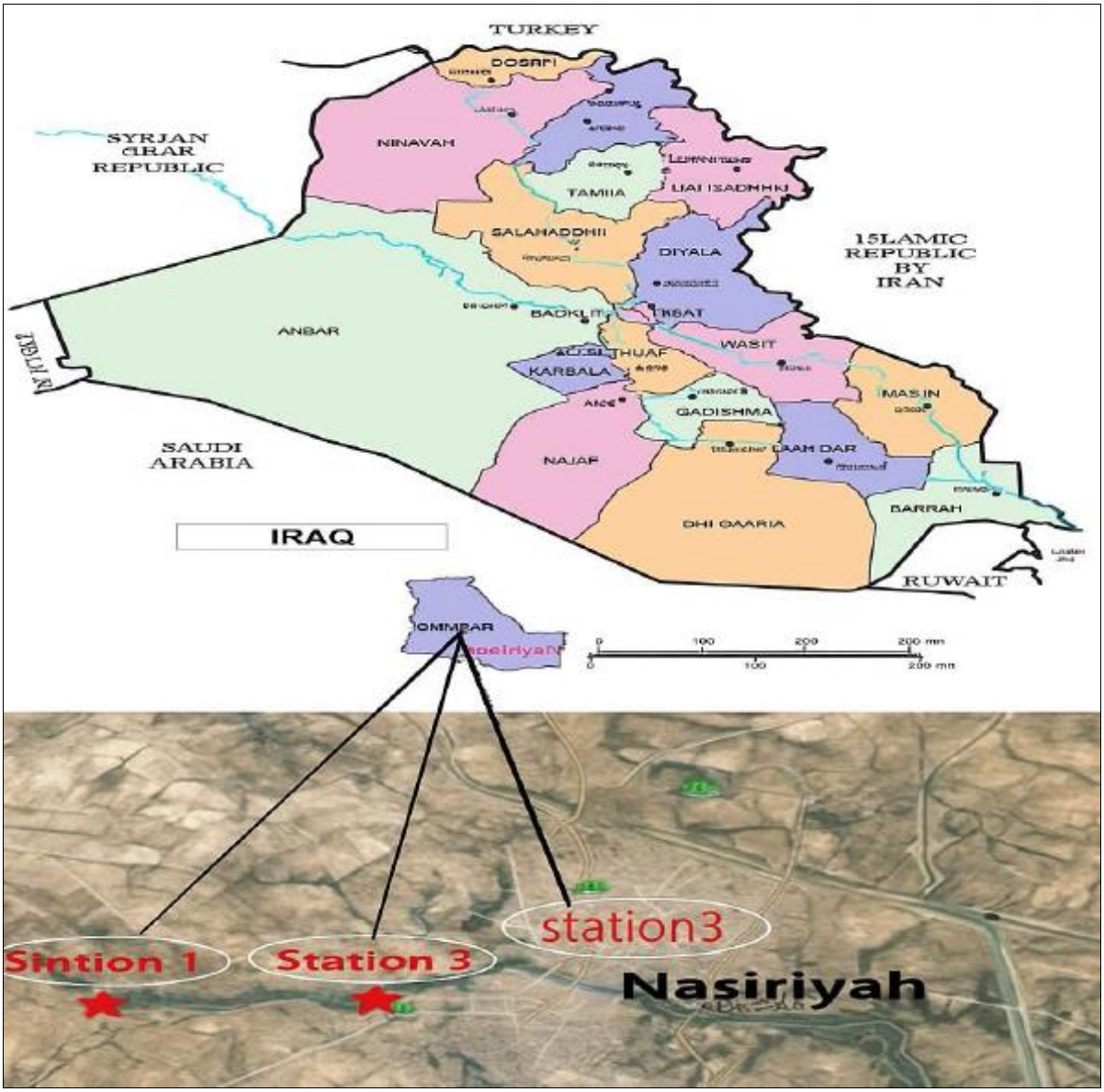

Fig 1: Map of the (Iraq) study area (Nasiriyah city) showed the study stations

Fish sample collection

The study samples were collected during the period from October 2023 to April 2024. 360 random fish samples were collected from the three studied fish species from the three selected study sites, at a rate of (10 individuals for each fish species) on a seasonal basis from each site. The fish under study were characterized by weights ranging between (500-1000) g, and the fish samples were stored on ice until they were transferred to the laboratory.

Digestion of fish samples

The individual fish was washed with double-distilled water, then 2 g wet weight samples were taken from the muscular part of the fish from the area between the middle of the body and the tail and another one close to the spine, using knife and clean plastic forceps, and placed in a clean test tube and later digested.

Determination of the concentration of heavy metals studied: The concentrations of the studied heavy metals (cadmium, lead, and copper) in river sediments from the studied areas were determined using a Varian 220 atomic absorption spectrometer available at the Marine Science Center in Basra. The device uses flame spectrometry and electro thermal spectroscopy techniques, and this is related to the concentrations of the studied mineral elements.

Results and Discussion

In this study, concentrations of three heavy metals (Cd, Cu and Pb) were determined in some freshwater fish species (*Cyprinus carpio*, *Barbus canis* and *Acanthopagrus latus*) living in the Euphrates River, which are loaded with heavy metals.

1. Heavy metal concentrations in water

Lead (Pb): The results showed in figure (2) that the highest lead concentration in the water at Al-Batha City during the summer was 0.009 µg, while no lead was observed at the Nasiriyah Center and Souq Al-Shuyukh sites during the winter, with the overall average being 0.0028 µg. The increase in the concentration of heavy elements, especially lead, in the Euphrates River in the city of Al-Batha is due to the lack of a sewage treatment plant in the city, as the sewage reaches the Euphrates River without treatment, which increases the concentration of heavy metals in the river (Al-Khuzaie *et al.*, 2024) [23].

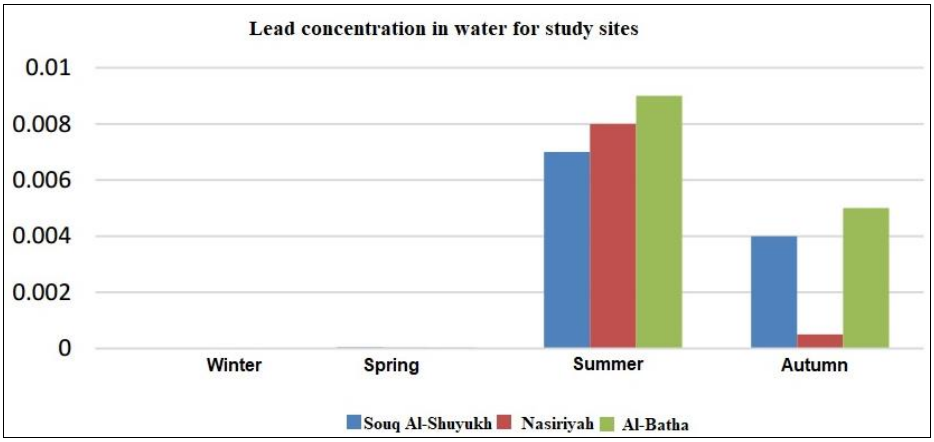

Fig 2: Seasonal changes in lead concentration (µg/g) in water

Cadmium (Cd): The results showed in figure (3) that the highest value of cadmium concentration in water was 0.0005 µg in the summer at the Nasiriyah Center site, while no cadmium concentrations were recorded in the winter for all sites, and the general average was 0.00002 µg. This may be due to the fact that the city center of Nasiriyah is exposed to many types of pollutants, as this station is located near residential areas, which increases the presence of sewage in the river, as well as the presence of animal waste, the leakage of plant fertilizers, chemicals used in fishing, and other pollutants (Nasir and Louhichi, 2024) [24].

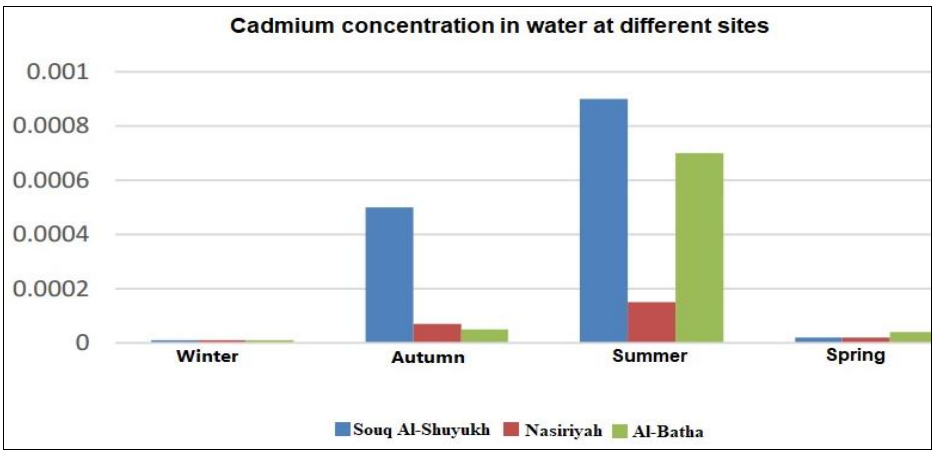

Fig 3: Seasonal changes in cadmium concentration (µg/g) in water

Copper (Cu)

The results showed in figure (4) that the highest value of copper concentration in the water during the summer was at the Batha site and was 0.0019 µg, while the lowest value was recorded during the spring season for all the studied sites and reached 0.0001 µg and the general average was 0.0006 µg. due to the lack of a sewage treatment plant in the city, as the sewage reaches the Euphrates River without treatment, which increases the concentration of heavy metals in the river Also due to the presence of plant fertilizers, chemical pesticides and other pollutants that may leak into the river, which increases the concentration of copper in the water. (Zahoor and Mushtaq, 2023) [25].

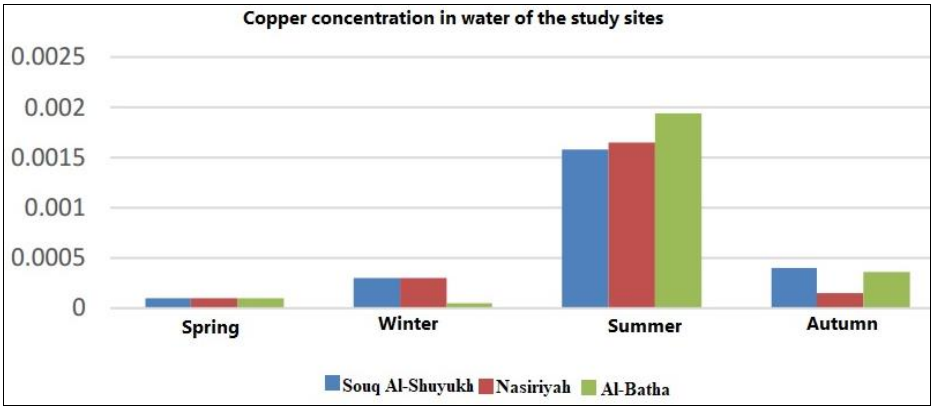

Fig 4: Seasonal changes in copper concentration (µg/g) in water

Heavy metal concentrations were generally higher in spring and summer than in winter and autumn at all sites and for all studied heavy metals. This can be attributed to higher summer temperatures, increased evaporation and consequently increased concentrations of these elements in the water, the effect of which is evident in increased concentrations in fish, as well as increased human activity and its intensity in summer and decrease in winter (Jawed & Shihab, 2024) [26].

2. Heavy metal concentrations in the studied fish species

Lead (Pb): Figure 5 shows the high average lead concentration values in muscle tissue of *the Cyprinus carpio* fish species, which reached or ranged between 0.847 µg/g and 1.259 µg/g followed by the *Acanthopagrus latus* fish species, which reached the highest value of 1.275µg/g at site T_1 and the lowest value was 0.728 µg\g. Finally, the species *Barbus canis* recorded the highest value of lead element concentration 0.862 µg\g at site T1 and the lowest value was 0.548 µg\g.

Statistical analysis showed that *Cyprinus carpio* outperformed other fish species in winter, with a significant difference. It was followed by *Acanthopagrus latus*, then *Barbus canis*. It was also shown that there were no significant differences between *Cyprinus carpio* and *Acanthopagrus latus* fish in summer, autumn and spring, and that they outperformed *Barbus canis* fish with significant differences.

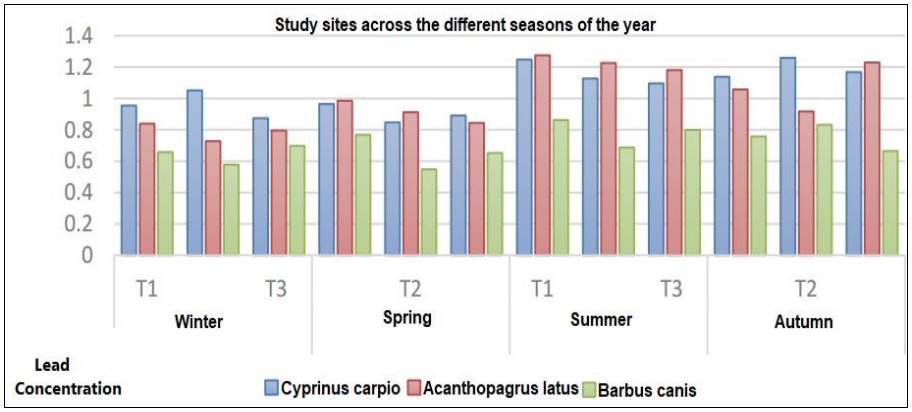

Fig 5: Lead concentrations for the three fish species during the study phases.

Copper (Cu)

Figure 6 shows the high average copper concentration values in muscle tissue of *Acanthopagrus latus*, with values ranging between 1.975 µg\g and 3.196 µg\g. This was followed by *Barbus canis*, which reached its highest value of 2.561 at site T_2 and its lowest value of 1.759 µg\g. Finally, *Cyprinus carpio* recorded the highest copper concentration value of 2.671 µg\g at site T_2 and the lowest value of 1.658 µg\g.

Through statistical analysis, it was found that *Cyprinus carpio* outperformed the other fish species in the summer at site T_2 by a significant difference. It was followed by *Acanthopagrus latus* at site T_3 and then *Barbus canis* at site T_1.

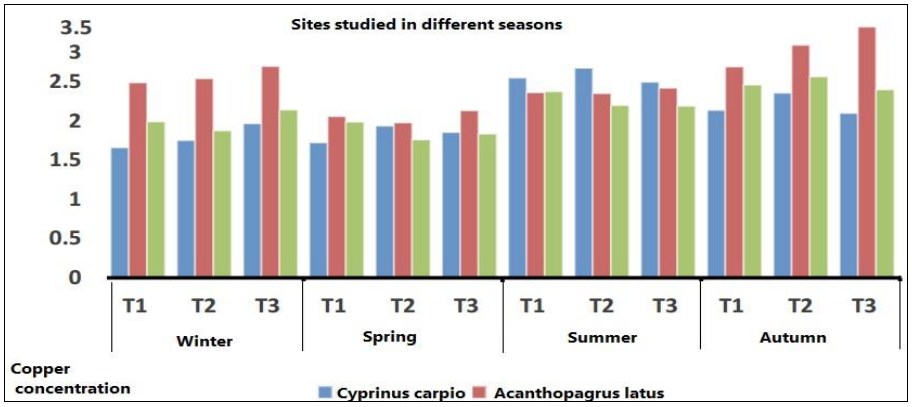

Fig 6: Copper concentration of the three fish species during the study period

Cadmium (Cd)

Figure 7 shows the high average values of cadmium concentration in muscle tissues of the fish species *Cyprinus carpio*, as this value ranged between 0.076 µg\g - 0.2021 µg\g, followed by the fish species *Acanthopagrus latus*, where the highest value reached 0.129 µg\g in site T3 and the lowest value 0.065 µg\g, and finally the fish species *Barbus canis*, which recorded the highest value of cadmium concentration 0.128 in site T3 and the lowest value was in winter and spring 0.073 µg\g.

Fish in the Euphrates River are characterized by relatively high concentrations of cadmium, and at all sites, two possible sources of the general increase in cadmium concentrations in the Euphrates River environment can be identified: phosphate fertilizers containing high concentrations of this element in a soluble form, which is transferred to the river environment via groundwater and the river through the soil layer. The second source is water discharged into the river without treatment (Al-Khuzaie *et al.*, 2024) [23].

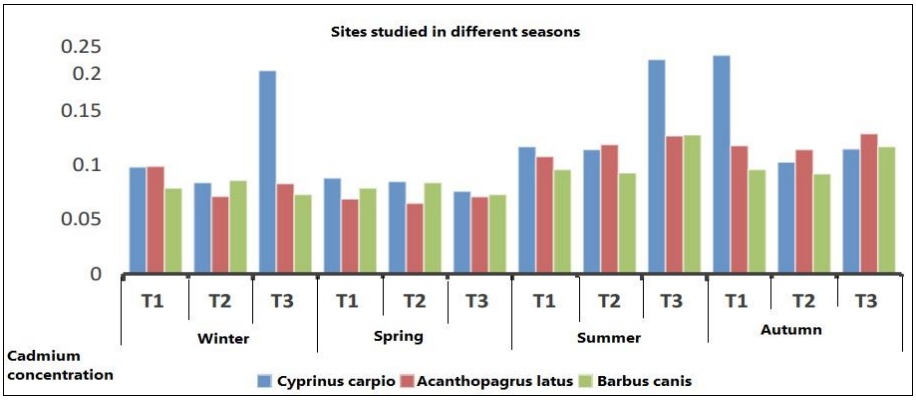

Fig 7: Cadmium concentration for the three fish species during the study period

Conclusion

Water samples recorded lower concentrations than fish samples in all study sites during the year, as living organisms, including fish, accumulate pollutants in their tissues (102-104) times their concentration in the surrounding water as a result of the property of bioaccumulation and biomagnification.

The results of the current study showed that the concentrations of the three heavy metal elements studied in fish are higher than in the Euphrates River water, making fish a vital indicator of pollution in the river. However, the concentrations of the elements are lower than the maximum limits permitted by international organizations for both water and fish, and therefore do not currently pose a risk to human health (EPA, 2001).

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Heavy metal concentrations were generally higher in spring and summer than in winter and autumn at all sites and for all studied heavy metals. This can be attributed to higher summer temperatures, increased evaporation and consequently increased concentrations of these elements in the water, the effect of which is evident in increased concentrations in fish, as well as increased human activity and its intensity in summer and decrease in winter.

Recommendations

- This study recommends the use of fish as valuable biological indicators in assessing environmental pollution, as it is necessary to provide more information about the pollution of aquatic organisms with heavy metals to ensure food safety and public health safety.
- Treating wastewater before releasing it into the river environment and establishing environmental controls on the concentrations of toxic elements it contains.
- Rationalization of the use of phosphate fertilizers in agriculture.
- Follow up on the issue by conducting accurate analyses of agricultural wastewater and treating it before discharging it into the river.
- Continuing such studies is important because they have a significant impact in determining and confirming the ability of fish to accumulate mineral elements and thus the possibility of using them later in the process of treating polluted water.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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