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Assessment of heavy metal toxicity in fish and its impact on human health: A review

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Abstract
The most harmful aspect of water pollution is the presence of heavy metals, which are substances that cannot be removed from the body by metabolic processes and have the capacity to bioaccumulate and amplify. These heavy metals have contaminated the aquatic system as a result of urbanization and industrialization, which is also having an impact on the diversity and ecosystem balance of aquatic species. As, Cr, Pb, Hg, and Cd are the most common heavy metals that have a systemic toxicant effect on human health. Heavy metals mainly enter the fish body through gills, body surface and digestive tract during ingestion of metal accumulated food materials. Heavy metal toxicity can alter individual development rates, physiological processes, mortality, and reproduction in fish. Fish consumption can cause heavy metal toxicity, which can lead to impaired energy levels, damage to the brain and central nervous system, as well as harm to the blood, lungs, kidneys, bones, liver, and other important organs. When eating metal-accumulated food materials, fish's gills, body surface, and digestive tract are the main entry points for heavy metals into the fish's body. Fish development rates, physiological functions, mortality, and reproduction can all be affected by heavy metal toxicity. Fish consumption can cause heavy metal toxicity, which can lead to impaired energy levels, damage to the brain and central nervous system, as well as harm to the blood, lungs, kidneys, bones, liver, and other important organs. The objective of this review is to evaluate the potential causes of heavy metal pollution in aquatic environments, as well as the effects of these pollutants on fish, and human health.

Keywords: Threats, water, sediment, fish, pollution

Introduction

In addition to being a vital human food supply, fish are a mainstay of many natural food webs. Pollutants from surrounding water and food can be readily absorbed by fish, who then deposit them in tissue through the processes of bioconcentration and bioaccumulation. Heavy metals are poisonous and can build up in marine species; they have long been acknowledged as significant pollutants in this regard (Isangedighi and David, 2019) [17]. Although higher amounts of heavy metals are poisonous, they are necessary for the body's metabolism to function. A tiny amount of heavy metals can enter the body through food, drinking water, and the air (Pandey and Madhuri, 2014) [26]. Inherent in the earth's crust, heavy metals are indestructible and cannot be broken down. Due to their toxicity and ability to bioaccumulate, these compounds pose a threat to aquatic life (Karunanidhi *et al*., 2017) [20].

Heavy metals in aquatic ecosystems are primarily caused by a variety of anthropogenic activities, including home waste, industrial and agricultural discharges, erosion from landfills, and different natural processes (Alam *et al*., 2023) [4]. They are only found in tiny concentrations in a range of environmental matrices from fewer than 10 parts per million (ppm) to parts per billion (ppb), heavy metals are categorized as trace elements (Anisha *et al*., 2023) [6]. Finding the causes of heavy metal contamination in aquatic ecosystems is mostly dependent on the distribution of heavy metals in fish, sediments, and water. Contaminant deposition in aquatic systems, particularly that of heavy metals, can result in increased amounts of sediment that may be harmful to the aquatic biota (Maurya and Malik, 2016) [23]. Lead (Pb), Cadmium (Cd), Zinc (Zn), Mercury (Hg), Arsenic (As), Silver (Ag), Chromium (Cr), Copper (Cu), Iron (Fe), platinum group elements, and arsenic are examples of heavy metals. Both necessary and non-essential elements make up heavy metals, which are recognized to be especially important in the field of ecotoxicology (Goswami *et al*., 2018) [12].

Fish are greatly sought after as food for a balanced diet, but when heavy metals are present in the water, they can accumulate in fish and constitute a serious threat to their health. These heavy metals can harm humans when they enter the body through the consumption of contaminated fish (Fatima *et al*., 2020) [10]. Additionally, it has been noted that many fish species take up heavy metals to concentrations that are several times higher than those found in the water or sediments where they live (Taiwo *et al*., 2019) [29]. It is considered vital for many species to have low concentrations of heavy metals including Zn, Fe, Mn, Cu, Co, and Cr because they play an important part in their metabolic processes. Non-essential or toxic metals include As, Hg, Pb, and Cd because they are hazardous even at low quantities and serve no significant use in human health (Leonard *et al*., 2022) [21].

Fish development and feed consumption are mostly attributed to essential metals; however, when these metals surpass their maximum limit, normal physiological and ecological systems within the aquatic environment are disrupted. The majorities of these metals are known to be carcinogenic and can also lead to serious health issues like liver disease, heart problems, kidney failure, and in severe cases, even death (Gulati *et al*., 2022) [13]. Fish with heavy metal accumulation experience adverse effects on their physiology, biochemistry, genetics, metabolism, and ability to grow, develop, feed, reproduce, and survive (Sulieman *et al*., 2019) [28]. In order to limit the influence of these metal elements on our environment, the present review intends to explore the hazardous effects of several heavy metals, such as mercury, arsenic, copper, lead, zinc, chromium, and cadmium, on fish health.

Sources of heavy metals

There are manmade and natural sources of heavy metal pollution (Malik and Biswas, 2013) [22]. Many sources of heavy metals are present in the environment, such as (1) naturally occurring resources, (2) mining operations, (3) electronic waste, and (4) power plants. There are four primary categories into which environmental contamination can be generically classified: industrial, residential, agricultural, and other (Elumalai *et al*., 2023) [9]. Since heavy metals and metalloids are poisonous, persistent, bioaccumulative, and bio-magnificent in the food chain, they pose a major risk at greater concentrations in water and sediment (Jatav *et al*., 2023) [18]. Metals can leak from their original sky into different environmental areas through volcanic eruptions, weathering of rocks holding metals, sea salt sprays, forest fires, and natural weathering processes. Numerous compounds, such as hydroxides, oxides, sulfides, phosphates, silicates, and organic molecules, can include heavy metals (Gulati *et al*., 2022) [13]. The chemical properties of heavy metals vary greatly, and they are widely used in high-tech applications as well as in electronics, machinery, and everyday objects. Heavy metals can enter both natural and anthropogenic food chains as well as the aquatic environment through a variety of anthropogenic causes. Metal concentrations in many aquatic habitats are higher than the water quality standards intended to safeguard people, animals, and the environment (Isangedighi and David, 2019) [17].

Heavy Metals uptake by Fish

Heavy metals are mainly absorbed by fish through their gills, food, skin, and, in the case of freshwater fish, through the water they drink while eating. Once ingested, heavy metals are transported to their organs through the bloodstream by carrier proteins, where they can bind to metal-binding proteins to form high concentrations. Fish concentrations of hazardous elements vary depending on the fish's age, sex, location, and season. Anthropogenic pollution of water sources causes aquatic loss, which upsets the food chain's equilibrium (Tastan, 2018) [31].

Heavy metals in water

The main source of heavy metal pollution in lakes is domestic garbage that finds its way into the water. Zinc is an element that is necessary, however it is said that the pollution in the lakes is higher due to the presence of dust particles that dissolve in the water and contaminate it. Zinc pollution is caused by dust particles as well as volcanic eruptions, fires, and fertilizers. Moreover, Heavy metal's primary cause of water contamination is residential garbage. Lead is another significant contaminant that finds its way into the rivers that are home to mining areas since the fuel used in the process contains a lot of lead. In addition to climate change, Pb also finds its way into water through airborne particulates (Fatima *et al*., 2020) [10].

Heavy metals in sediments

In the aquatic environment, sediment serves as a sink and a carrier of pollutants, particularly heavy metals, whose presence in water bodies suggests the presence of both natural and man-made sources. Additionally, the sediment serves as a helpful indicator of the long- and medium-term metal flux in industrialized water bodies, which aids in the evaluation of current pollution controls' sources and the improvement of management plans. Heavy metals can occasionally be adsorbed or deposited to dangerous amounts in sediments, where they can also show distinct physical and chemical interactions, mobility, biological availability, and potential toxicity (Malik and Biswas, 2013) [22].

Effects of heavy metals on fish

A certain amount of heavy metals can be stored by certain aquatic creatures. Despite not being toxic or dangerous, certain heavy metals can nevertheless enter the food chain and have an impact on human health. Metal concentrations in aquatic species, such fish and shellfish, can accumulate to several times higher levels than those found in water or sediment. As the top predators in the water, fish can absorb heavy metals from other organisms and store them in different parts of their bodies. Certain environmental factors, including as the food chain, predation competition, and hydrodynamics in the water, can cause metals to accumulate in fish tissues to dangerous quantities. Fish are stressed not just by reproduction but also by hypoxic environments, overcrowding, and hunger due to heavy metal effects. Stress factors, such as pollution, have a negative impact on growth, development, and reproduction by altering physiological, biochemical, and metabolic processes (Agbugui and Abe, 2022) [2].

Effect of heavy metals on humans

Lower energy levels, harm to the blood composition, lungs, kidneys, liver, and other essential organs, as well as impairment or diminished mental and central nervous system function, can all be consequences of heavy metal toxicity. Prolonged exposure can cause multiple sclerosis, Alzheimer's disease, Parkinson's disease, muscular dystrophy, and slowly developing physical and muscle problems. Allergies are widespread, and prolonged exposure to certain metals or their compounds over time may even lead to cancer. When it manifests itself, heavy metal poisoning is a severe chemical issue. Toxicology can cause serious sickness and a lower quality of life if it is ignored or managed improperly. Acute heavy metal poisonings can harm the lungs, kidneys, liver, endocrine glands, bones, cardiovascular and gastrointestinal systems, and the central nervous system (Isangedighi and David, 2019) [17].

Types of Heavy metal

Chromium (Cr)

Extended and high-volume contact with Cr can cause skin irritation, corrosion, human cancer, and significant harm to a variety of aquatic life. The role that Cr plays in insulin and fat metabolism emphasizes how important it is to nutrition. Fish can be exposed to Cr through their respiratory system or gastrointestinal tract. Fish have varying amounts of chromium, depending on the form that is available, how long the fish was exposed for, and how concentrated the fish is. Transport of chromium (VI) across the plasma membrane is facilitated by its interaction with plasma proteins (Elumalai *et al*., 2023) [9].

Cadmium (Cd)

Fish and the environment are affected by cadmium in both acute and long-term ways, and it demonstrates substantial toxicity even at extremely low concentrations. Aquatic life is susceptible to a variety of acute and long-term consequences from prolonged cadmium exposure. These include pathological changes in the liver, such as congestion, necrosis of pancreatic cells, fatty changes in the peripancreatic hepatocytes, and congestion and engorgement of blood vessels, as well as an increase in the humoral immune response and the induction of structural and functional changes in the intestine, liver, kidney, and gills. In addition, it leads to the formation of kidney stones, hypercalciuria, and disturbance of calcium metabolism. Fish toxicity varies, however salmonids are particularly sensitive to cadmium exposure, and sublethal consequences including pronounced spine deformity have been documented. It modifies the generation of free radicals and the antioxidant defense system (Tastan, 2018) [31].

Copper (Cu)

Human bodies need a specific amount of copper, but when that quantity is consumed in excess, it can lead to major illnesses like renal failure and liver damage, particularly in Wilson's disease. Drinking water from copper pipes may produce copper-like metal problems since the copper in the pipes is designed to prevent the formation of algae (Munawar *et al*., 2021) [24].

Iron (Fe)

While iron is necessary for animal physiological processes, larger quantities of the metal than what is ideal may be harmful to living things. Over 1.0 mg/l of iron had negative effects on fry and juvenile eating, prolonged stress, and stunted growth (Tastan, 2018) [31].

Manganese (Mn)

Manganese is a metal that is found in extremely minute concentrations in the human body. That being said, it is among the most important nutrients for human health. The average person has about 12.000 mg of manganese in their body. The liver, pancreas, kidneys, brain, and central nervous system include the remaining ones. About 43% of the skeletal muscle is made up of the skeletal system. Adult males require 2.3 mg of Mn daily, while adult females require 1.8 mg. Manganese (Mn) and cobalt (Co) are not very poisonous. India (Elumalai *et al*., 2023) [9].

Mercury (Hg)

One of the heavy metals that is most harmful to the environment is mercury. Because of massive industrialization, mercury contamination in the environment has rapidly increased. Following lead and arsenic on the United States Environmental Protection Agency's (EPA) and the Agency for Toxic Substances and Disease Registry's (ATSDR) list of environmentally harmful substances, mercury came in third. Forest fires and volcanic eruptions are the element's natural sources; fungicides, electronics, paint, batteries, and other man-made materials are its artificial sources. The combustion of fossil fuels and mining are significant contributors to the environmental contamination caused by mercury (Garai *et al*., 2021) [11].

Arsenic (As)

Long-term exposure to heavy metals like arsenic and cadmium can cause illnesses like skin sores, brain damage, skin cancer, and blood vessel ailments. One of the hazardous metals is arsenic, which is essentially present in two forms: inorganic and organic. The majority of organic arsenic is found in seafood, which is not more dangerous (Munawar *et al*., 2021) [24].

Nickel (Ni)

Naturally occurring in the environment at extremely low concentrations is nickel, a known heavy metal. It is released by volcanic activity and can be found in many kinds of soil and meteorites. In the natural world, nickel mostly reacts with sulfur or oxygen to generate oxides or sulfides in the crust of the Earth, respectively. Nickel (Ni) is an important heavy metal since it is essential to every living thing's ability to function biologically. Even though nickel is a trace element, human activities like nickel mining and improper handling of industrial waste can cause its concentration in soil to rise to dangerous levels. These actions hasten the contaminating of the environment. Ni is well-known for its carcinogenic, hematotoxic, immunotoxic, neurotoxic, genotoxic, reproductive, pulmonary, nephrotoxic, and hepatotoxic effects (Elumalai *et al*., 2023) [9].

Lead (Pb)

Lead is more sensitive in infants than in adults, it is also a dangerous metal. The degree of lead absorption determines how serious the condition is. Environmental issues arise from lead. Most often, lead is inadvertently consumed in food, particularly food that has been tainted with lead. Water that is constantly poured through lead pipes may be the cause of some lead problems. The source of lead emissions may have contributed to the environmental concern. Lead pollution can result from the use of paint flakes in older homes or polluted ground, as well as from soil that contains lead particles, dust, etc (Munawar *et al*., 2021) [24].

Zinc (Zn)

The environment is becoming more contaminated by zinc due to a variety of human-caused factors, including steel production, mining, burning coal and other waste, and industrial operations. As a ubiquitous trace element, zinc is one of the micronutrients that are necessary for all living things. Zinc has a role in several metabolic processes, including the synthesis of proteins and nucleic acids, immunity, energy metabolism, cell division, and bodily growth. Many physiological illnesses, including cancer, heart disease, and low conception rates, are brought on by zinc deficiency. However, too much zinc can be hazardous. Additionally species-specific, zinc toxicity varies with fish developmental stages. Temperature, water hardness, and dissolved oxygen content are the main environmental variables that affect how harmful zinc is to aquatic life. Fish are killed by zinc at acute toxic concentrations because it destroys gill tissue; at chronic toxic concentrations, fish die from stress (Garai *et al*., 2021) [11].

Some studies of heavy metals toxicity in aquatic enviroment

Numerous studies have been conducted to determine the levels of heavy metals in fish, sediment, and water. Some of them are presented in Table 1.

Table 1: Heavy metals concentrations in different sample

Country	Type of source / animal	Heavy metals	Reference
India	Fish (*Channa punctatus*)	Cu- 14.0 (mg kg^{-1}) Ni- 14.0 (mg kg^{-1}) Fe- 209 (mg kg^{-1}) Co- 3.0 (mg kg^{-1}) Mn- 11.0 (mg kg^{-1}) Cr- ND Zn- 46.0 (mg kg^{-1})	(Javed and Usmani, 2011) [19]
	Fish (*Clarias gariepinus*)	Cu- 9.0 (mg kg^{-1}) Ni- 12.0 (mg kg^{-1}) Fe- 39.0 (mg kg^{-1}) Co- 4.0 (mg kg^{-1}) Mn- ND Cr- ND Zn- 42.0 (mg kg^{-1})	
	Fish (*Labeo rohita*)	Cu- 20.2 (mg kg^{-1}) Ni- 20.2 (mg kg^{-1}) Fe- 560.8 (mg kg^{-1}) Co- 10.8 (mg kg^{-1}) Mn- 109.4 (mg kg^{-1}) Cr- 1.3 (mg kg^{-1}) Zn- 194.5 (mg kg^{-1})	
India	Fish (*R. kanagurta*)	Cu- 0.42 (µg/g) Cr-0.66 (µg/g) Cd-0.35 (µg/g) Co-0.25 (µg/g) Ni- 0.62 (µg/g) Zn-20.1 (µg/g)	(Vijayakumar *et al*., 2011) [32]
	Fish (*K. axillaris*)	Cu- 0.43 (µg/g) Cr-0.86 (µg/g) Cd-0.43 (µg/g) Co-0.29 (µg/g) Ni-0.79 (µg/g) Zn-25.4 (µg/g)	
	Fish (*S. longiceps*)	Cu-0.61 (µg/g) Cr-0.76 (µg/g) Cd-0.42 (µg/g) Co-0.37 (µg/g) Ni-0.65 (µg/g) Zn-26.2 (µg/g)	
India	Water sample	Pb- 0.036 (mg L^{-1}) Cd- 0.011 (mg L^{-1}) Zn- 0.302 (mg L^{-1}) Ni- 0.188 (mg L^{-1}) Cu- 0.013 (mg L^{-1})) Cr- 0.043 (mg L^{-1}) Hg- 0.0011 (mg L^{-1}))	(Malik and Biswas, 2013) [22]
India	Fish (*Labeo rohita*)	Cu- BDL Cd- 0.130 (µg/g) Cr- 0.260 (µg/g) Zn- 0.173 (µg/g) Pb- 4.237 (µg/g) Fe- .567 (µg/g)	(Batvari *et al*., 2015) [7]
	Fish (*Chirrhina mirgala*)	Cu- BDL	

		Cd- 0.106 (µg/g) Cr- 0.248 (µg/g) Zn- 0.274 (µg/g) Pb- 2.222 (µg/g) Fe- 3.636 (µg/g)	
India	Shrimp (*Oratosquilla nepa*)	Cadmium- 0.86 to 1.94 ppm Copper- 12.3 ppm (Highest) Zinc- 8.84 to 13.26 ppm	(Murthy and Mohan, 2015) [25]
Bangladesh	Fish (*L. rohita*)	Zn- 13.31 (mg/kg) Cd- 0.034 (mg/kg) Cr- BDL As- 0.015 (mg/kg) Pb- BDL Ni- BDL	(Alam *et al*., 2023) [4]
	Fish (*C. cirrhosus*)	Zn- 6.36 (mg/kg) Cd- 0.026 (mg/kg) Cr- 0.654 (mg/kg) As- BDL Pb- BDL Ni- BDL	
	Fish (*H. molitrix*)	Zn- 6.50 (mg/kg) Cd- 0.017 (mg/kg) Cr- BDL As- 0.033 (mg/kg) Pb- 0.534 (mg/kg) Ni- BDL	
	Fish (*L. bata*)	Zn- 8.07 (mg/kg) Cd- 0.025 (mg/kg) Cr- BDL As- BDL Pb- BDL Ni- BDL	
	Fish (*P. sophore*)	Zn- 7.66 (mg/kg) Cd- 0.049 (mg/kg) Cr- BDL As- BDL Pb- BDL Ni- 0.08 (mg/kg)	
Bangladesh	Sediment	Cd- 0.22 (µg/g) Cr- 5.01 (µg/g) Pb- 4.35 (µg/g) Cu- 3 (µg/g) Zn- 7.09 (µg/g) Mn- 48.78 (µg/g) Ni- 6.85 (µg/g)	(Hossain *et al*., 2023) [15]
China	Fish muscle (16 species)	Cr- 0.018 (mg kg^{-1}) Ni- 0.019 (mg kg^{-1}) Cu- 0.27 (mg kg^{-1}) Zn- 7.97 (mg kg^{-1}) As- 7.97 (mg kg^{-1}) Cd- 0.0012 (mg kg^{-1}) Pb- 0.034 (mg kg^{-1}) Hg- 0.079 (mg kg^{-1})	(Huang *et al*., 2019) [16]
China	Fish (15 species)	As- 0.315–3.172 (mg/kg) Cd- 0.002–0.04 (mg/kg) Cr- 0.016–0.173 (mg/kg) Hg- 0.009–0.060 (mg/kg) Pb- 0.021–0.082 (mg/kg)	(Han *et al*., 2021) [14]
Nigeria	Water sample	Lead-0.051 (mg/L) Cadmium-0.045 (mg/L) Chromium-Not detected Zinc-0.253 (mg/L)	(Akintujoye *et al*., 2013) [3]
Nigeria	Fish (*Clarias anguillaris*)	Zn- 5.35 (mg/kg) Pb- 0.23 (mg/kg) Cd- 0.54 (mg/kg) Cu- 0.5 (mg/kg)	(Bawuro *et al*., 2018) [8]
	Fish (*Heterotis niloticus*)	Zn- 4.48 (mg/kg) Pb- 0.01 (mg/kg) Cd- 0.30 (mg/kg) Cu- 0.15 (mg/kg)	
	Fish (*Tilapia zilli*)	Zn- 10.18 (mg/kg)	

		Pb- 3.51 (mg/kg) Cd- 0.35 (mg/kg) Cu- 0.15 (mg/kg)	
Ivory Coast	Water sample	Cd- 0.018-0.022 (mg/L) Hg- 0.011-0.012 (mg/L) Pb- 0.006-0.007 (mg/L) As- 0.033-0.061 (mg/L)	(Sanou *et al*., 2021) [27]
	Sediment	Cd- 0.182-0.187 (mg/L) Hg- 29.74-35.23 (mg/L) Pb- 11.6-12.67 (mg/L) As- 4.01-5.6 (mg/L)	
	Fish (*Oreochromis niloticus*)	Cd- 0.021-0.026 (mg/kg) Hg- 0.061-0.08 (mg/kg) Pb- 0.042-0.067 (mg/kg) As- 1.75-1.89 (mg/kg)	
Turkey	Fish (*A. marmid*)	*Al- 129.99* (mg kg-1) *Cr- 3.08* (mg kg-1) *Mn- 5.65* (mg kg-1) *Fe- 150.92* (mg kg-1) *Co- 0.74* (mg kg-1) *Ni-3.89* (mg kg-1) *Cu-2.54* (mg kg-1) *Zn-51.48* (mg kg-1) *Cd-0.* (mg kg-1) *Pb-0.57* (mg kg-1)	(Tanlr, 2021) [30]
	Fish (*C. umbla*)	*Al- 130.63* (mg kg-1) *Cr- 2.18* (mg kg-1) *Mn- 6.13* (mg kg-1) *Fe- 86.05* (mg kg-1) *Co- 0.54* (mg kg-1) *Ni-3.10* (mg kg-1) *Cu-4.30* (mg kg-1) *Zn-36.39* (mg kg-1) *Cd-0.54* (mg kg-1) *Pb-0.53* (mg kg-1)	
	Fish (*C. trutta*)	*Al- 108.58* (mg kg-1) *Cr- 2.15* (mg kg-1) *Mn- 3.88* (mg kg-1) *Fe- 55.96* (mg kg-1) *Co- 0.53* (mg kg-1) *Ni-3.06* (mg kg-1) *Cu-1.90* (mg kg-1) *Zn-32.01* (mg kg-1) *Cd-0.52* (mg kg-1) *Pb-0.51* (mg kg-1)	
	Fish (*C. regium*)	*Al- 95.12* (mg kg-1) *Cr- 2.84* (mg kg-1) *Mn- 6.98* (mg kg-1) *Fe- 62.02* (mg kg-1) *Co- 0.51* (mg kg-1) *Ni-3.14* (mg kg-1) *Cu-2.87* (mg kg-1) *Zn-45.77* (mg kg-1) *Cd-0.54* (mg kg-1) *Pb-0.52* (mg kg-1)	
Saudi Arabia	Shrimp (*Fenneropenaeus indicus*)	As- 0.53-0.75 (mg/kg) Pb- ND Co- 2.18-2.35 (mg/kg) Ni- ND Cu- ND Zn- 1.01-2.62 (mg/kg) Fe- 4.60-5.75 (mg/kg) Cd- 0.21-0.25 (mg/kg) Cr- 1.80-2.50 (mg/kg)	(Aljabryn, 2022) [5]
	Fish (*Chaceon quinqueden*)	As- 4.25-4.41 (mg/kg) Pb- ND Co- 2.33-2.48 (mg/kg) Ni- ND Cu- ND Zn- 2.19-4.23 (mg/kg) Fe- 4.36-5.94 (mg/kg)	

		Cd- 0.14-0.19 (mg/kg) Cr-2.45-3.01 (mg/kg)	
	Fish (*Lethrinus nebulosus*)	As- 0.21-0.25 (mg/kg) Pb- 1.45-1.57 (mg/kg) Co- 4.29-4.98 (mg/kg) Ni- 1.97-2.44 (mg/kg) Cu- ND Zn- 3.41-5.50 (mg/kg) Fe- 7.72-9.44 (mg/kg) Cd- ND Cr-3.48-3.90 (mg/kg)	
	Fish (*Scomberomorus commerson*)	As-0.13-0.24 (mg/kg) Pb- 0.73-1.00 (mg/kg) Co- 5.42-5.99 (mg/kg) Ni- 2.00-2.33 (mg/kg) Cu- ND Zn- 5.75-6.98 (mg/kg) Fe- 4.80-5.95 (mg/kg) Cd- ND Cr- 4.00-4.50 (mg/kg)	
	Fish (*Pampus argenteus*)	As- 0.15-0.23 (mg/kg) Pb- 1.66-1.72 (mg/kg) Co- 7.43-8.27 (mg/kg) Ni- 1.47-2.23 (mg/kg) Cu- 0.00-0.05 (mg/kg) Zn- 1.06-2.67 (mg/kg) Fe- 4.76-6.34 (mg/kg) Cd- ND Cr-2.10-2.80 (mg/kg)	
	Fish (*Plectropomus pessuliferus*)	As- 0.12-0.22 (mg/kg) Pb- 4.19-5.90 (mg/kg) Co- 2.63-2.78 (mg/kg) Ni- 5.55-6.00 (mg/kg) Cu- 0.00-0.16 (mg/kg) Zn- 2.52-4.53 (mg/kg) Fe- 3.21-3.68 (mg/kg) Cd- ND Cr- 1.51-1.84 (mg/kg)	
	Fish (*Epinephelus summana*)	As- 0.09-0.14 (mg/kg) Pb- 2.40-3.04 (mg/kg) Co- 2.20-2.39 (mg/kg) Ni- 0.99-1.15 (mg/kg) Cu- 0.51-2.44 (mg/kg) Zn- 3.58-4.49 (mg/kg) Fe- 8.20-9.97 (mg/kg) Cd- ND Cr-2.95-3.51 (mg/kg)	
Egypt	Water sample	Zn- 68.49 (ppb) Fe- 320.67 (ppb) Cu- 37.02 (ppb) Pb- 10.72 (ppb) Cd- 2.94 (ppb) Mn- 24.99 (ppb)	(Abbas *et al*., 2023) [1]
	Sediment	Zn- 58.33 (ppm) Fe- 60332 (ppm) Cu- 18.49 (ppm) Pb- 10.56 (ppm) Cd- 2.31 (ppm) Mn- 846.33 (ppm)	
Egypt	Fish (*Mugil Cephalus*)	Cd- 0.26 (µg/g) Pb- 0.05 (µg/g) Cu- 0.04 (µg/g) Zn- 4.91(µg/g)	(Zaghloul *et al*., 2024) [33]
	Fish (*Liza Auratus*)	Cd- 0.38 (µg/g) Pb- 0.36 (µg/g) Cu- 0.53 (µg/g) Zn- 5.28 (µg/g)	
	Fish (*Sparus Aurata*)	Cd- 0.42 (µg/g) Pb- 0.48 (µg/g) Cu- 0.44 (µg/g) Zn- 6.85 (µg/g)	

	Fish (*Dicentrarchus Labrax*)	Cd- 0.29 (µg/g) Pb- 1.00 (µg/g) Cu- 0.20 (µg/g) Zn- 11.02 (µg/g)	
	Fish (*Siganus Rivulatus*)	Cd- 0.30 (µg/g) Pb- 0.96 (µg/g) Cu- 0.50 (µg/g) Zn- 36.81 (µg/g)	
	Fish (*Anguilla Anguilla*)	Cd- 0.35 (µg/g) Pb- 0.28 (µg/g) Cu- 0.52 (µg/g) Zn- 36.01 (µg/g)	
	Fish (*Solea Solea*)	Cd- 0.29 (µg/g) Pb- 0.30 (µg/g) Cu- 0.56 (µg/g) Zn- 17.35 (µg/g)	

***** ND= Not detected, BDL= Below detection level

Conclusion

The health of humans and fish populations are seriously threatened by heavy metal pollution of aquatic ecosystems. This study reviewed the literature and looked at the impact of heavy metals on fish. Fish exposed to heavy metals experience early life responses, as shown by changes in the structure and function of various organs, including enzymatic and genetic effects. This affects the fish's innate immune system and makes them more vulnerable to a variety of diseases. Lead (Pb), Cadmium (Cd), Zinc (Zn), Mercury (Hg), Arsenic (As), Silver (Ag), Chromium (Cr), and other pollutants can enter the water from both point and non-point sources. Several organs may be toxically affected by heavy metals. In addition to having an impact on the fish population in the aquatic ecosystem, the deposited heavy metals also go up the food chain and web to the next tropical level. There are major health consequences for humans when these components are trophically transferred from aquatic to terrestrial ecosystems. Future studies should look on ways to lower heavy metal levels by involving plants and microbes. Before disposing of trash into water bodies, enterprises need to use heavy metal detecting equipment. Some management strategies, such as environmental legislation, environmental monitoring programs, education on environmental sustainability, technological advancements to reduce the pollution load in water, etc., should be implemented in order to regulate the pollution caused by heavy metals.

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