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*Review Article*

# Ecological impact of heavy metals on aquatic environment with reference to fish and human health

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**Abstract**
Heavy metals have a high density that is harmful even in low quantity. These metals enter aquatic habitats through various sources, home effluents, including industrial waste, atmospheric sources, and other metal-based businesses, as well as E-Waste. Heavy metal pollution is responsible for degenerating aquatic species, creating physical abnormalities in creatures and contaminating the aquatic environment. These poisonous heavy metals cause a variety of fish ailments like decrease in hatching rate, teratogenesis and bioaccumulation in the tissues etc. The contamination of heavy metals in aquatic bodies and ecosystems has a significant influence on the food chain. Because fish people consume fish, it has an indirect impact on their health. These heavy metals also have a higher impact on the environment because they remain for longer periods and have bio-accumulative capabilities, leading water health to deteriorate. This study offers insight into the disruption of fish and human physiology, their reproductive ability by heavy metals. This review provides baseline data on the heavy metals and aquatic environment, especially fish and human health. The data will increase sensitivity to preventing and managing aquatic environmental pollution, particularly heavy metal contamination.

**Keywords:** Aquatic environmental pollution, Bio-accumulative, Fish physiology, Heavy metal, Human health

## INTRODUCTION

Heavy metal contamination is a major problem for aquatic ecosystems because it imparts a wide spectrum of toxicities that substantially affect aquatic organisms (Mohammed *et al.,* 2011). The majority of these heavy metals are the result of uncontrolled population that leads to anthropogenic activities such as agricultural cultivation, docking, landfill erosion, and embarking operations, sewage from industry and home waste, and certain natural processes that produce a variety of contaminants causing major repercussions for aquatic ecosystems (Nikiema and Asiedu, 2022). Trace amounts of heavy metals integrate at a certain concentration in abiotic components and pass to aquatic creatures via food chains, where they accumulate in their body tissues, posing major problems to them (Sonone *et al.,* 2020). Increasing industrialization leads to the emission of harmful metal-contaminated effluents such as iron (Fe), nickel (Ni), copper (Cu), chromium (Cr), lead (Pb), and zinc (Zn). Metals can be categorized in two classes: physiologically essential and non-essential. The metals like tin (Sn), aluminum (Al), cadmium (Cd), mercury (Hg), and lead (Pb) have no records of specialized biological roles, hence their toxicity increases with increasing concentration (Kumar *et al.,* 2021; Taslima *et al.,* 2022). Essential metals are generally responsible for the growth and feed utilization in fish, but when their maximum limit exceeds, they disrupt the normal physiological and ecological systems in the aquatic environment (Ediagbonya *et al.,* 2022). Most of these metals are carcinogenic and may also cause significant health complications such as cardiovascular problems, liver illness, renal dysfunction, and death in extreme situations. Heavy metal contamination substantially impacts the physiology of various aquatic creatures, particularly fish. Heavy metal poisoning significantly alters the hemato-biochemical parameter of fish, resulting in many abnormalities (cellular and nuclear) in various blood cells (Mishra *et al.,* 2022). Heavy metal toxicity has also been linked to genetic abnormalities and drastically impairs fish reproductive performance. Previous studies revealed that there are many reproductive compromises, such as decreased fecundity or (Gonadosomatic Index) GSI, hatching rate, fertilization, and aberrant form of reproductive organs, ultimately reduce the reproductive performance of fish (Gárriz and Miranda, 2020). Furthermore, heavy metals had a negative impact on fish embryonic and larval development, causing various complications such as increased mortality rate, deformed shape, decreased cardiac activity, increased heart rate, and vertebral column deformities in the developmental stages of the embryo (Taslima *et al.,* 2022). The current study focuses on gathering up-to-date knowledge on the effects of heavy metals on embryonic and larval development, growth, and reproductive performance, focusing on the most economically relevant aquaculture species.

## SOURCES OF HEAVY METALS

Heavy metals in water bodies can arise from both natural and man-made sources. Volcanic eruptions, weathering of metal-containing rocks, sea-salt sprays, forest fires, and natural weathering processes can all lead to the release of metals from their native skies into various environmental sections (Nikiema and Asiedu, 2022). Heavy metals can be found in a variety of forms, including hydroxides, oxides, sulfides, sulfates, phosphates, silicates, and organic compounds.

### Volcanic activity

Volcanic ash is the consequence of explosive volcanic eruptions, and ash falls can reach places hundreds of kilometers away from an erupting volcano. Even trace amounts of ash can cause havoc in the water system (Ma and Kang, 2022)). Volcanic ash spills into the water system, contaminating it with turbidity, acidity, and low pH. Surface coatings on fresh volcanic ash are very acidic due to the action of aerosols containing the strong mineral acids $H_2SO_4$, HCl, and HF in the plume (Delmelle *et al.,* 2007). As a result, when freshly erupted ash comes into contact with water, it can reduce the pH beyond safe levels for aquatic life preservation (Guffanti and Tupper, 2015).

### Mining

Global industrialization and urbanization have increased the anthropogenic component of heavy metals in the atmosphere. Mining, smelting, power plant waste, and industrial and agricultural operations are all common anthropogenic sources of heavy metals. Certain metals are released into the environment through mining and the extraction of certain elements from their ores (Adnan *et al.,* 2022). Heavy metals released into the atmosphere by mining, smelting, and other industrial activities are caused by dry and wet deposition. They are added to the environment via wastewater discharges such as industry effluents and residential faeces (Sharma and Agrawal, 2005). Elements commonly found in wind-blown dust come from industrialized areas. Vehicle exhaust, which emits lead; smelting, which liberates arsenic, copper, and zinc; pesticides, which emit arsenic; and the combustion of fossil fuels, which emit nickel, vanadium, mercury, selenium, and tin, are all substantial contributors to heavy metal pollution in the environment. Individual actions contribute to environmental degradation owing to the everyday creation of assets to meet the needs of consumers (Purves, 2012).

### Effluents from industry

Some of the biggest sources of pollution include municipal trash, home sewage, and industrial waste that is directly released into the natural water system. Untreated garbage discharge contaminates water (Bukola *et al.,* 2015). The discharge of industrial effluents into bodies of water without treatment is the most significant source of pollution of surface and groundwater water (Ilyas *et al.,* 2019). Wastewater, which contains microbes, heavy metals, nutrients, radionuclides, pharmaceuticals, and personal care items, all finds its way to surface water resources, inflicting irreparable damage to the aquatic ecology and humans by lowering the aesthetic value of such water. These contaminants reduce the availability of usable water, raise the cost of purification, pollute aquatic resources, and impact food supplies (Saha *et al*, 2013). Water pollution is caused by pollutants such as acid, a poisonous metal, agrochemicals, dyes, and other untreated waste discharged by factories (Singarea and Dhabardeb, 2014). Discharged materials create pollution, also result in a loss of biodiversity in the aquatic ecosystem and may pose health hazards to human (Mushtaq *et al.,* 2020).

**Agriculture-related activities**

In response to the ever-increasing demand for food, agricultural systems have expanded and intensified (Bommarco *et al.,* 2018). Overuse and misuse of agrochemicals, water, animal feeds, and pharmaceuticals aimed at increasing production have increased environmental pollution burdens, including rivers, lakes, aquifers, and coastal waterways (Li, 2017). Agricultural pollution also influences aquatic ecosystems, for example, eutrophication produced by nutrient buildup in lakes and coastal waterways impacts biodiversity and fisheries (Withers *et al.,* 2014). In response to the ever-increasing need for food, agricultural systems have expanded and intensified. Farms dump significant amounts of agrochemicals, organic debris, drug residues, sediments, and salty drainage into bodies of water (Mishenin *et al.,* 2021). Water contamination as a result has been shown to endanger aquatic ecosystems, human health, and productive activity (Brooks *et al.,* 2014). Agricultural waste dumped into aquatic ecosystems negatively impacts aquatic animals, including fish, by concentrating toxins directly from dirty water and moving them up the food chain (Oribhabor, 2016). In many nations, insecticides, herbicides, and fungicides are widely used in agriculture. They can damage water supplies with carcinogens and other hazardous compounds when inadequately selected and handled (Anju *et al.,* 2013).

**Electroplating**

It is a plating process that employs electrical flow to extract desired substance cations from a solution and coat a conductive device with a thin layer of the material, such as metal (Hosseini *et al.,* 2016). It is most commonly used to apply a layer of metal beneath the desired component (e.g., abrasion and wear resistance, corrosion protection, lubricity, aesthetic qualities, and so on) to a surface that would otherwise be deficient in that quality (Sierka, 2015). Electroplating a major polluter since it releases hazardous compounds and heavy metals into the environment through the water, air emissions and solid waste in an environment and known to have high amounts of heavy metals such as nickel, iron, lead, zinc, chromium, cadmium, and copper. (He *et al.,* 2021). Electroplating industries' effluent pollutes the air, water and land (Sonone *et al.,* 2020).

**E-waste/electronic waste**

Uncontrolled disposal and improper recycling of e-waste pose substantial risks to human health and the environment (Rao, 2014). Toxic chemicals found in e-waste include heavy metals like lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), and nickel (Ni), as well as persistent organic compounds like brominated flame retardants (BFRs) and phthalates (Chen *et al.,* 2011). Polychlorinated biphenyls (PCBs), nonylphenol (NP), and triphenylphosphate (TPPs) are among the other substances found in e-waste. Heavy metals, toxic compounds, and carcinogens are known to be abundant in e-waste. Certain skin, respiratory, digestive, immunological, endocrine, and neurological disorders, including cancer, can be avoided by properly managing and disposing of E-waste (Ouabo *et al.,* 2019). To close the digital gap, there is an exponential increase in the usage of electrical and electronic equipment (EEE), which has a worrisome effect on the environment and human health when Information and computation Technology (ICT) waste is not disposed of correctly (Tale, 2020). There is a growing need to align existing rules and guidelines with international standards and best practices for a healthy E-waste management system (Ilankoon *et al.,* 2018)

**Power plants**

Thermal pollution from nuclear and fossil fuel facilities is substantial in bodies of water. The worsening of water quality caused by a change in ambient water temperature is known as thermal water pollution (Taslima *et al.,* 2022). The Environmental Protection Agency (EPA) estimates that thermoelectric power stations alone generate 50 to 60 percent of all harmful pollutants emitted to surface waterways by all industrial categories under the Clean Water Act (CWA) (DeNooyer *et al.,* 2016). Coal-fired power stations are the most harmful polluters among the numerous types of thermoelectric generating units. Approximately half of the 1,100 steam-electric facilities now in operation in the United States are coal-fired power plants. These facilities release millions of tons of harmful heavy metals into the environment every year, including arsenic, selenium, lead, mercury, boron, and cadmium. When heated water is released into an aquatic ecosystem, it causes many problems. The most noticeable difference is a decrease in dissolved oxygen levels and an increase in pH. Warm water cannot store as much dissolved oxygen as cold water, thus, organic matter decomposes more quickly in warm water (Mishra *et al.,* 2022). Eutrophication is caused by an increase in decomposed aqueous nutrient concentrations, which is most commonly manifested as algae blooms that block sunlight for underlying aquatic plants. The abundance of algae is a simple food supply for aerobic microorganisms that surge in the population and further deplete the dissolved oxygen (Newell, 2004). Low oxygen levels create hypoxic dead zones, which are inhospitable to most aquatic organisms (Broman *et al.,* 2010). Furthermore, rapidly heated water stimulates the metabolism of cold-blooded aquatic creatures such as fish, resulting in malnutrition owing to a lack of food sources (Sonone *et al.,* 2020). Many species flee as the environment becomes more unsuitable to the area's aquatic wildlife, while more sensitive species may perish, altering the biodiversity of both the original and invaded places. These impacts are most noticeable around coral reefs, which are home to over 2 million aquatic species and approximately 25% of all marine life (Kumar *et al.,* 2021).

## IMPACT OF HEAVY METALS ON THE AQUATIC ENVIRONMENT

Unlike organic substances, the bulk of metals cannot simply be converted into less hazardous molecules. Metals are dispersed throughout the water column, deposited in sediments, or consumed by aggregation once introduced into the aquatic environment. The sediments constitute a semi-permanent offer of contamination to the natural phenomena due to metal's activity and remobilization processes. Metal residues in polluted settings have the ability to bioaccumulate in aquatic ecosystems (aquatic flora and fauna) which may then enter the natural human phenomena and cause health concerns (Mishra *et al.,* 2022). Metal accumulation in sediments occurs as a result of processes such as positive compound precipitation, fine solid particle binding, association with organic molecules, co-precipitation with metal or Mn oxides, or species delimited as carbonates all depending on the physical and chemical conditions that exist between the sediment and the associated water column. Metal bioavailability is defined as the proportion of the metal's total concentration that has the potential to accumulate at various points in the body of living organism. Metal bioavailability is controlled by the following factors: metal natural science (distribution in water sediment, suspended materials, and metal speciation); physical and chemical parameters (temperature, salinity, pH, ionic strength, dissolved organic carbon content. Metal bioavailability governs the buildup of metals in aquatic organisms (Kumar *et al.,* 2021). Metals are taken up in two ways: through the receptive stratum if they are dissolved or by food intake, if they are particulate. The presence of organic or inorganic complexes, pH, temperature, salinity, and reaction conditions are the primary variables that modify metal toxicity. Intake uptake is affected by comparable parameters, including feeding speed, enteral transit duration, and digestive efficiency. Many studies have demonstrated that free hydrated metallic particles are the most accessible form of metal, Cd, Zn, and elements. However, there are notable exceptions. As a result, the significance of various chemical types of dissolved metals and complexes built with appropriate organic ligands with low relative molecular mass shouldn't be neglected. Organic binders have been reported to boost Cd bioavailability in mussels and fish by enabling the migration of the hydrophobic molecule at intervals in the lipid membrane. Metal-organic compounds are also more bioavailable than metal ionic forms (El-Greisy and El-Gamal, 2015). Mercurial organic chemicals are macromolecule-soluble and easily permeate lipid membranes, increasing toxicity when compared to corrosive sublimate, which is not lipid-soluble. The action on suspended particles affects the overall concentration of metals in water. The interaction of solid particles and metals is also significant for metal absorption into organisms via food consumption. The insoluble metal compounds build in the suspended particulates, but under positive circumstances, the metal reaches the gap water being dissolved. Because significant metal concentrations from sediments or suspended solids are loads of over in the water, a little low proportion of them is also a truly essential offer for bioaccumulation in organisms and benthic species. Because the dynamics of various metals at different points in the aquatic environment are not fully known, further studies are needed to investigate the many accumulation/bioaccumulation routes supported by dissolved or suspended metal forms (Samson and Shenker, 2000). Because of their filter-feeding activity, the bioavailability of metals in bivalve molluscs is dependent on sediment particle size, according to several studies. The bioavailability of Cd, Zn, and Ag was dramatically increased when the particles were covered with living organisms, polymers, or fulvic acids. Overall, metal binding decreased the bioavailability of metals from sediment. Heavy metal breakdown in water sources is a significant environmental hazard that negatively affects plants, animals, and human health. Freshwater fish are exposed to a variety of hazardous heavy metals dumped into bodies of water from numerous sources (Ediagbonya *et al.,* 2022). Heavy metal pollution of aquaculture has reached a global crisis since it endangers fish and poses health hazards to seafood customers (Fig 1).

## HEAVY METAL INTAKE VIA THE FOOD CHAIN

To a lesser extent, these heavy metals enter our systems through nutrition, drinking water, and air by inhalation (Fig. 2). Some of these heavy metals, such as zinc, copper, and selenium, are essential for metabolism. However, at higher concentrations, they can cause poisoning. Heavy metal poisoning might occur as a result of tainted drinking water (lead pipes), high ambient air concentrations near emanation sources, or food chain consumption (Javed, 2012). Heavy metals bioaccumulate in the body and are hence dangerous to humans. Bioaccumulation refers to an increase in the absorption of a chemical in an organism that is proportional to the concentration of the chemical in the environment (Agarwal *et al.,* 2010). Indeed, the buildup of metals in food crops and their implications on human health is a topic of great concern across the world. However,

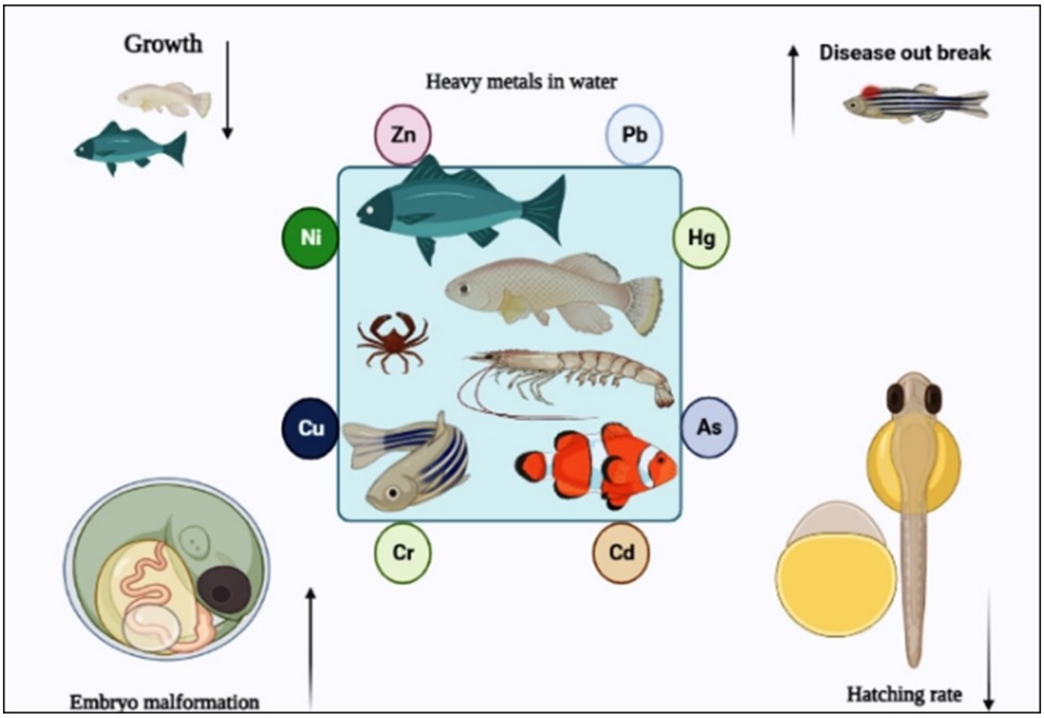


**Fig. 1.** *Impact of heavy metals on the aquatic health*

knowledge of geophysical patterns may assist us in determining the extent to which they affect human health. Difficulties may differ among nations, as may the origin of metallic pollution, which has been poorly explained (Taslima *et al.,* 2022). Heavy metals are toxicants that cause acute illnesses in aquatic creatures. Absorption of heavy metals in the food chain in aquatic creatures may result in occasional fever, cramps, kidney impairment, and hypertension in humans. Fish play an important role in metal biomagnification since they are at the top of the food pyramid and act as permitted transfer media to humans. Heavy metals may be extremely harmful to humans, causing toxic and carcinogenic effects as well as oxidative degradation of biological macromolecules.

**Lead**

It is commonly found in wastewater from electroplating, electrical, steel, and explosive makers. Lead acid battery discharge is the primary reason for the presence of lead (Pb) in industrial waste. It occurs as sulfide, cerussite ($PbCl_2$), and galena, all of which are heavy and soft metals (Taslima *et al.,* 2022). Lead is typically found in aquatic systems as a result of electrical waste. Excessive (Reactive Oxygen Species) ROS generation from lead accumulation in fish tissues induces oxidative damage in fish (Javed, 2012). Furthermore, as an immuno-toxicant, Pb exposure alters immune responses in fish (Table 1). In humans, lead causes memory loss, hearing problems, digestive issues and cancer. Lead is a dangerous metal that easily accumulates in the human body. When lead is ingested, it can cause permanent harm to the Central Nervous System (CNS), Brain, and Excretory System (Biswas *et al.,* 2022).

**Arsenic (As)**

Arsenic is released into the environment during lead, copper, and zinc smelting (Yao *et al.,* 2020). Furthermore, the mix of chemicals and glassware is responsible for the production of arsenic. Arsine gas is produced during the manufacturing of arsenic-containing insecticides (Wang *et al.,* 2014). Arsenic comes from a variety of sources, including industrial waste, metallic trash, and so on (Topare and Wadgaonkar, 2022). Arsenic exposure in the water bodies causes bioaccumulation in fish/ aquatic organisms and can cause physiological and biochemical disorders (Erickson *et al.,* 2010) (Table 2). It is also extremely hazardous to human health since it harms the neurological system, weakens muscles, and causes protein coagulation (Kumar *et al.,* 2022). It can start cancer and also has an impact on the endocrine, hepatic, and reproductive systems.

**Mercury (Hg)**

Bioaccumulation of mercury in marine affect the physiological and ecological properties of fish. When mercury is flashed in large quantities can cause neurotoxicity and reproductive damage. These impacts can then disrupt cells, tissues, ultimately threatening marine fish survival (Samson and Shenker, 2000) (Table 3). Long-term mercury exposure has been linked to unsteady walking, poor focus, tremulous speech, clouded eyesight, and decreased psychomotor function **(**Nail *et al.,* 2022). Involuntary abortion is common in pregnant women when high mercury concentrations (Mukherjee, 2022**).** When mercury is consumed, it has been shown to cause cardiovascular and gastrointestinal consequences (Nguyen and Kim, 2022).

**Cadmium (Cd)**

It is also the most hazardous heavy metal found in industrial waste. It is used extensively in sectors such as plating, cadmium nickel batteries, phosphate fertilizers, stabilizers, and alloys (Singh *et al.,* 2022). Even at low concentrations, cadmium compounds are very toxic and accumulate in the environment. It is a trace element that is extremely harmful to fish. It is frequently found in surface waters that have been polluted with industrial effluents. Cd can quickly cause physiological alterations in freshwater fish gills and kidneys when dissolved in water. Cadmium accumulation can cause "Itai-Itai" illness. Human suffer from bone tempering and fractures as a result of it. When consumed in large quantities, cadmium causes kidney toxicity (Upadhyay, 2022). It has been linked to kidney damage and bone weakening after long-term or high-dose exposure, and increased levels of Cd have been linked to prostate cancer in human. Cadmium is too responsible for the high risk of lung cancer (Forcella *et al.,* 2022).

**Nickel (Ni)**

Sources of nickel in the atmosphere are volcanic dust particles, alloy production plants, weathering of rocks, welding, electroplating, grinding, and cutting processes (Poonkothai and Vijayavath, 2012). Nickel exposure caused certain histological abnormalities in the structure of fish gills (Samim *et al.,* 2022). These modifications included hyperplasia, hypertrophy, secondary lamellae shortening, and fusing of neighboring lamellae (Table 5). It also has a number of pathologic consequences and is known to be carcinogenic in humans. Nickel ingestion causes a considerable decrease in body weight (Parveen *et al.,* 2022). Hair loss is a common side effect of nickel overdose. People who have inhaled nickel have experienced the most serious adverse health effects, including chronic bronchitis, reduced lung function, and lung and nasal sinus cancer (Haddad *et al.,* 2016).

**Copper (Cu)**

Copper is required by all species, including fish. It plays a crucial function in metabolism. It is one of the most hazardous metals to fish, affecting enzyme function, blood parameters, behavior, growth, and reproduction (Johnson *et al.,* 2007) (Table 6). The fish exposed to copper appeared to have changed the structure of their gills, with an increased number of mucous cells, chloride cells, and respiratory epithelium thickness detected (Xing *et al.,* 2022). The fish exposed to copper appeared to have changed the structure of their gills, with an increased number of mucous cells, chloride cells, and respiratory epithelium thickness detected (Sarnowski, 2003**).** Copper is non-biodegradable and are key environmental contaminants that cause cytotoxicity, mutagenesis, and carcinogenesis in animals (Kumar *et al.,* 2022).

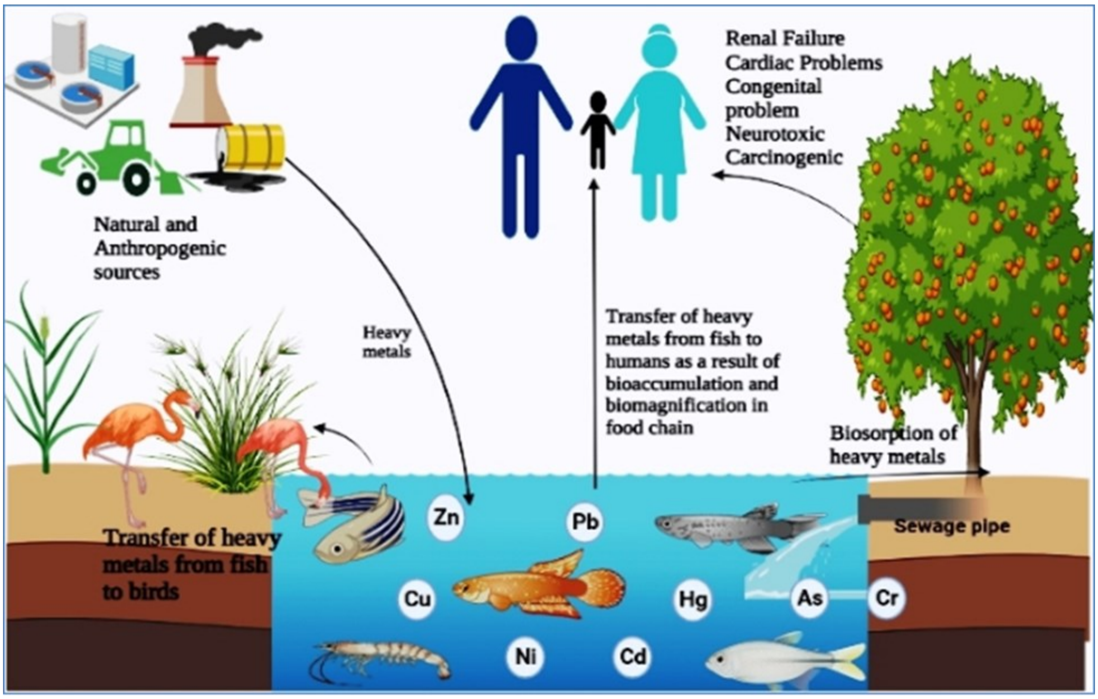


**Fig. 2.** *Heavy metal intake via the food chain*

**Table 1.** Impact of lead on growth performance of larval and adult fish

| S. No. | Scientific name | Common name | Days of exposure and dose | Deformities recorded in fish | References |
|---|---|---|---|---|---|
| 1 | *Clarias gariepinus* | African sharptooth catfish | 48–168 h & 0.1–0.5 mg/L | Irregular head<br>Notochord Defects | Gárriz and Miranda, 2020. |
| 2 | *Chanos chanos* | Milkfish | 40 days & 85.2 mg/L | Weight gain decrease<br>Length Gain decrease<br>Specific growth rate decrease<br>Feed Conversion Ratio declined | Taslima *et al.,* 2022 |
| 3 | *Catla catla* | Katla | 60 days & 1/3rd of LC50 | Weight gain decrease<br>Length Gain decrease<br>Specific growth rate decrease<br>Feed Conversion Ratio declined | Javed, 2012 |
| 4 | *Labeo rohita* | Rohu | | | |
| 5 | *Cirrhina mrigala* | Mrigal | | | |

**Table 2.** Impact of arsenic on growth performance of larval and adult fish

| S. No. | Scientific name | Common name | Days of exposure and dose | Deformities recorded in fish | References |
|---|---|---|---|---|---|
| 1 | *Anguilla japonica* | Japanese eel | 15 days and 0.1, 100 μM | Spermatogenesis via Steroidogenesis suppression | Celino *et al.,* 2009 |
| 2 | *Oncorhynchus mykiss* | Rainbow trout | 30 days and 26 –77 μg/kg | Growth reduced<br>Slower feeding<br>Reduced FCR | Erickson *et al.,* 2010 |

**Table 3.** Impact of mercury on the growth performance of fish

| S. No. | Scientific name | Common name | Days of exposure and dose | Deformities recorded in fish | References |
|---|---|---|---|---|---|
| 1 | *Danio rerio* | Zebra danio | 20 and 30 mg/l | Abnormal fin | Samson and Shenker, 2000. |

**Chromium (Cr)**

This metal is contaminating natural water as a result of anthropogenic activities. Various studies have shown that chromium accumulation can increase the risk of lung cancer. Chromium can quickly cause physiological alterations when dissolved in water in fish gills and kidneys (Table 7) (Benaduce *et al.,* 2008). Damage to the circulatory system and nervous tissue is also recorded in human due to chromium toxicity. Cr in the presence of other metals has been shown to increase glycogen levels in numerous organs that are stressed due to metal exposure (Ngo *et al.,* 2022).

**Zinc (Zn)**

Zinc can be derived through rock weathering, industrial and household wastewater outflows where it plays important functions in preserving cellular integrity. At low concentrations it may kills fish by destroying gills. But at large concentrations it may induce stress resulting in death (Table 8). The role of zinc differs at different concentrations and varies with life history of organism (Williams and Holdway, 2000). Zinc also increases the risk of cardiovascular disease. It has the potential to induce hypertension, nausea, and stomach damage. It is also responsible for neurotoxic effects on human health (Fig 3). When used in excess, zinc might induce psychical disorder. The injection of zinc into the body also causes other neurological alterations like deformities in spinal cord, neuron degeneration etc. (Islam *et al.,* 2022).

Heavy metals are crucial components required for the body's optimal growth and development. Human population growth has resulted in a rise in medical waste, industrial waste, and pollution (Yadav *et al.,* 2022). All garbage containing dangerous heavy metals is deposited in water bodies, either directly or indirectly (Benaduce *et al.,* 2008). This discharge from various pollutes the water and harms aquaculture. Using industrial effluents, fertilizers, and medical waste directly impacts groundwater sources that are linked to neighbouring water sources (Akhtar *et al.,* 2021). Excessive heavy metals can cause breeding issues and physical abnormalities, and even jeopardize survival capacity. Fish is a major source of food for people who live near seashores and water bodies (Huang *et al.,* 2010). Consumption of heavy metal-enriched fish may have an impact not only on human health but also affect the entire food chain (Ali *et al.,* 2022). Humans may experience serious complications such as organ failure, bodily deformities, and even mental health problems.

**Table 4**. Impact of cadmium on growth performance of larval and adult fish

| S. No. | Scientific name | Common name | Days of exposures and dose | Deformities recorded in fish | References |
|---|---|---|---|---|---|
| 1 | *Danio rerio* | Zebra danio | 7 dpf & 60 ppb | Decreased diameter of the otolith fiber like appearance between knobs of otolith | Green *et al.,* 2017 |
| 2 | *Cyprinus carpio* | Common carp | 60 days & 0.3, 0.06 mg/l | Survival and growth become reduced<br>Malformation in the yolk sac<br>Shortening of body<br>Cardiac edema Curve in vertebral column | El-Greisy and El-Gamal, 2015. |
| 3 | *Danio rerio* | Zebra danio | 80 hpf & 3.3, 6.7 & 13.3 μM | Edema Decreased in tail length in larval stage, lordosis | Fraysse *et al.,* 2006 |
| 4 | *Cyprinus carpio* | Common carp | 30 days & 0.2 mg/l | Growth retardation | Sarnowski, 2003 |
| 5 | *Clarias gariepinus* | African sharptooth catfish | l -5 days & 0.05 –5.00 mg/l | Pigmentation reduced<br>100% mortality | Nguyen and Janssen, 2002 |
| 6 | *Cyprinus carpio* | Common carp | 5–50 mg/l | Swelling of eggs | Calta, 2001 |
| 7 | *Melanotaenia fluviatilis* | Murray River rainbowfish | 2 h & 0.033–3.3 mg/l | Spinal cord abnormalities | Williams and Holdway, 2000 |
| 8 | *Oncorhynchus mykiss* | Rainbow trout | 56 days & 0.05, 0.25,<br>0.50 & 2.50μg/l | Premature and delayed Hatching | Jurgelėnė *et al.,* 2019 |
| 9 | *Pagrus major* | Red seabream | 0–3.2 mg/l | Skeletal deformities<br>Cardiac edema<br>Blastodermal lesions | Cao *et al.,* 2009 |
| 10 | *Rhamdia quelen* | Silver catfish bagre | 0.0005–0.018 mg/l | Deformed spinal cord | Benaduce *et al.,* 2008 |
| 11 | *Odontesthes bonariensis* | Silver catfish bagre | 10 days & 0.25, 2.5 μg/l | Reduced embryo and larval survival | Gárriz and Miranda, 2020. |
| 12 | *Leuciscus idus* | Ide | 21 dah & 0.1 mg/l | Body perimeter area reduced, swim bladder become deformed<br>Low survival<br>Body length reduced | Witeska *et al.,* 2014 |
| 13 | *Silurus soldatovi* | Northern sheatfish | 144 h & 0.0001 –30 mg/l | Spinal cord became curved | Zhang *et al.,* 2012 |
| 14 | *Gambusia affinis* | Western Mosquitofish | 30 days &0.4 mg/l | Spinal cord deformities | Sassi *et al.,* 2010 |

**Table 5.** Impact of nickel on growth performance of larval and adult fish

| S. No. | Scientific name | Common name | Days of exposure and dose | Deformities recorded in fish | References |
|---|---|---|---|---|---|
| **1** | *Catla catla* | Katla | 8 weeks & 70.40g,71.99g and 79.11g | Growth reduced<br>Slower feeding<br>Reduced FCR<br>Hepatoxicity<br>Loss of apetite<br>Growth reduced<br>Slower feeding<br>Reduced FCR<br>Total protein decreased | Javed, 2013 |
| **2** | *Labeo rohita* | Rohu | | | |
| **3** | *Cirrhina mrigala* | Mrigal | | | |

**Table 6**. Impact of copper on growth performance of larval and adult fish

| S. No. | Scientific name | Common name | Days of exposure and dose | Deformities recorded in fish | References |
|---|---|---|---|---|---|
| 1 | *Danio rerio* | Zebra danio | 120 haf & 0.068-0.244mg/l | Deformities in Lateral line | Johnson *et al.*, 2007 |
| 2 | *Cyprinus carpio* | Common carp | 20 day & 0.2 mg/l | Curve in spine<br>C-shape larva<br>Deformed yolk sac,<br>Shortened body | Witeska and Ługowska, 2004 |
| 3 | *Danio rerio* | Zebra danio | 3 dpf & 50-1000 µg/l | Hatching Rate decreased<br>High heart rate<br>Large yolk sac | Johnson *et al.*, 2007 |
| 4 | *Cyprinus carpio* | Common carp | 30 days & 0.2 mg/l | Growth retardation | Sarnowski, 2003 |
| 5 | *Clarias gariepinus* | African sharptooth catfish | 5 days & 0.15–2.5 mg/L | Reduced pigmentation | Nguyen and Janssen, 2002 |
| 6 | *Cyprinus carpio* | Common carp | 0.2 mg/l | Development Retardation | Ługowska, 2007 |
| 7 | *Oncorhynchus mykiss* | Rainbow trout | 4 days & 0.22 mg/l | Increased mortality | Erickson *et al.*, 2010 |
| 8 | *Oryzias melastigma* | Marine medaka | 7 days & 0.32 mg/l | Abnormalities in Skeletal and vascular system | Wang *et al.*, 2020 |
| 9 | *Fundulus heteroclitus* | Mummichog | 50 days & 0.0005 –0.004 mg/l | Deformities in Vertebral column | Mochida *et al.*, 2008 |
| 10 | *Odontesthes bonariensis* | Silver catfish bagre | 10 days & 22, 220 µg/l | Reduced survivability | Gárriz and Miranda, 2020. |
| 11 | *Leuciscus idus* | Ide | 21 days & 0.1 mg/l | Vertebral Curvatures<br>Yolk sac deformities and in swim bladder<br>shorten body length | Witeska *et al.*,2014 |
| 12 | *Carassius auratu* | Goldfish | 24 hah & 0.1–1 mg/l | Scoliosis<br>Tail curvature | Kong *et al.*, 2013 |
| 13 | *Oryzias latipes* | Japanese rice fish | 6.95–23.1 µg/l &10 days | Spinal cord deformities<br>Abnormal cardiovascular System | Barjhoux *et al.*, 2012 |

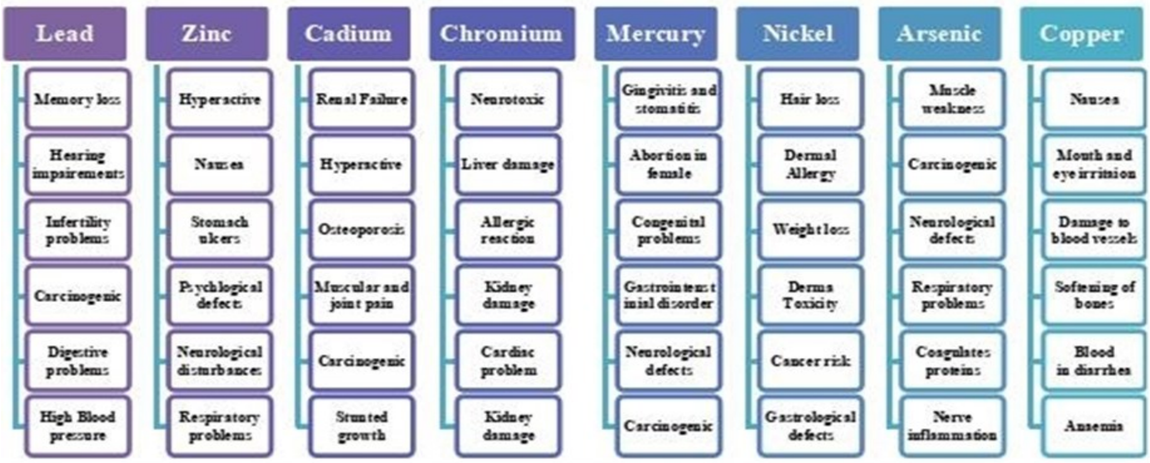


**Fig 3.** *Effect of heavy metals on human health*

**Preventive measures**

Excessive concentrations of heavy metals in aquatic environment are a big problem. Prioritizing heavy metal removal from wastewaters is required. Before release into freshwater or water sources, wastewater must be treated to decrease toxins, pollutants, and unwanted components. The detection technologies for heavy metals must be employed in industries prior to dumping waste into water bodies. To detect the heavy metals in wastewater, a variety of chemical procedures and equipment must be utilized. These industries must be guided under World Health Organization (WHO) standards. Medical waste should be disposed of in safe areas that are away from drainage systems so that it cannot enter the source of contamination. Prior to discharging any effluents into bodies of water, water treatment plants must be established and utilized appropriately. Industrial employees, hospital cleaning personnel, cleaners, and sweepers, among others, should be aware. These individuals will aid in the reduction of garbage from diverse sources. Special awareness initiatives for farmers must be developed to demonstrate the adverse impacts of excessive pesticide use in farming. People should be advised to test their fish for the presence of heavy metals before consuming them. Water sources must be monitored regularly by competent authorities using newer and more modern procedures. Academic education must include methods for educating future generation about heavy metals and their hazardous effects.

## Conclusion

The heavy metals, viz., As, Cd, Pb, Cr, Zn, Cu and Hg are most toxic to all fishes and humans. Though some heavy metals are essential for fish and human organisms, the excess of heavy metals in the aquatic environment exhibits their toxic effects via metabolic interference and mutagenesis. Heavy metal contamination substantially impacts the physiology of various aquatic creatures, significantly alters the hemato-biochemical parameter, resulting in genetic abnormalities and drastically impairs the reproductive performance of fish. In humans, heavy metals causes' memory loss, hearing problems, digestive issues and cancer. The detection technologies for heavy metals must be employed in industries prior to dumping waste into water bodies. To detect the heavy metals in wastewater, a variety of chemical procedures and equipment must be utilized. These industries must be guided under World Health

**Table 7.** Impact of chromium on growth performance of larval and adult fish

| S. No. | Scientific name | Common name | Days of exposure and dose | Deformities recorded in fish | References |
|---|---|---|---|---|---|
| 1 | *Danio rerio* | Zebra danio | 4 days & 50, 500 mg/l | Embryo mortality<br>Increase heart rate | Benaduce *et al.,* 2008 |
| 2 | *Clarias gariepinus* | African sharp-tooth catfish | 5 days & 11–114 mg/l | Body axis become abnormal, Survivability become reduced | Gárriz and Miranda, |
| 3 | *Odontesthes bonariensis* | Silver catfish bagre | 10 days & 4, 40 µg/l | Morphological alteration | Nguyen and Janssen, 2002 |

**Table 8.** Impact of zinc on growth performance of larval and adult fish

| S. No. | Scientific name | Common name | Dose and days of exposure | Deformities recorded in fish | References |
|---|---|---|---|---|---|
| 1 | *Danio rerio* | Zebra danio | 4 days & 50, 500 mg/l | High mortality<br>Increase Heart rate | Benaduce *et al.,* 2008 |
| 2 | *Melanotaenia fluviatilis* | Murray River rainbow fish | 2 h & 0.33–33.3 mg/ l | Deformities in Spinal cord | Williams and Holdway, 2000 |
| 3 | *Pagrus major* | Red sea-bream | 10 days & 0.1, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0, 2.5mg/l | Visceral hemorrhage<br>High mortality<br>Abnormal pigmentation | Huang *et al.,* 2010 |
| 4 | *Odontesthes bonariensis* | Silver catfish bagre | 10 days & 211, 2110 µg/ L | Less survival | Gárriz and Miranda, 2020. |

Organization (WHO) standards.

## Conflict of interest

The authors declare that they have no conflict of interest.

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