Review Article

Bioaccumulation of heavy metals in various tissues of fish and their Human health risk assessment

Abstract

Heavy metals are used in a wide range of industries, agriculture, food processing, and domestic applications. Metals are unusual among industrial and environmental contaminants in that they are not generated or damaged by humans, but rather transported and changed into a variety of goods. The purpose of this review study is to look at the varied effects of heavy metals on aquatic organisms. Polluted locations that receive effluents from industrial, agricultural, municipal, and household garbage. Fe > Zn > Cu > Mn > Cd > Pb > Cr > Ni > Hg > As were the metals in order of abundance. The majority of research concluded that important metals (Zn, Fe, Mn , and Cu,) are abundant in aquatic species, whereas non-essential metals are few. Fish and aquatic creatures are utilized as bio-monitoring species in heavy metal contamination, according to this review. Such research, both in relations of human health and the assessment of metal contamination in aquatic environments, should be ongoing.

Keywords: Metals, Pollution, Species, Human health and Bio-monitoring

Introduction

Toxic contaminants, such as heavy metals, emitted from point and nonpoint sources have a significant impact on the aquatic ecosystem's health and ecological integrity. In the last few decades, poisoning of aquatic ecosystems has become a major environmental concern (Maurya and Malik 2016b). “In recent years, global fish consumption has increased in tandem with growing awareness about the nutritional and medicinal benefits of fish. Fish is a good supply of critical vitamins, minerals, unsaturated fatty acids, and protein, in addition to being a good source of protein” (Medeiros et al. 2012).

- Bioaccumulation may thus be influenced by sources of food, the physical condition of the fish, the species' toxicological dynamics. Their toxicity, extended persistence, biomagnification and bioaccumulation in the food chain, metals in higher quantities pose a major concern. Fish are the important bio-monitors in aquatic systems for determining the level of metal pollution. They have a number of advantages when it comes to characterising the properties of aquatic systems and evaluating habitat change. Furthermore, because fish are at the bottom of the aquatic food chain, they may store metals and pass them on to humans through food, resulting in chronic or acute disorders. Fish are important in the human diet because they provide a lot of protein. Numerous research on hazardous chemicals and metal contamination in edible fish species have been conducted. Heavy metals can enter fish tissues through five different mechanisms. Food is ingested by the gills, skin, and vocal cavities, as well as water and integument intake. Metals are absorbed into the bloodstream and distributed to different organs for storage or disposal. The level of trace metals in various organs is utilised as a measure of metal pollution in an ecosystem, and it's a useful tool for determining an organism's health. Heavy metals can enter fish tissues through five different mechanisms. Heavy metals can enter fish tissues through five different mechanisms. Food is ingested by the gills, skin, and vocal cavities, as well as water and integument intake). Metals are absorbed into the bloodstream and distributed to different organs for storage or disposal. The level of trace metals in different organs is utilised as a measure of metal pollution in an ecosystem, and it's a useful tool for determining an organism's health. Fish are especially vulnerable to pollution because they feed and dwell in aquatic environments, where they are unable to avoid the damaging effects of contaminants. Fish are more susceptible to numerous toxicants than invertebrates, making them an ideal investigation subject for determining biome health (Adams and Ryon 1994). Heavy metals are present in a wide range of man-made and natural environments (Bauvais et al. 2015; Gupta et al. 2015; Yadav et al. 2017a). Cadmium (Cd), lead (Pb), chromium (Cr), copper (Cu) and zinc (Zn), were among the heavy metals studied in this study, all of which are essential in very small amounts for the proper functioning of many biotic systems. Pb and Cd have been shown to have negative impacts on biological systems. The goal of present research was to examine at the accumulation of heavy metals in chosen fish species, also assess the risk to human health. The fish species were collected from several locations along the Ganga River in Kanpur, Allahabad, and Varanasi. Respiratory difficulties and consequences, lung function, and alterations in the nasal mucosa were all linked to occupational exposure to chromium, cadmium, copper and lead. Chronic lung inflammation was discovered during a histological analysis of respiratory tract tissues. Heavy metal toxicity has negative consequences not just for humans, but also for aquatic, animals, and plants microbes (Yadav et al. 2018). The absorbed dose, the way of exposure, and the length of exposure (chronic or acute) all effect metal toxicity. This can be a reason of various of problems, as well as excessive damage from oxidative stress caused by free radical formation). Acute poisoning can take place as a result of deliberate ingesting of arsenic in the circumstance of suicidal attempts or unplanned consumption by youngsters. Lead is a highly dangerous heavy metal that interferes with a range of plant physiological systems, and it serves no biological role, unlike other metals such as zinc, copper, and manganese. High doses can cause mortality within 2–4 weeks of commencement of symptoms. Even at modest concentrations, this causes significant metabolic changes in photosynthetic capability and, as a result, a substantial inhibition of plant development .

Table 1: Heavy metals permissible concentration ppm in water.

Heavy metals	**Limiting concentration in water (ppm)**
Aluminum	0.05 - 0.2
Arsenic	0.01
Mercury	0.002
Lead	0.015
Chromium	0.1

ppm= part per million

CONTAMINATIONS OF HEAVY METALS IN WATER:

Heavy metal contamination in water causes alter the aquatic environment chemical components, which in turn affects fish behaviour, cell structures, ionic balance physiological, and bloodstream patterns , carbohydrate metabolism and liver function). Anthropogenic activities and home wastewater have already been shown to be significant resources of heavy metal, contributing to the constantly rising metallic pollution in aquatic environments in maximum parts of the biosphere. Increased heavy metal pollution in freshwater and marine habitats is a result of recent development and developments in the agriculture sector, industrialisation, and urbanisation. Anthropogenic activities such as smelting and mining), burning of fossil fuel refining, pesticide use in agriculture, release and removal of local and municipal wastes , sewage irrigation in more or less countries), urea application and fertilizer, dust contribute to blowout the levels and concentrations of hazardous heavy metals in the aquatic environments. Table 1 summarises the key resources of heavy metal. Metals are distributed into two classes: biologically essential and non-essential. Essential metals (e.g., iron (Fe), zinc (Zn), copper (Cu), (chromium (Cr), nickel (Ni), molybdenum (Mo) and cobalt Co)) have identified for biological role, and their toxicity rise with growing levels and concentration of these metals. Nonessential metals (e.g., mercury (Hg), lead (Pb), aluminium (Al) and cadmium (Cd)). An essential metal deficit can have negative health consequences, but high quantities of necessary elements can have negative consequences that are comparable to or more bad than those affected by non-essential metals. Zn, Cu, Cr, Pb, Hg, Cd, Ni, Mo, Co, and Sn are widely researched and detected heavy metals in fish and other aquatic creatures in many researches.

HEAVY METAL AND HUMAN HEALTH:

Humans are mostly exposed to heavy metals with the consumption of contaminated food. Heavy metal contamination in commercial fish can endanger human health. As a result, it is critical to understand the amount and absorption of heavy metal concentration in aquatic organisms in order to confirm that they do not constitute a health risk to humans and that concentrations remain within allowed limits. Environmentalists are increasingly recognizing heavy metal pollution as a harmful environmental issue, with persistence high levels of toxicity and potential for accumulation inside the human body posing a severe health threat to city dwellers. The extreme allowable concentration of heavy metals in foodstuffs, including other seafood and fish, has been established by a number of organizations and institutions from various countries, including the European Union (EU), the World Health Organization (WHO), and the Food and Agriculture Organization (FAO).According to the European Union (2006), the extreme tolerated limit (MTL) of lead (Pb) in fish edible tissues is 0.3 mg/kg, whereas Cd and Hg were around 0.05-0.30 and 0.5-1.00 mg/kg wet weight, depending on the kind of fish. Heavy metals such as lead, cadmium, and mercury classified as non-essential elements, but even at low concentrations, they are extremely poisonous and dangerous to humans and aquatic organisms. Zn, Mn, Cu, and Ni, additionally, are essential elements because of their crucial roles in biotic systems. The dose-response curve for critical metals is U-shaped because some metals have both shortage and excess copper, both cause fitness problems (Stern et al. 2007).

HEAVY METAL ACCUMULATION AND THE ECOLOGICAL STATUS OF AQUATIC ORGANISMS:

Heavy metal pollution of coastal areas has increased as a result of rapid industrial and agricultural expansion, which has been highlighted as a important environmental concern for fish , invertebrates, and humans). Heavy metals in wastewater are discharged in large quantities into aquatic habitats. These metals can be biomagnified and deposited in large amounts in sediment, water, and aquatic food chains, causing sub lethal effects or mortality in confined fish inhabitants and further aquatic species. Heavy metals like as copper and zinc are required for fish metabolism, whereas lead, cadmium, and mercury not recognized for biological purpose. As a result, it's critical to well know the links between aquatic creatures' ecological condition and metal concentrations, both essential and non-essential. Researchers have focused their attention on heavy metal pollution of sediment and water in the Karachi Coast.

Heavy metal exposure in natural fish populations

The investigations of natural fish populations' contact to heavy metals have not been accompanied with controlled laboratory environments and therefore care in facts are important parameters (like the metal's exact absorption, the possible synergistic effect of other pollutants current in that zone etc.) is missing. Those examinations are created on the metal’s tracing mainly on fish materials or secondarily in the sediment or water of the natural habitat. In terms of fish deformities, it is now widely accepted that they occur more frequently in cultured populations, owing primarily to environmental circumstances and secondarily to other variables such as general husbandry, genetics, , and so on. The frequency of malformations in aquaculture fish inhabitants has been reported as high as 80% in some circumstances. Wild inhabitants are said to be ideal and, as a result, abnormalities free in general. Therefore, when ordinary fish inhabitants bearing deformities are exposed, the primary statement is that there obligation have been – at some level – an contact to definite pollutants (usually heavy metals or organic compounds)

Discussion and Conclusion:

The exact mechanism through which heavy metals cause malformations in fish is unknown, and it appears to be distinct for each metal. propose that Cd disrupts the Ca balance in G. affinis cellular bone tissue, which would lead to hypocalcemia being compensated by increased Ca release from skeletal bone. As a result, the spinal column would grow more fragile and abnormalities would become more common. Cd can also cause bone abnormalities by disrupting bone remodeling and mineralization by negatively influencing the bone matrix or bone tissue itself. Cd may inhibit the crystallization of hydroxyapatite, the main bone mineral, as well as osteoblast activity. Cadmium-induced body abnormalities in fish were linked to a decline in Ca and P levels, according to Muramoto (1981). The genotoxic activity of Cd and Cu may potentially cause developmental abnormalities. The influence of heavy metals on mitotic divisions has been blamed for the delay in hatching seen in heavy metal exposure.

In the case of fish larvae, a decline in growth affected by cadmium or copper poisoning could be the outcome of a variety of metabolic abnormalities. Couture and Kumar (2003) found that copper and cadmium exposure inhibited mitochondrial enzymatic action and oxidative metabolism in Perca flavescens. Detoxification is a costly metabolic process that may also impede the development of fish exposed to Cu and Cd. Cu and Cd exposures enhanced metallothionein production in O. mossambicus larvae, according to. Additionally, these metals produce ion regulatory abnormalities in fish, which can lead to an increase in the metabolic cost of compensatory osmoregulation, as well as a loss in growth due to the inevitability of an energetic shortfall. According to some writers, heavy metal damaging can also have an indirect effect, with spinal abnormalities resulting from a nutritional shortage as fish bare to heavy metals discontinue feeding (which consequences in vitamin C shortage etc.).

In the case of fish, it is generally known that the earlier the stage, the more vulnerable the organism. A current heavy metals investigation challenges this common belief, showing that the Chinese infrequent sprat (Gobiocypris rarus) was additional susceptible throughout the larval stage than the embryonic stage when exposed to three various heavy metals (Cu, Zn, and Cd). Two previous research on the effects of copper and cadmium on Common carp came to the same conclusion.

In teleost species, skeletal deformities can be caused in one of two techniques: I by altering biological processes essential for sustaining the biochemical reliability of bone, or (ii) by neuromuscular effects, which cause abnormalities deprived of causing a chemical alteration in vertebral composition The vertebral column or its antecedent – in fish growth the notochord, account for the majority of abnormalities documented in fish. The notochord is the basic axial structure that regulates the creation and differentiation of many other tissues. Toxicants that interfere with the notochord's normal growth and differentiation may cause irreversible skeletal malformations, muscle abnormalities, and neurological dysfunction. Uncontrolled muscular spasms can potentially cause axial malformation.

Aside from their harmful side effects, it is well known that certain heavy metals (at specific doses) have a beneficial influence on fish development. Earlier feeding red sea bream (P. major) larvae, examined several amalgamations of Artemia enrichment with manganese (Mn) and zinc both critical metals for fish – and decided that the occurrence of these metals benefits development and skeletal abnormalities.

The toxicity of metals to fish can be affected by environmental issues like water oxygen content, temperature, dissolved, salinity, hardness, alkalinity, and organic carbon. Increases in mineral content (salinity and hardness) lower metal injuriousness, while hypoxic circumstances, temperature rises, and acidity make fish more susceptible to poisoning. Furthermore, interactions between many metals existing in the water may alter the toxicity, resulting in additive, antagonistic effects, or synergistic (Witeska and Jezierska, 2003).

Bao et al. (2008) investigated “the synergistic toxic effects of copper and zinc pyrithione on three marine species and suggested that water quality standards should be designed in such a means that the synergistic effects of the researched metals are taken into account”.

In addition to heavy metals, fish inhabitants face a variety of additional threats. According to Murl , commercial marine fisheries and freshwater fish species have experienced extraordinary reductions around the world, spurring a exploration for the reasons of these decreases and developing worry for the future viability of fishing resources. Overfishing has put a lot of pressure on commercial fishery species, causing fast population losses in some of them.

In addition to eutrophication, alien species introduction, habitat changes, aquatic contamination exposure, and (possibly) the consequences of global climate alteration, fish populations are exposed to extensive range of stressors caused by human activities. Classifying the dangers sat by all aspects now affecting the health and existence of these inhabitants is critical to reversing the present decrease in numerous fish inhabitants and ensuring fruitful management in the future.

There are many investigations on additional contaminants such as selenium and nutritional phases like vitamin shortages in the literature, while there is little data on the influence of heavy metal destroying with specific monitoring of the consequences on the fish. While there have been a number of articles on the subject in recent years, further research into the effects of various heavy metals on numerous fish species is needed. Furthermore, as all – or most – studies evaluate their samples at hatching or a few days later, the precise influence on fish abnormalities has not been explored.

Furthermore, having the precise absorptions (thresholds) overhead which heavy metal pollution creates a harm to the creature (decrease in death or welfare), the aquaculture and fisheries business (via unmarketable fish displaying abnormalities), and, of sequence, the customer's health is critical (over the food chain).

According to Barbee et al. (2013), toxicological investigation has newly shifted from a conventional emphasis on the lethality of toxicants to creatures to a greater importance on pollutants' sub lethal effects. Environmental contaminants' sublethal effects may be latent, making them difficult to detect, but they can have serious ramifications for an individual's long-term development, reproduction, and existence.

Additionally, properly understand the long-term repercussions of heavy metal poisoning on fish organisms, future studies must emphasis on using lesser exposure doses (non-lethal), allowing the fish to reach adulthood (or at least the juvenile stage).

Furthermore, as previously indicated), the occurrence of abnormalities in wild fish inhabitants can be a good indicator of water contamination. The impact of sublethal metal absorptions on fish might provide data about the level of contamination in definite ecosystems, making fish deformities more useful as biomarkers of pollution. To do this, however, tolerant fish species need be used in adding to well-established effect and cause correlations among biomarkers and numerous contaminants

There have been a number of research on wild fish abnormalities, while the majority of them merely assume that the causal factor is most likely the occurrence of heavy metals in the natural habitat. Few publications in recent literature have found a direct link between the occurrence of heavy metals in fish tissues or in the sediment or water of the habitat.

Kessabi et al. (2009) took samples of the Mediterranean killifish, Alphanius fasciatus, from numerous unpolluted and polluted locations off the Tunisian coast and found that deformed specimens (just from the contaminated sampling locations) had greater Cd concentrations in their livers and spinal columns than normal specimens. Furthermore, they found that the bioaccumulation issues of Cd in the liver of distorted fish were much greater than in normal fish, implying that fish's propensity to store large amounts of Cd could be a risk factor for spinal abnormalities. Quantitative RNA biomarkers were utilised in a follow-up investigation in the similar species , and it was proposed that a mutual influence of mutually heavy metals and organic pollutants is what really leads to the occurrence of malformations.

Sun et al. (2009) looked at Tilapia (Oreochromis spp.) inhabitants from various Taiwanese rivers. Many various skeletal abnormalities were observed in the vertebral column, operculum, cranium, jaws and fins. They linked these defects to river contamination from heavy metals (Cr , Hg, Pb, Cu, and Zn) as well as organic substances. There appears to be a tiny association between certain abnormalities and specific contaminants in this study, but nothing is conclusive. According to the authors, Tilapia is more tolerant has additional abnormalities than other species, making it a good biomarker for environmental contamination in general.

In a latest report, high levels of heavy metals (Cd, Cu, and Zn), polycyclic aromatic hydrocarbons (PAHs), and estrogenic compounds detected in the water and sediment of the sample regions were connected to skeletal abnormalities in Mediterranean killifish specimens taken from the Tunisian coast. Distorted specimens were found up to 18 percent of the time in a contaminated sample location, but not more than 5% in the uncontaminated reference area. Because the writers did not differentiate among the various xenobiotics observed, only the direct consequence of heavy metals is unidentified.

Skinner et al. (1999) came up with the notion of exposing hatched eggs of two species (Japanese medaka, O. latipes, and Inland Silverside, Menidia beryllina) to various percentages of storm water collected in an urban area and tainted with numerous contaminants (including Cd, Cu, Pd, Zn, Cr and Ni). Their results revealed that polluted storm water caused a variety of abnormalities in both species' hatched larvae, the most notable of which were aberrant swimbladder inflation, spine curvatures, and pigmentation loss. The occurrence of substantial unfavourable impacts did not associate significantly with any of the different contaminants found in the storm water in this investigation, but it did correlate with whole toxic metal contaminants in the samples (especially Cd, Zn, Cu, and Pb).

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