



Heavy Metals: A Desolation for Fishes

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ABSTRACT

The review highlights the influences of heavy metals on fishes. Through bioaccumulation, these heavy metals get stored in different organs of the fishes and gets biomagnified at the higher trophic levels and eventually reach humans. Fishes are usually contemplated as the bioindicators of heavy metal contamination. Heavy metal also ensues the instability of the ecosystem, resulting in the deprivation of the biodiversity at all the levels. Heavy metals perturb various behavioural and physiological changes in the fishes, eventually leading to their death. Heavy metals also pose enormous health effects on humans including cancer.

KEYWORDS: Heavy metals, Fishes, Bioaccumulation, Effects, Toxicity

1. INTRODUCTION

Pollution of the aquatic environment by heavy metals can be contemplated as a prime commination to all the aquatic organisms including fishes (ECDG Report, 2000). Heavy metal contamination is usually the most treacherous chemical pollution in water (Sönmez et al., 2012a). Heavy metals have the potential to cause ecological and health concern by virtue of their toxicity, bioaccumulation and biomagnification at higher trophic levels. Heavy metal ensues the instability of the ecosystems and also influence human health (IARC, 1980).

Fishes, being the top carnivores in the aquatic environment, are badly influenced by the heavy metal contamination (Rashed, 2001). The past and present pollution load in the aquatic environment can be perceived by the concentrations of heavy metals in the fishes (Ravera et al., 2003). Thus, various fishes are reliable bioindicators of heavy metal contamination and assessing the changes in their surrounding habitats (Svobodova, 2004). Freshwater fishes usually migrate to less contaminated areas or die off when their habitat is being tainted by heavy metals and this process muddle the food chains (Rashed, 2001). Heavy metals when present in elevated concentrations have both acute and chronic effects on fishes (Kotze et al., 1999). Five possible direct routes of heavy metal uptake in fishes were proposed by Nussey (2000) viz food, suspended particles, gills, integument, water intake and indirectly through consumption of other contaminated organisms such as small fishes, invertebrates, vegetation etc. After ingestion, these heavy metals enter their target organs for storage or excretion through body fluid of the fishes (Tarrio et al., 1991). Their reserves in the organs depend upon their way of exposure or their concentration levels in the surrounding water (Tarrio et al., 1991 & Alam et al., 2002). Several factors ascertain heavy metal accumulation in distinct parts of the fish body viz solubility of water, feeding behaviour, age, reproductive state, species, size, health of

fish, habitat etc (Perguini et al., 2014 & Anand et al., 2017). Gills, liver and kidneys are the major repositories of heavy metal accumulation. Enormous amount of heavy metal accumulation takes place in the liver (Wepener et al., 2001). Fishes present in the aquatic environment with low concentration of heavy metals don't reflect any signs of disease, but even this small amount of pollution reduces the fecundity of the fish population and in long term, leads to their extinction (Sankar et al., 2007).

Several perilous effects on fishes due to heavy metal contamination on fishes include deformities in skeleton, problems in metabolism, kidney disorders, liver damage, infertility, behavioural and physiological changes (Fatima et al., 2020).

2. SOURCES OF HEAVY METALS INTO THE AQUATIC ENVIRONMENT

Heavy metals can enter into the aquatic environment through various sources, both anthropogenic and natural and gets bioaccumulated in the food chains of various plants and animals (Al-Yousuf et al., 2000).

Prominent sources are (ATSDR, 2007)

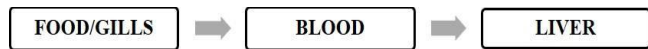
- Urban run-off
- Industrial waste waters
- Mining wastes
- Landfill leaches
- Municipal wastewater

2.1 Heavy Metal uptake by Fishes

Fishes or aquatic organisms uptake heavy metals in two phases: firstly through rapid adsorption and later on its entry into the cell occurs through slower transport, either by

diffusion or by active transport (Crist et al., 1988 and Brezonik et al., 1991).

The route of heavy metals uptake and absorption is



3. HEAVY METALS AND THEIR EFFECTS

Heavy metals are those chemical elements having high density and are toxic even when present at low concentrations and get accumulated in the soft tissues of the body without even getting metabolized (Baby et al., 2010).

Toxicity of the heavy metals in fishes depends upon many factors (Afshan et al., 2014):

- Sex
- Age
- Species
- Season
- Feeding behaviour
- Habitat
- Temperature
- pH
- Alkalinity of water

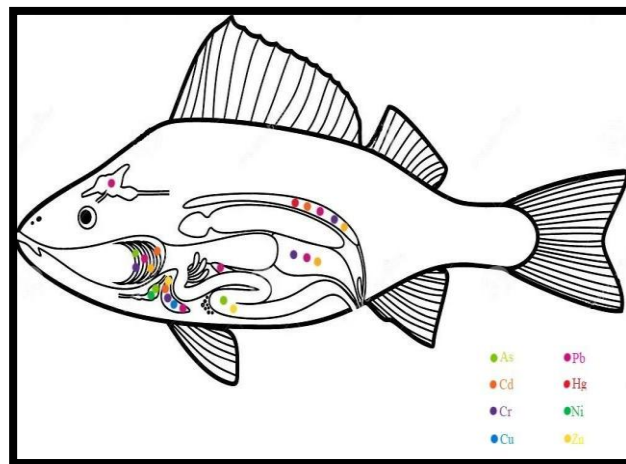
3.1 Effects of Heavy Metals on Fishes

U.S. “Environmental Protection Agency” (EPA) in cooperation with the ‘Agency for Toxic Substances and Disease Registry’ (ATSDR), Atlanta, Georgia has reported ‘Top 20 Hazardous substances’. Among these, heavy metals like Arsenic (As), Lead (Pb) and Mercury (Hg) holds the 1st, 2nd and 3rd position in the study whereas Cadmium (Cd) is ranked at the 7th place.

Heavy Metals are present in the water bodies naturally at a level not toxic to the aquatic life (Fatima et al., 2020) [Table Number 1].

Heavy metals cause various adverse effects on fishes viz decrease in fitness level, starvation, shocks, hypoxic conditions, reproductive interference, cancer and finally death (Levesque et al., 2002; Arslan et al., 2006; Govind and Madhuri, 2014). By interfering with the metabolic, biochemical and physiological functions, heavy metal contamination affects growth, development and reproduction (Heath, 1995; Çiftçi et al., 2017). Despite being carcinogenic, heavy metal contamination also pose genotoxic effects on the fishes, directly or indirectly (Snow, 1992; Bolognesi et al., 1999). Both estrogenic and androgenic secretions are curtailed on exposure to heavy metals toxicity (Ebrahimi and Taherianfard, 2011). Enormous contagious diseases become prevalent in fishes due to immune system flaws caused by toxic nature of heavy metals. These changes bare fishes to the risk of mortality (Abel and Papoutsoglou, 1986; Çelik, 2006; Akgün et al., 2010; Larsson and Haux, 1985; Nemesok and Huphes, 1988; Sehgal and Saxena, 1986; Al-Weher, 2008).

Figure shows various heavy metals affecting different organs of fish and are also discussed in following sections. Detrimental effects of these heavy metals along with some other contaminants on fish community can be demonstrated as:



Effects of Arsenic: Barnes et al., 2002 and Gornati et al., 2002 cited ‘Arsenic’ as a genotoxic agent. Arsenic intake in the fish occurs through gills as well as adulterated feeds (Ahmed et al., 2008). Sudden fish death occurs during acute exposure to arsenic because of increase in mucous secretion, altered structure of gill epithelium and suffocation whereas chronic exposure to arsenic may lead to several pathological changes and itself gets accumulated in various tissues of the fish body (Hughes et al., 2002).

Arsenic causes oedema in the gills of *Odontesthes bonariensis* (Puntorero et al., 2018). Exposure to sodium arsenite in *Channa punctata* causes apoptosis of the heart muscle and intestinal mucosal and submucosal enlargement (Hossain, 2012). In *Oryzias latipes*, complete ceasation in development can be observed on exposure to arsenic toxicity (Ishaque et al., 2004).

Table 1. Showing the concentration of Heavy Metals in marine and freshwater

Heavy Metal	Marine Water [Concentration in µg/l]	Fresh Water [Concentration in µg/l]
Arsenic (As)	1.7	10
Cadmium (Cd)	0.1	0.1
Chromium (Cr)	0.3	1.0
Copper (Cu)	0.3	3
Lead (Pb)	0.03	3
Mercury (Hg)	0.03	0.1
Nickel (Ni)	0.6	0.5
Zinc (Zn)	5	15

Effects of Cadmium: Due to its high rate of bioaccumulation, cadmium is known to be one of the most toxic heavy metals for fishes (Garai et al., 2021). Cadmium is accumulated mostly in liver, kidney, gills and its accumulation is found to be lowest in the skin (Handy R, 1992). Fish can take cadmium directly through gills, skin as well as gastrointestinal tract (Zhang et

al., 2017). Cadmium is known to cause severe toxicity in fishes by inhibiting the electron transport chain in mitochondria and reviving the production of reactive oxygen species (Wang et al., 2004).

Exposure of cadmium even at low level causes DNA damage in *Cyprinus carpio* (Jia et al., 2011). Cadmium works as an endocrine disrupter and it inhibits vitellogenesis in *Oncorhynchus mykiss* (Vettillard and Bailhache, 2005). *Puntius conchonius* shows the symptoms of hyperglycemia (on exposure to high cadmium concentrations) and hypoglycemia (when exposed to low cadmium concentrations) (Çelik et al., 2008). Haemoglobin and RBCs level decrease during cadmium toxicity in *Oreochromis mossambicus* (Ruparella et al., 1990; Çelik, 2006).

Effects of Chromium: Chromium exists in two forms, trivalent (Cr+3) which is a stable one and hexavalent (Cr+6), being the most toxic as it has the ability to cross the cell membranes (Ram et al., 2019). Chromium uptake by fishes is mainly through gills or gastrointestinal tract (Rashed,2001). Chromium toxicity in fishes is species specific and depends upon many factors such as age, phase of development, pH, temperature etc (Sekar et al., 2016).

Sublethal concentration of Cr+6 in *Oreochromis massambicus* causes histopathological changes in gills, gonads, kidneys and liver (Ackermann, 2008). *Labeo rohita* shows a decrease in protein content in many organs viz muscle, liver and gill on accumulation of chromium in the gills (Vutukuru SS, 2003). In *Colisa fasciatus*, liver glycogen gets depleted when exposed to chromium toxicity (Nath and Kumar, 1987).

Table 2. Showing some histopathological conditions caused due to Heavy Metal toxicity

Heavy Metals	Histopathological Conditions
Arsenic	Apoptosis
Cadmium	Inhibition of Vitellogenesis
Chromium	Changes in histology of gills, gonads, kidneys and liver
Copper	Apoptosis, Larval mortality
Lead	Lipid cholesterol decrease in brain and gonads
Mercury	Necrosis of kidney tubules, Decrease in fecundity
Nickel	Skin lesions
Zinc	Decrease in fecundity

Effects of Copper: Copper uptake by fish is through die or ambient exposure. Various environmental factors affect copper toxicity viz hardness of water, anions, pH etc (Dang et al., 2009). Reduced growth, life span shortening, lessen immune response etc are some of the effects caused by chronic exposure to copper in fishes.

Teleost fish, *Oreochromis niloticus*, when exposed to copper, exhibited induction in apoptosis (Eyckmans et al., 2011). Liver tissues are found to be affected on exposure to copper sulfate (Gainey et al., 1990). Appetite, navigation and

awareness of surroundings are likely to be affected by copper contamination as it affects the sense of olfaction in fishes (Solomon, 2009). Copper can cause larval mortality and deformities of the body in the goldfish *Carassius auratus* (Kong et al.,2013). Muscle and liver glycogen level decrease and serum glucose levels increase on exposure to copper toxicity in *Oncorhynchus mykiss*, *Heteropneustes fossilis* and *Clarias lazera* (Singh and Reddy, 1990; Dethloff et al., 1999; Arslan et al., 2006).

Effects of Lead: Lead enters the fish body through diet via gills causing two distinct responses. Chronic lead toxicity in *Clarias gariepinus* causes pathological effects viz epithelium damage, desquamation and aneurism (Olojo et al., 2005). Lead is bioaccumulated in the fish mainly in the liver, spleen, kidney and gills (Creti et al., 2010).

Exposure to lead nitrate in *C. batrachus* lessens the levels of lipid cholesterol in brain and gonadal organs (Ghosh et al., 2006). Çiftçi et al. (2017) conducted a study on Nile tilapia (*Oreochromis niloticus*) and concluded that lead decrease HSI (Hepatosomatic Index) in the same. Ovarian tissue showed some histological changes in *Mastacembelus pancalus* on exposure to lead toxicity (Biswas et al., 2016).

Effects of Mercury: The mercury uptake in fishes occurs through ingestion. Through circulation, mercury reaches its target organ i.e. liver. The site of deposition, detoxification and reproportionment of mercury is the fish liver (Hansen et al., 2011). Mercury shows high affinity to proteins, therefore, fish muscle accumulates the highest percentage (approximately 90%) of the total mercury in the fish body (Basu et al., 2017). The toxic form of mercury which affects the fishes is ‘Methylmercury’, an environmental contaminant which have known to cause Minamata Disease of waterways in Japan and human poisoning in Iraq (Bakir et al.,1973 and Tsubaki and Irudayaraj, 1977).

The kidney of *Clarius batrachus* shows the symptoms of kidney damage and necrosis of kidney tubules when exposed to mercurial compounds (Kirubakaran et al., 1988). Mercury toxicity is also shown to disrupt functions of male reproductive system in *Gymnotus carapo* viz germ cell reduction, proliferation of interstitial tissue, disorganization of seminiferous tubules etc (Vergilio et al., 2013).

Effects of Nickel: Nickel gets accumulated in the body of the fish without getting magnified along the trophic levels (Pandey et al., 2014). Abnormality in swimming behaviour, skin lesions, disorders in respiratory systems etc are observed on exposure of nickel to Nile Tilapia (Ibrahim et al., 2008).

Cyprinus carpio, on being exposed for a short term to nickel, causes stress reaction along with other behavioural changes (Al Ghanim, 2011). High amount of nickel gets bioaccumulated causing lymphopenia and leucopenia in *Tilapia nilotica* (Garai et al., 2021). *Carassius auratus*, *Prochilodus lineatus* and *Fundulus heteroclitus* undergo oxidative stress on exposure to nickel toxicity (Kubrak et al., 2013; Blewett and Wood, 2015; Palermo et al., 2015). Nickel contamination also affects locomotion in *Carassius auratus* and *Neogobius melanostomus* (Ellgaard et al., 1995; Leonard et al., 2014; Blewett and Leonard, 2017).

Effects of Zinc: Zinc intake by fish occurs through the gastrointestinal tract and gills (Gaw et al., 2016). Toxicity of zinc in fishes is found to be species specific and this differs among the distinct advancing stages of the fish. Various

environmental factors viz temperature, water hardness, concentration of dissolved oxygen etc influence the toxic effect of zinc on fishes. Zinc, when present at an acute concentration, destroys tissues of the gill and eventually kills the fish and when present long-term leads to fish death due to chronic stress to the fish (Skidmore, 1964).

Table 3. Showing the effects of Heavy Metals on Fish species

Heavy Metal	Fish species affected
Arsenic	<i>Channa punctata</i> <i>Clarias batrachus</i> <i>Clupea sprattus</i> <i>Engraulis encrasicolus</i> <i>Merlangius merlangus</i> <i>Mugil cephalus</i> <i>Mullus barbatus</i> <i>Oreochromis niloticus</i> <i>Oreochromis massambicus</i> <i>Odontesthes bonariensis</i> <i>Oryzias latipes</i> <i>Pomatomus saltor</i> <i>Salmo gairdneri</i> <i>Sarda sarda</i> <i>Sprattus sprattus</i> <i>Trachurus trachurus</i>
Cadmium	<i>Anguilla rostrata</i> <i>Capoeta tinca</i> <i>Caranx rhoncus</i> <i>Chondrostoma regium</i> <i>Clarias gariepinus</i> <i>Clupea sprattus</i> <i>Cyprinus carpio</i> <i>Engraulis encrasicolus</i> <i>Epinephelus areolatus</i> <i>Galaxius fasciatus</i> <i>Glossogobius giuris</i> <i>Gobiocypris rarus</i> <i>Labeo rohita</i> <i>Lepomis gibbosus</i> <i>Leuciscus cephalus</i> <i>Lutjanus russelli</i> <i>Merlangius merlangus</i> <i>Mugil cephalus</i> <i>Mullus barbatus</i> <i>Onchorhynchus mykiss</i> <i>Oreochromis niloticus</i> <i>Pegusa lascaris</i> <i>Perca flavescens</i> <i>Pimephales promelas</i> <i>Pleuronectes platessa</i> <i>Puntius chola</i> <i>Puntius sophore</i> <i>Puntius ticto</i> <i>Onchorhynchus mykiss</i> <i>Sarda sarda</i> <i>Saurida undosquamis</i> <i>Scomber japonicus</i> <i>Scomber scombrus</i> <i>Sparus aurata</i> <i>Sparus sarba</i> <i>Sprattus sprattus</i> <i>Trachurus trachurus</i>

Chromium	<i>Channa punctata</i> <i>Clarias gariepinus</i> <i>Clupea sprattus</i> <i>Colisa fasciatus</i> <i>Coregonus lavaretus</i> <i>Cyprinus carpio</i> <i>Epinephelus areolatus</i> <i>Engraulis encrasicolus</i> <i>Glossogobius giuris</i> <i>Labeo rohita</i> <i>Lutjanus russelli</i> <i>Merlangius merlangus</i> <i>Mugil cephalus</i> <i>Mullus barbatus</i> <i>Onchorhynchus mykiss</i> <i>Oncorhynchus tshawytscha</i> <i>Oreochromis massambicus</i> <i>Pomatomus saltor</i> <i>Puntius chola</i> <i>Puntius sophore</i> <i>Puntius ticto</i> <i>Salmo gairdneri</i> <i>Saurida undosquamis</i> <i>Scomber scombrus</i> <i>Sparus aurata</i> <i>Sparus sarba</i> <i>Sprattus sprattus</i> <i>Tilapia sparrmanii</i> <i>Trachurus trachurus</i>
Copper	<i>Capoeta tinca</i> <i>Caranx rhoncus</i> <i>Carassius auratus</i> <i>Chondrostoma regium</i> <i>Clupea sprattus</i> <i>Cyprinus carpio</i> <i>Epinephelus areolatus</i> <i>Fundulus heteroclitus</i> <i>Glossogobius giuris</i> <i>Gobiocypris rarus</i> <i>Labeo rohita</i> <i>Lepomis gibbosus</i> <i>Leuciscus cephalus</i> <i>Lepomis macrochirus</i> <i>Lutjanus russelli</i> <i>Menidia menidia</i> <i>Merlangius merlangus</i> <i>Mugil cephalus</i> <i>Mullus barbatus</i> <i>Onchorhynchus mykiss</i> <i>Oreochromis niloticus</i> <i>Oreochromis massambicus</i> <i>Pegusa lascaris</i> <i>Pomatomus saltor</i> <i>Puntius chola</i> <i>Puntius sophore</i> <i>Puntius ticto</i> <i>Perca flavescens</i> <i>Sarda sarda</i> <i>Saurida undosquamis</i> <i>Scomber japonicus</i> <i>Scomber scombrus</i> <i>Sparus aurata</i> <i>Sparus sarba</i>

	<i>Sprattus sprattus</i> <i>Trachurus trachurus</i>
Lead	<i>Acipenser sinesis</i> <i>Caranx rhoncus</i> <i>Capoeta tinca</i> <i>Chondrostoma regium</i> <i>Clupea sprattus</i> <i>Cyprinus carpio</i> <i>Engraulis encrasicholus</i> <i>Epinephelus areolatus</i> <i>Glossogobius giuris</i> <i>Pegusa lascaris</i> <i>Pimephales promelas</i> <i>Clarius batrachus</i> <i>Clarias gariepinus</i> <i>Labeo rohita</i> <i>Lepomis gibbosus</i> <i>Leuciscus cephalus</i> <i>Lutjanus russelli</i> <i>Mastacembelus pancalus</i> <i>Merlangius merlangus</i> <i>Mugil cephalus</i> <i>Mullus barbatus</i> <i>Onchorhynchus mykiss</i> <i>Oreochromis niloticus</i> <i>Pomatomus saltor</i> <i>Puntius chola</i> <i>Puntius sophore</i> <i>Puntius ticto</i> <i>Sarda sarda</i> <i>Saurida undosquamis</i> <i>Scomber japonicus</i> <i>Scomber scombrus</i> <i>Sparus aurata</i> <i>Sparus sarba</i> <i>Sprattus sprattus</i> <i>Tinca tinca</i> <i>Trachurus trachurus</i>
Mercury	<i>Clupea sprattus</i> <i>Cyprinus carpio</i> <i>Engraulis encrasicholus</i> <i>Gambusia affinis</i> <i>Fundulus heteroclitus</i> <i>Merlangius merlangus</i> <i>Mugil cephalus</i> <i>Mullus barbatus</i> <i>Notemigonus crysoleucas</i> <i>Oreochromis niloticus</i> <i>Pimephales promelas</i> <i>Pomatomus saltor</i> <i>Sarda sarda</i> <i>Scomber scombrus</i> <i>Trachurus trachurus</i>

Nickel	<i>Capoeta tinca</i> <i>Channa punctatus</i> <i>Chondrostoma regium</i> <i>Clarias batrachus</i> <i>Clarias gariepinus</i> <i>Clupea sprattus</i> <i>Cyprinus carpio</i> <i>Danio rerio</i> <i>Epinephelus areolatus</i> <i>Engraulis encrasicholus</i> <i>Glossogobius giuris</i> <i>Gymnotus carapo</i> <i>Labeo rohita</i> <i>Lepomis gibbosus</i> <i>Leuciscus cephalus</i> <i>Lutjanus russelli</i> <i>Merlangius merlangus</i> <i>Mugil cephalus</i> <i>Mullus barbatus</i> <i>Onchorhynchus mykiss</i> <i>Pomatomus saltor</i> <i>Puntius chola</i> <i>Puntius sophore</i> <i>Puntius ticto</i> <i>Poecilia reticulata</i> <i>Oreochromis niloticus</i> <i>Sarda sarda</i> <i>Saurida undosquamis</i> <i>Scomer scombrus</i> <i>Sparus aurata</i> <i>Sparus sarba</i> <i>Sprattus sprattus</i>
Zinc	<i>Capoeta tinca</i> <i>Caranx rhoncus</i> <i>Channa punctatus</i> <i>Chondrostoma regium</i> <i>Cyprinus carpio</i> <i>Clupea sprattus</i> <i>Epinephelus areolatus</i> <i>Engraulis encrasicholus</i> <i>Gobiocypris rarus</i> <i>Glossogobius giuris</i> <i>Fundulus heteroclitus</i> <i>Labeo rohita</i> <i>Lepomis gibbosus</i> <i>Leuciscus cephalus</i> <i>Lutjanus russelli</i> <i>Merlangius merlangus</i> <i>Mugil cephalus</i> <i>Onchorhynchus mykiss</i> <i>Pegusa lascaris</i> <i>Puntius chola</i> <i>Puntius sophore</i> <i>Puntius ticto</i> <i>Mullus barbatus</i> <i>Saurida undosquamis</i> <i>Sarda sarda</i> <i>Scomber japonicus</i> <i>Sparus aurata</i> <i>Sparus sarba</i> <i>Sprattus sprattus</i> <i>Tilapia nilotica</i> <i>Trachurus trachurus</i>

Murugan et al., 2008 reported in *Channa punctatus* the sequence of zinc deposit in different organs of fish as: Liver>Kidney>Intestine>Gill>Muscle. Zinc chloride is known to cause hatching delay, defect in growth and malformation of the skeleton in Zebrafish embryos (Salvaggio et al., 2016).

Behavioural changes along with changes in movement pattern viz less activity, easily frightened etc can be seen in exposure of zinc to *Phoxinus phoxinus* (Bengtsson, 1974).

Table 4. Showing the effects of Heavy metals on Behaviour and Physiology of some Fish species

Heavy Metal	Behaviour affected	Fish Species	Source
Arsenic	Learning	<i>Carassius auratus</i>	Sarasamma et al., 2018
Cadmium	Food and foraging	<i>Abramis brama</i> <i>Cyprinus carpio</i>	Gerasimov et al., 1991 Kasumyan & Morsi, 1998
	Neurology Musculature	<i>Danio rerio</i>	Sarasamma et al., 2018
Copper	Locomotion	<i>Carassius auratus</i> <i>Cyprinus carpio</i> <i>Danio rerio</i> <i>Onchorhynchus mykiss</i> <i>Salmo trutta</i>	Beaumont et al., 1955; De Boeck et al., 2006
	Avoidance	<i>Carassius auratus</i> <i>Onchorhynchus tshawytscha</i> <i>Salmo salar</i>	Kleerekoper et al., 1972 Hansen et al., 1999 Sprague, 1964
	Olfaction	<i>Fundulus heteroclitus</i> <i>Menidia menidia</i>	Gardener & Roche, 1973
Lead	Learning	<i>Carassius auratus</i>	Sarasamma et al., 2018
	Neurology Musculature	<i>Danio rerio</i>	Sarasamma et al., 2018
Mercury	Food and Foraging	<i>Cyprinus carpio</i>	Kasumyan & Morsi, 1998
	Learning	<i>Carassius auratus</i>	Sarasamma et al., 2018
Nickel	Neurology Musculature	<i>Chrysichthys nigrodigitatus</i> <i>Tilapia zilli</i>	Olowu et al., 2010
Zinc	Food and foraging	<i>Cyprinus carpio</i> <i>Gambusia holbrooki</i> <i>Onchorhynchus kisutch</i>	Kasumyan & Morsi, 1998 Falcão et al., 2019 Bowen et al., 2006
	Neurology Musculature	<i>Clarias gariepinus</i> <i>Danio rerio</i>	Farombi et al., 2007 Sarasamma et al., 2018
	Olfaction	<i>Poecilia vivipara</i>	Leitemperger et al., 2019

4. EFFECTS OF BIOACCUMULATION OF HEAVY METALS IN HUMANS

Fishes accumulate enormous amounts of heavy metals within themselves. Humans, being the top carnivores amass heavy metals when consume fishes. Health issues of some of the heavy metals on humans are described as follows- (Afshan et al., 2014 & Pandey et al., 2014 & Isangedighi et al., 2019 & Catalano et al., 2020).

Table 5. Showing various health issues in Humans due to the following Heavy Metals

Heavy Metals	Health Issues in Humans
Arsenic	Hyperkeratosis Pigmentation Skin lesions Diabetes Cardiovascular diseases Cancer
Cadmium	Osteoporosis Osteomalacia Kidney dysfunction Hypertension Weaken immune system Infertility Hepatic cancer

Chromium	Allergic reactions Ulcers Respiratory and Circulatory problems Weaken immune system Genetic problems Hepatic cancer
Copper	Anaemia Liver disorders Kidney damage Stomach irritation Cramps High cholesterol
Lead	Constipation Memory Depression loss High blood pressure Infertility Cancer
Mercury	Abortion Tremors Damage to brain and CNS Contact dermatitis Stroke Autoimmune diseases

Nickel	Skin irritation Lung fibrosis Nose and sinus irritation Contact dermatitis Asthma Respiratory tract cancer
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Zinc	Birth defects Loss of appetite Skin annoyances Stomach cramps Arteriosclerosis Anaemia
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4. CONCLUSION

The heavy metals are toxic not only to the aquatic organisms like fishes but also to the humans. These are toxic even when present at their lower concentrations. Both point and non-point sources add enormous amount of heavy metals into the aquatic environment. Heavy metals plunge into the biogeochemical cycle which leads to toxicity among the animals and the human beings. These not only affect the fishes in many ways but also poses various health risks to humans including cancer.

Heavy metal pollution has created a havoc in the aquatic life around the world. Different measures should be taken to

lessen the entry as well as leakage of the heavy metals in water, this includes pollution control boards to take strict actions when violated and policies need to be updated time to time. Moreover, chemical and biological indicators must be used regularly to put a check on the water pollution. By taking all the necessary measures, we can restore a better and safe environment now and sustain clean water bodies for the future.

5. REFERENCES

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