Heavy Metals Present in Industrial Effluents and Their Effect on Fish: An Overview

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Abstract- ***This review gives a brief account of the toxic effects of heavy metals on fish. In aquatic ecosystem, heavy metals are considered as the most important pollutants, since they are present throughout the ecosystem and are detectable in critical amounts. Heavy metals, such as cadmium, copper, lead, Nickle and zinc are of the most important pollutants which effect aquatic environment and fish. They are extremely hazardous for the health of fish. Most of these heavy metals are characterized by being accumulated in tissues, and lead to the poisoning of fish. These metals can effectively influence the vital operations and reproduction of fish; weaken the immune system, and induce pathological changes. As such, fish are used as bio-indictors, playing an important role in monitoring heavy metals pollution.***

Indexed Terms- ***Aquatic pollution, Bio-indicators, Fish, Heavy metals,***

I. INTRODUCTION

At present, the pollution has become a serious threat, and has brought hazards to the growing population as well as the earth environment. The contamination of fresh waters with a wide series of pollutants has become a matter of concern over the last few years (Voegborlo *et al*., 1999; Canli *et al*., 1998). The rapid urbanization and industrialization has led to increased disposal of pollutants like heavy metals, radio nuclides, and various types of organic and inorganic substances into the environment. The metal which has a relatively high density and toxic at low quantity is referred as 'heavy metal', e.g., arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), thallium (Tl), etc. Some 'trace elements' are also known as heavy metals, e.g., copper (Cu), selenium (Se) and zinc (Zn). They are essential to maintain the body metabolism, but they are toxic at higher concentrations. The heavy metals can enter the bodies to a small extent via food, drinking water and air. The heavy metals concerned with the environmental science chiefly include Pb, Hg, Cd, Cr, Cu, Zn, manganese (Mn), nickel (Ni), silver (Ag), etc. Further, the heavy metals are metallic elements which have a relatively high density, and they are poisonous at low quantity. The excess quantities of heavy metals are detrimental as these destabilize the ecosystems because of their bioaccumulation in organisms, and elicit toxic effects on biota and even death in most living organisms (Gupta, 2013).

The industrial wastes are the main source of metal pollution for aquatic organisms. It has been cited that the heavy metals constitute the major pollutants in the environment. The paper industry has been one of the chief industries causing aquatic pollution because the effluent releasing by it is highly toxic. The pulp and paper mill industry is one of the oldest industries in India and there has been tremendous expansion of these industries during last 25 years. Many chemicals have been identified in effluents which are produced at different stages of papermaking. Their toxic nature is derived from the presence of several naturally occurring and xenobiotic compounds which are formed and released during various stages of papermaking (Sangeeta *et al.*, 2013).

The heavy metals are important pollutants for fishes, because these are not eliminated from aquatic systems by natural methods, such as organic pollutants, and are enriched in mineral organic substances. The metal contaminants are mixed in the aquatic system through smelting process, effluents, sewage and leaching of garbage which cause severe harm to the aquatic system.

The main problem with heavy metals in our bodies is their ability to bio-accumulate. Bio-accumulation means the metals do not leave the body by their own accord and accumulate in certain tissues. Due to bio-

accumulation, heavy metals are passed up the food chain from smaller species (fish) to humans. The main tissues targeted by heavy metals include: the liver, kidneys, bowel, brain and nervous system, spleen and eyes (Sharma and Agrawal, 2005).

The natural aquatic systems may extensively be contaminated with heavy metals released from domestic, industrial and other man-made activities. Heavy metal contamination may have devastating effects on the ecological balance of the recipient environment and a diversity of aquatic organisms (Farombi, *et al*., 2007; Vosyliene and Jankaite, 2006; Ashraj, 2005).

Among animal species, fishes are the inhabitants that cannot escape from the detrimental effects of these pollutants (Olaifa *et al*., 2004; Clarkson, 1998; Dickman and Leung, 1998). Fish are widely used to evaluate the health of aquatic ecosystems because pollutants build up in the food chain and are responsible for adverse effects and death in the aquatic systems (Farkas *et al*., 2002; Yousuf and El-Shahawi, 1999). The studies carried out on various fishes have shown that heavy metals may alter the physiological activities and biochemical parameters both in tissues and in blood (Basa and Rani, 2003; Tort and Torres, 1988). The toxic effects of heavy metals have been reviewed, including bioaccumulation (Waqar 2006; Adami *et al*., 2002; Rasmussen and Anderson, 2000; Rani, 2000; Aucoin *et al*., 1999).

Even though some of the heavy metals such as zinc, iron, cobalt and copper are essential for enzymatic activity and other biological processes at low levels they become toxic when they exceed certain limit. On the other hand other metals such as lead, cadmium and mercury have no essential role in living organisms and are toxic even at too low concentrations (Bryan, 1976). Heavy metals do not pend in water and settle down swiftly onto sediment due to their higher density than that of water. This was demonstrated with Cd and Cu exposure, metals showed 72 to 97% decrease from their initial concentration after 96 hours of experiment (Ghosal and Kaviraj, 2002; Ghosh *et al*., 2016; Ghosh *et al*., 2018).

The bioaccumulation of heavy metals in different tissues of aquatic organisms leads to several harmful effects. It may have genotoxic, mutagenic, Immunosuppressive and cytotoxic effects. It may also result in histopathological changes, abnormalities in fish reproduction; and public health hazard effects for human consumption such as polluted fish.

II. CLASSIFICATION OF HEAVY METALS

1. Essential heavy metals - Copper, chromium, zinc-nickel, cobalt and iron are essential metals required for all vital processes inside the body with optimum level. Otherwise, inadequate amount causes deficiency diseases and high-level cause's toxicity (Sivaperumal *et al*., 2007).
2. Non-essential heavy metals- Those haven't biological roles and also called xenobiotic. When they are increased in concentrations, it will cause toxopathic effects in tissue; those involve Aluminum, Mercury, Lead, Cadmium and others. (Sfakianakis *et al*., 2015).

- Cadmium (Cd):

Cadmium is the seventh most toxic heavy metal as per ATSDR ranking. Cadmium distributed in the environment will remain in soils and sediments for several decades. Plants gradually take up these metals which get accumulated in them and concentrate along the food chain, reaching ultimately the human body. Once this metal gets absorbed by humans, it will accumulate inside the body throughout life. Fish exposed to cadmium revealed a negative effect on their the growth rate, meat quality and blood and biochemical parameters (Vijayram *et.al* 1989; Shukla *et al.,* 2002; Abbas *et al.,* 2007). The morphological and histological alterations in the liver, intestine and kidneys of cadmium exposed fish (Thophon *et al.,* 2003; Omer *et al*.,2012). Higher doses of cadmium caused visible external lesions such as discoloration of fish (Cavas *et al.,* 2005). The cadmium poisoning caused softening of the bones and kidney failure. It can cause osteoporosis, nonhypertrophic emphysema, irreversible renal tubular injury, eosinophilia, anosmia and chronic rhinitis. Chronic exposure to inorganic Cd results in accumulation of the metal mainly in the liver and kidneys as well as in other tissues and organs causing many metabolic and histological changes, membrane damage, altered gene expression and apoptosis (Soeginato 2008; Bais and Lokhande, 2012).

- Chromium (Cr):

Chromium is a metal found in natural deposits such as rocks (ores), animals, plants and soil and can be a liquid, solid or gas Chromium is used in textile industries, electroplating, leather tanning, metal finishing and chromate preparation, protective coatings on metal (electroplating), magnetic tapes and pigments for paints, cement, paper, rubber, composition floor covering and other materials. Its soluble forms are used in wood preservatives. Chromium compounds bind to soil and are not likely to migrate to ground water, but they are very persistent in sediments in water. Like other heavy metals, chromium enters the body of fish through gills or digestive tracts, but it is known that it has a lower ability to accumulate than others (Rashed, 2001). The accumulation of Cr (VI) in the kidney led to macroscopic and microscopic abnormalities and negatively affected fish growth and survival (Farag *et al.,* 2006). Impact of chromium trivalent and hexavalent toxicity on the behavior of *Danio rerio* (Zebra fish), erratic motion, mucus discharge, opening mouth for gasping, color and shade alteration, irregular swimming was usually point out (Nisha, 2016). The behavioral changes in gold fish (Carrassius arratus) and noted that all the fingerlings come to the aquarium and there was also appetite decrease due to chemical effects (Faward, *et al*., 2017). Acute poisoning by chromium compounds causes excess mucous secretion, damage in the gill respiratory epithelium and the fish may die with symptoms of suffocation (Benoit ,1976).

Chromium (VI) compounds are toxic and known human carcinogens, whereas chromium (III) is less toxic and an essential nutrient for human (WHO, 1988; Jordao *et al*., 2002; Abbas *et al*., 2016; Martin and Griswold, 2009). Exposure to higher amounts of chromium compounds in humans can lead to the inhibition of erythrocyte glutathione reductase, which in turn lowers the capacity to reduce methemoglobin to hemoglobin (Koutras *et al*., 1965).

- Copper (Cu):

Copper (Cu) is an essential trace metal and micronutrient for cellular metabolism in living organisms on account of being a key constituent of metabolic enzymes. However, it can be extremely toxic to intracellular mechanisms in aquatic animals at high concentrations which exceed normal levels (Hernández *et al.,* 2006). Although the crucial role of Cu in several enzymatic processes, this heavy metal can exert adverse toxicological effects, when present in high concentrations in water. In fact, it is potentially toxic when the internal available concentration exceeds the capacity of physiological detoxification processes. Increasing agricultural production has resulted in increasing number of freshwater systems being impacted by the contaminants present in wastewater releases (Li, and Wu, 1999).

It is an abundant element which occurs as a natural mineral with a wide spread use. Copper pollution is through extensive use of fungicides, algaecides, molluscicides, insecticides and discharge of industrial wastes. Copper sulfate (CuSO4) is often used as an algaecide in commercial and recreational fish ponds to control the growth of phytoplankton and filamentous algae and to control certain fish disease. Fish can accumulate copper via diet or ambient exposure (Sfakianakis *et al.,* 2015). Even at low environmental concentrations, copper shows distinct affinity to accumulate in the fish liver. It decreases the total protein content in liver and muscles with increasing the concentration of free amino acids and gluconeogenic enzyme activity in copper exposed fish.The typical patho-anatomical appearance includes a large amount of mucus on body surface, under the gill covers and in between gill filaments (Svobodova ,1993). Cu exposed different fish species posed behavioural changes such as decrease in swimming ability and food intake and increase in operculum movements (Venkataramana and Radhakrishnaiah, 2001; Ali *et al*., 2003). Hepatocyte vacuolization, necrosis, shrinkage, nuclear pyknosis and increase of sinusoidal spaces were the distinct changes observed in the liver of copper-exposed fish (Figueiredo-Fernandes *et al.,* 2007). Gainey and Kenyon (1990) mentioned that exposure of fishes to sublethal concentrations of copper leads to cardiac activity and reduction in heart rate. Radhakrishnaiah *et al.* (1992) have recorded stimulation of glycogenolysis in fish *L. rohita* on exposure to a sub lethal concentration of copper. Sanchez *et al.* (2005) showed that Cu is able to induce oxidative stress in fish (Gasterosteus aculeatus) even before significant metal accumulation occurs in the liver.

Copper plays an important role in human metabolism, largely because it allows many fundamental and essential enzymes to function properly and also plays a role in the production of hemoglobin, myelin, and melanin. Copper is playing an important role as transition metal signaling, transferring information in and beyond the brain, between and within the living cells. Some significant evidences were found that a physiological imbalance of the redox-active bio metals, Cu and Fe, and oxidative stress lead to the neuropathology of Alzheimer's disease. The Menkes syndrome and Wilson disease are also due to the severe copper deficiency and severe copper toxicity, respectively (Turnlund, 2005).

- Lead (Pb):

Lead (Pb) is a naturally occurring substance, its environmental concentrations are significantly increased by anthropogenic sources which include base metal mining, battery manufacturing, Pb-based paints and leaded gasoline. Lead in water may come from industrial and smelter discharges; from the dissolution of old lead plumbing, lead containing pesticides, through precipitation, fallout of lead dust, street runoff, and municipal wastewater (Sepe, *et al*., 2003).

The main mechanisms of lead toxicity are the activation of cellular functions due to this metal's calcium mimicking effect, and the inhibition of the activity of different proteins through its binding to sulfhydryl groups. Lead has high affinity for sulfhydryl groups and can inactivate enzymes, especially those involved in heme synthesis, such as aminolevulinic acid dehydratsase and ferrochelatase (Gwalteney-Brant, 2002). Fish exposed to 5 ppm of lead nitrate for 150 days, it exhibited marked inhibition of gonadal growth and showed decrease in cholesterol and lipid levels in brain, testis and ovary whereas the liver showed an elevation of both (Katti, *et al.,* 1983).

Acute lead toxicity is initially characterized by damaging gill epithelium and ultimately suffocation. Two types of structural alterations of gill, defense/ compensatory responses and direct deleterious effects were observed in chronic lead exposed fish (Parashar and Banerjee, (1999). The necrosis and desquamation of gill epithelium as well as lamellar curling and aneurisms were the direct deleterious effects reported in chronic lead exposed *Clarias gariepinus* (Olojo 2005). The characteristic symptoms of chronic lead toxicity include changes in the blood parameters with severe damage to erythrocytes and leucocytes and damage in the nervous system (El-Badawi, (2005). Low levels of Pb pollution could cause some adverse effects on fish health and reproduction (Delistraty and Stone, 2007). Also, lead was found to inhibit the impulse conductivity by inhibiting the activities of mono aminooxidase and acetylcholine esterase, to cause pathological changes in tissue and organs (Rubio,1991).

Chronic lead poisoning has similar toxic effects in fish as in mammals. These include hematological and neural disorders and tetanic spasms together with some morphological changes such as darkening in caudal fin, deformation of vertebrate, anomalies in pigment formation and covering of the gills by a mucus layer (Shah, 2006).

- Nickel (Ni):

Nickel is a non-biodegradable toxic heavy metal ion present in waste water. The main source of nickel pollution in the water derives from a number of industrial production processes such as battery manufacturing, production of some alloys, zinc base casting, printing, electroplating and silver refineries(Li *et al.,* 2000 ; Meche *et al*., 2010). Once released to the environment, nickel readily forms complexes with many ligands, making it more mobile than most heavy metals .While nickel is an essential element at low concentrations for many organisms, it is toxic at higher concentrations (Palaniappan and Karthikeyan ,2009) .

Primarily, Nickel accumulate in the gills, kidney and muscles of fishes. Nickle toxicity is responsible for increased mucus secretion, dark red colour of gill, to swell up the gill lamellae as well as increasing oxygen consumption, ventilatory stroke volume and respiratory rate (Sreedevi *et al*., 1992; Pane *et al.,* 2004; Ghosh *et al*., 2018). Nickel alters the haematological parameters (erythrocyte, leucocytes, hematocrit and hemoglobin count) and lowered values of mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) in fishes when compared with the control (Al-Ghanim ,2011).

- Zinc (Zn):

Zinc (Zn) is the second most abundant trace element after Fe and is an essential trace element and micronutrient in living organisms, found almost in every cell and being involved in nucleic acid synthesis and occurs in many enzymes. Zinc is an essential trace element for both plants and animals but it induces toxicity at elevated concentrations particularly under conditions of low pH, low alkalinity, low dissolved oxygen and elevated temperatures (Eisler, 2010).

Zinc dissolves in water, and releases free zinc ions which become primary source of aquatic toxicity (Blinova *et al*., 2010). Additionally, Zn is involved in more complicated functions, such as the immune system, neurotransmission and cell signaling (Celik, 2004). Cicik, (2003) also suggested that high concentrations of Zn might have occured due to mucus secretion and structural alterations in gill tissue caused by contamination. Zinc causes morphological changes, alteration in haematological and biochemical parameters, mortality, growth retardation, respiratory and cardiac changes, inhibition of spawning, and a multitude of additional detrimental effects which threaten survival of fish. Gill, liver, kidney, and skeletal muscle are damaged (Sorensen ,1991; Srivastava and Prakash, 2018a, b&c).

III. IMPACT OF HEAVY METAL ON HUMAN HEALTH

Every water body receives the effluents containing heavy metals either from point or from nonpoint sources. These heavy metals persist in environment due to their unbiodegradable nature and accumulate in the tissues of aquatic fauna particularly fish, and thus, they remain in the tissues of the fish for long time. Fishes are the important source of protein. Unfortunately, fishes are now becoming the major source of heavy metals due to the pollution caused by industries. Health problems caused by low level chronic exposure to heavy metals may take years to appear. According to United States Environmental Protection Agency (USEPA), these metals generally cause two types of health effects. One is carcinogenic and other is non-carcinogenic effects. These heavy metals have been linked to conditions ranging from cardiovascular disease, high blood pressure, insomnia, and many more. Much of the exposure to heavy metal pollution has been scientifically proven to be linked to causing free radical damage leading to: Heart attacks, strokes and cancer. There are also many circulatory diseases other than cardiovascular disease that may not cause death, but can affect the quality of life. Some of these are: Impotency, Alzheimer's disease, Arthritis, Diabetes, Fatigue, Memory Loss. Lead poisoning is a serious and very common type of heavy metal poisoning. Symptoms of lead poisoning in children mimic those of attention deficit hyperactivity disorder (ADHD). Lead poisoning also causes behavioral and learning problems, nervousness, headaches, and many other related symptoms. Pregnant women, lactating mother and children are more prone to heavy metal health hazards.

Lead poisoning in children causes neurological damage leading to a reduction in intelligence, loss of short-term memory, learning disabilities and problems with coordination. Prenatal exposure can cause reduced birth weight and immune suppression or oversensitisation, which could explain why some children develop asthma and allergies (Day, 1998).

It has been detected that Pb inhibits Na+/K+-ATPase enzyme and d-aminolevulinic acid dehydratase enzyme that participates in growth and hem synthesis in erythrocytes and affects lipid peroxidation enzyme. It has been shown that Pb also has influence on intercellular communication by changing alanine aminotransferase (ALT) and aspartate aminotransferase (AST) concentrations in tissues and organs (Çogun and Şahin, 2012).

CONCLUSION

Based on the present review it is believed that for biomonitoring studies only single parameter is insufficient. Hence, biomarkers such as bioaccumulation, blood profiles, biochemical profiles, pathological marker enzyme activities, enzymatic and non-enzymatic antioxidants, lipid peroxidation, DNA damage and tissue damage could serve as useful tools to monitor the health of aquatic fauna. These heavy metals will enter the food web through water and food, to cause the adverse health effects like that in indicator organisms (fish) as well as their consumers.

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