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Research Journal of Animal, Veterinary and Fishery Sciences ______________________ ISSN 2320 – 6535
Vol. **2(2),** 17-23, February **(2014)** *Res. J. Animal, Veterinary and Fishery Sci.*

Review Paper

Heavy Metals Causing Toxicity in Animals and Fishes

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Available online at: www.isca.in, www.isca.me
Received 13th January 2014, revised 24th January 2014, accepted 20th February 2014

Abstract

The heavy metals chiefly include Pb, Hg, Cd, Cr, Cu, Zn, Mn, Ni, Ag, etc. The heavy metals, viz., As, Cd, Pb and Hg are considered most toxic to humans, animals, fishes and environment. Excessive concentrations of heavy metals are detrimental. They destabilize ecosystems because of their bioaccumulation in organisms, and toxic effects on biota and even death in most living beings. All heavy metals, in spite some of them are essential micronutrients, have their toxic effects on living organisms via metabolic interference and mutagenesis. The bioaccumulation of toxic metals can occur in the body and food chain. So, the toxic metals generally exhibit chronic toxicity. The heavy metals like Pb and Hg have significant toxic effects. 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. Occurrence of heavy metals differs in fishes, depending on their age, development and other physiological factors. Among animal species, the fishes are inhabitants which can be highly affected by these toxic pollutants. Heavy metals can have toxic effects on different organs. They can enter into water via drainage, atmosphere, soil erosion and all human activities by different ways. As the heavy metals concentrated more in the environment, they enter biogeochemical cycle, leading to toxicity.

Keywords: Animals, environment, fishes, heavy metals, toxicity.

Introduction

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[1]. The heavy metals concerned with the environmental science chiefly include Pb, Hg, Cd, Cr, Cu, Zn, manganese (Mn), nickel (Ni), silver (Ag), etc.[2]. 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[3].

Due to formation of toxic soluble compounds, certain heavy metals become toxic. However, some metals are without any biological role or they are not needed by the body and they become poisonous only in specific forms. However, any amount of Pb can result to detrimental effect. The *'lighter metals'*, e.g., beryllium can also be toxic in certain circumstances. Some *'essential elements/metals'*, e.g., iron (Fe) may also be toxic. Sometimes, the action of essential elements can be changed by the toxic metals, resulting into toxicity by interfering with the metabolic process. Therefore, most of the heavy metals are poisonous, while some metals are less toxic, e.g. bismuth (Bi). Metalloids like As and polonium may also be toxic. Beside, both radiological and chemical toxicities can be induced by the radioactive metals. Similarly, the metals with abnormal oxidation phase can also be poisonous, e.g., Cr(III) is an essential trace element, while but Cr(VI) exhibit the carcinogenic effect[4]. All heavy metals, in spite some of them are essential micronutrients, have their toxic effects on living organisms via metabolic interference and mutagenesis. Such toxic effects of heavy metals include reduction in fitness, interference in reproduction leading to carcinoma and finally death[2]. It has been reported that both insoluble compounds and metallic forms of heavy metals generally have no toxic effect. The ligands of any metal may be the important factor to cause toxicity. For example, the organometallic forms, e.g., methyl Hg and tetraethyl Pb, can be highly toxic; while the organometallic derivatives are less toxic, e.g., cobaltocenium cation. The bioaccumulation of toxic metals can occur in the body and food chain. So, the toxic metals generally exhibit chronic toxicity. For example, the radioactive heavy metals like radium can imitate calcium (Ca) to be incorporated into the bone, but the similar health hazards can also be due to Pb or Hg. However, barium (Ba) and aluminium (Al) are exceptions as they can be quickly excreted by the kidneys[4].

Industrialization has spoiled the environment by putting more and more concentrations of several metals. The heavy metals like Pb and Hg cause severe toxicity, as there are some historic cases, e.g., Hg poisoning of waterways in Japan. The Hg toxicity (by methyl Hg) and Minamata disease exhibited significant neurotoxicity similar to *'Hunter Russell syndrome'*. Besides direct toxicity heavy metals, the significant reduction in foetal growth and chronic effects should also be noted. Much of the basic research relies on studies in different animal species. Many heavy metals (including essential ones) are poisonous above their threshold levels. The heavy metals usually enter the body through respiration, ingestion and skin.

At present, the pollution has become a serious threat, and has brought hazards to the growing population as well as the earth/environment. The speedy 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. Thus, 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 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. Tannery industry has added pollutants to the aquatic environment. The tannery waste waters continue to cause hazardous effects on the aquatic organisms as they also have endocrine disruption effects. A large number of chemicals are being used by the tanners during process, and thus discharge the toxic materials into waters. Due to this, the agricultural lands are also degraded. Uncontrolled release of tannery effluents has increased the health risks to different organisms[5].

Death in aquatic animals may occur due to nutrient pollutions (e.g., nitrogen, phosphates, etc.) present in the toxic algae. The frog biodiversity and tadpole mass can be declined by chemical contamination. The oil pollution (as chemical contamination) can badly affect the development of marine organisms. It enhances the susceptibility to diseases and also affects the reproduction. It can also cause gastro-intestinal irritation, and damage to liver, kidney and nervous system. The deaths of aquatic animals can also be due to the high level of sodium chloride (NaCl) in waters. The manufacturing, farming, city septic systems, construction, automotive garages, laboratories, hospitals and other industries byproducts are highly toxic. These byproducts may be in different forms like liquid, solid or sludge which can contain chemicals, heavy metals, radiation, pathogens or other toxic materials. The items like batteries, used computer equipment and leftover paints or pesticides can also produce toxins. If these wastes are buried in the ground, or present in the stream runoff, in groundwater for drinking water, or in floodwaters, they are toxic to humans, animals as well as plants. The toxic metals like Hg accumulate in the aquatic system, and can be toxic to humans or animals when they eat fish. The *'Environmental Protection Agency'* (EPA) of USA states that the toxic materials must be handled with precautions and be disposed off properly. More often, the heavy metals are mixed in fertilizers. However, the toxic levels of such metals are absorbed by some plants, ultimately consumed by humans resulting into detrimental negative effects on children[6].

Furthermore, heavy metals are said to be most important toxic pollutants for aquatic organisms. The As, Cd, Pb and Hg can be tolerated at very low levels, and are highly toxic to human beings. The Sn is very much used for studding in canning, but its toxicity is not much as of other heavy metals. The presence of metals in fish species depends on the age and development fishes, and other physiological factors. The fishes are the single largest sources of As and Hg for human beings. The heavy metals released from domestic, industrial and other man-made activities can highly contaminate the aquatic systems. Such contaminations can seriously affect the ecological balance and diversity of aquatic species. For evaluation of health of aquatic systems, fishes are widely used because pollutants present in food chain cause ill-effects and death of aquatic animals. Therefore, the problem of metal pollution is one of the major health problems in the persons who eat sea foods. Due to metal pollution, cellular level damage has been observed, which possibly affect the ecological balance. The As is commonly present in air, water, soil and all living tissues. It is at the 20^{th} place found abundantly in the earth's crust, 14^{th} in seawater and 12^{th} in human body. It is reported as a carcinogen, and causes foetal death and malformations in many mammal species. Most of the As compounds are used in manufacture of agricultural products such as insecticides, herbicides, fungicides, algaecides, wood preservatives, and growth stimulants for plants and animals. The atmospheric emissions from smelters, coal-fired power plants and arsenical herbicide sprays; water contaminated by mine tailings, smelter wastes and natural mineralization; and diet, especially from consumption of marine biota, all cause As toxicity. Generally, the inorganic As compounds are more toxic than organic compounds, and trivalent As (arsenites, As^{+3}) are more toxic than pentavalent As (arsenates, As^{+5}). The cancers of skin, lung, liver, lymph, nasal passage, kidney, bladder, prostate and haematopoietic systems of humans have been associated with inorganic arsenical toxicity. The As induced cancer risks have been especially found among smelter workers, and in those engaged in the production and use of arsenical pesticides[7].

The industries pour wastes containing Cr and large amount of chromates, dichromate, and other Cr compounds into the aquatic system. The Cr is widely used in industry, paints and metal platings as corrosion inhibitor, and its particulates enter the aquatic system through effluents discharged from tanneries, textiles, and electroplating, mining, dyeing, printing, photographic and pharmaceutical industries. The Cr exists primarily in the trivalent and hexavalent forms; but its hexavalent form predominants the trivalent form in natural water. Contamination of natural water by Cr bearing industrial wastes is related to increased anthropogenic uses of this metal. The hexavalent form of Cr is very toxic to man and animals.

The Cr(VI) salts have several applications in divers industries and their indiscriminate introduction into aquatic ecosystem poses a serious threat to growth and survival of aquatic species, including fish population[7]. The Hg is rapidly absorbed from coal fumes, contaminated seafood, pain, canvas and contaminated waters. This seriously affects the fish and food chain. Therefore, the fishes having high Hg content from industrial pollution should not be eaten. The presence of Hg in the oceans, and therefore in the ocean's fish, has had a detrimental effects on human beings[8].

Environmental and Health Risks by Heavy Metals

The heavy metals are accumulated in living organisms when they are taken up, and stored faster than they are broken down (metabolized) or excreted. They enter into the water supply by industrial and consumer materials, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers and groundwater. The three most pollutant/environmental heavy metals have been reported include Pb, Hg and Cd[1], but some other heavy metals can also badly affect the environment. *'Heavy metals toxicity'* has been reported to be caused by different means; e.g., from contamination of drinking-water (Pb pipes), high ambient air concentrations near emission sources, or from food chain. The heavy metals are poisonous since they **bioaccumulate**. The *'bioaccumulation'* means an increase in the level of a chemical/toxicant in an biological organism over time, compared to chemical/toxicant level in the environment[1,3]. It is important to point out here that the most of the zoos which were once located on the outskirts of the cities and towns are now surrounded by human activities, such as vehicular traffic and industries. All these activities can cause heavy metal pollution, which may adversely affect the health and wellbeing of the wild animals housed in such protected areas[3]. The environmental and health risks caused by various pollutants heavy metals are described as under[1]:

Environmental and Health Risks by Lead: Exposure of Pb can cause many effects depending on level and duration of Pb. The developing foetus and infant are more sensitive than the adult. Mostly, the bulk of Pb is received from food; however, other sources may be more important like water in areas with Pb piping and plumb solvent water, air near point of source emissions, soil, dust and paint flakes in old houses or contaminated land. In air, the Pb levels are brought in food through deposition of dust and rain containing metal on crops and soil. Eight broad categories of Pb use are: batteries; petrol additives; rolled and extruded products; alloys; pigments and compounds; cable sheathing; shot; and ammunition. In environment, the Pb comes from both natural and anthropogenic sources. The Pb exposure can be through drinking water, food, air, soil and dust from old paint. The Pb is among the most recycled non-ferrous metals, so its secondary production has grown steadily. The high levels of Pb may result in toxic effects in humans which in turn cause problems in the synthesis of haemoglobin (Hb), effects on kidneys, gastrointestinal tract (GIT), joints and reproductive system, and acute or chronic damage to nervous system.

Environmental and Health Risks by Mercury: The Hg is not present naturally in living organisms. It is a toxic substance with no known function in biochemistry or physiology. It has complex and unusual chemical and physical properties. Degassing of earth's crust, emissions from volcanoes and evaporation from natural bodies of water are the major natural sources of Hg. World-wide mining of metal leads to indirect discharges into atmosphere. The Hg is widely used in industrial processes and in different products (e.g., batteries, lamps and thermometers). It is also used in dentistry as an amalgam for fillings and in pharmaceutical industry. The Hg is mostly present in a relatively unreactive form as a gaseous element. The methylated forms of Hg are bioaccumulated over a million-fold and concentrated in living beings, especially fish. These forms of Hg (monomethyl Hg and dimethyl Hg) are highly toxic, causing neurotoxicological disorders. Inorganic Hg toxicity is associated with tremors, gingivitis and/or minor psychological changes, together with spontaneous abortion and congenital malformation in humans. Monomethyl Hg causes damage to brain and CNS, while foetal and postnatal exposures have given rise to abortion, congenital malformation and development changes in young children.

Environmental and Health Risks by Cadmium: The Cd derives its toxicological properties from its chemical similarity to Zn (an essential micronutrient for plants, animals and humans). The Cd once absorbed by an organism, present for many years (over decades for humans), though it is eventually excreted. It is produced as an inevitable by-product of Zn (or occasionally Pb) refining, since these metals occur naturally within the raw ore. But once collected, the Cd is relatively easy to recycle. The Cd is mostly used in Ni/Cd batteries, rechargeable or secondary power sources exhibiting high output, long life, low maintenance and high tolerance to physical and electrical stress. The coatings of Cd provide good corrosion resistance, particularly in high stress environments like marine and aerospace applications where high safety or reliability is required; the coating is preferentially corroded if damaged. It is also used as pigment, stabilizer for PVC, in alloys and electronic compounds. As an impurity, it is present in several products, including phosphate fertilizers, detergents and refined petroleum products. Average daily intake of Cd for humans is 0.15 µg from air and 1 µg from water. The Cd if exposed for long time may cause kidney dysfunction. Its high exposure may cause obstructive pulmonary disease and lung cancer. Bone defects (osteomalacia, osteoporosis) have also been reported in humans and animals. Besides, it can also cause increased blood pressure and myocardial disease in animals.

Environmental and Health Risks by Selenium: The Se is needed in small amounts by humans and other animals but in larger quantity, it can damage to nervous system, and cause fatigue and irritability. It accumulates in living tissue, and its high contents in fish and other animals can cause serious health problems in humans over a lifetime of overexposure. There may be hair and fingernail loss, damage to kidney and liver tissue, damage to circulatory tissue, and more severe damage to nervous system.

Environmental and Health Risks by Antimony: The antimony (Sb) is used in compound, antimony trioxide (a flame retardant). It is also found in batteries, pigments, and ceramics and glass. Its high exposure for short duration can cause nausea, vomiting and diarrhoea. The long-term exposure of Sb can cause cancer in humans.

Environmental and Health Risks by Copper: In humans, the Cu is essentially needed but in high doses, anaemia, liver and kidney damage, and stomach and intestinal irritation may occur. During Wilson's disease, it affects greatly. It is normally found in drinking water from Cu pipes and additives designed to control the algae growth.

Environmental and Health Risks by Chromium: The Cr has been reported to be used in metal alloys and pigments for paints, cement, paper, rubber and other materials. The low level Cr can irritate skin and can produce ulcer. Its chronic exposure can produce kidney and liver damage. The Cr can also damage to circulatory and nerve tissues. In aquatic animals, it is normally accumulated and can cause toxicity to eating fish.

Environmental and Health Risks by Nickel: The Ni is needed in small amounts to produce red blood cells (RBCs), but it becomes slightly toxic in excess quantity. Its chronic exposure can cause decrease in body weight, heart and liver damage, and skin irritation. In aquatic animals, the Ni is accumulated but its presence is not magnified along the food chains.

Most Toxic Heavy Metals

In cooperation with the U.S. "Environmental Protection Agency" (EPA), the 'Agency for Toxic Substances and Disease Registry' (ATSDR) in Atlanta, Georgia (a part of the U.S. Department of Health and Human Services) reported that in a 'Priority List for 2001' called the 'Top 20 Hazardous Substances', As, Pb and Hg are at the 1st, 2nd and 3rd position, respectively in the list; while Cd is at the 7th place. Therefore, the "elements/heavy metals", viz., As, Cd, Pb and Hg are considered most toxic to the humans, animals and environment. The detrimental effects*/ toxicities associated with these four* heavy metals *are described in t*able-1[1,9]. Similarly, the limits (*maximum daily dose* or exposure) of various elements/heavy metals for human and animals are described in table-2[9].

Table-1
Detrimental Effects/Toxicities Associated with Arsenic, Lead, Mercury and Cadmium

Heavy Metal	Detrimental Effects/Toxicities
Arsenic (As)	Water-soluble inorganic As is readily absorbed from digestive system. Inorganic forms of As are particularly toxic. It causes irritation to lung, stomach and intestine, skin disturbances, and decreased formation of RBCs and WBCs. Very high concentrations of inorganic As can cause infertility, skin disturbances, decreased resistance to infections, heart disruptions, brain damage and death. The acute LD_{50} (oral) of As ranges from 10-300 mg/kg.
Lead (Pb)	It can enter the body through ingestion and inhalation. Its maximum allowable levels may be 5 µg/L (in bottled water) to set elemental impurities limit. It can cause disruption of biosynthesis of Hb, anaemia, high B.P., kidney damage, reproductive/fertility problems and brain or nervous system damage.
Mercury (Hg)	Its prevalence in environment can lead to biomagnification in food chain. The organic Hg, such as methyl Hg, is more toxic than inorganic Hg due to ease of absorption into human system. The toxicity of Hg include: kidney damage, disruption of nervous system, damage to brain, DNA and chromosomal damage, allergic reactions, sperm damage, birth defects and miscarriages. The LD_{50} of Hg is as low as 1 mg/kg in small animals.
Cadmium (Cd)	Cd is more readily absorbed through the lungs than the digestive system. It can damage kidneys, CNS and immune system. It can also cause bone fractures and reproductive problems. It can cause stomachaches, diarrhoea and vomiting. The LD_{50} (oral) of Cd in animals ranges from 63-1125 mg/kg.

Table-2
Limits (Maximum Daily Dose or Exposure) of Various Elements/Heavy Metals

Element/ Heavy Metal	Daily Dose (µg/day)		Element/ Heavy Metal	Daily Dose (µg/day)	
	Parenteral	Oral/Topical/ Dermal/Mucosal		Parenteral	Oral/Topical/ Dermal/Mucosal
Arsenic (Inorganic)	1.5	15	Nickel	25	250
Cadmium	0.5	5	Palladium	10	100
Lead	1	10	Platinum	10	100
Inorganic Mercury	1.5	15	Vanadium	25	250
Chromium	25	250	Osmium	10 (combination not to exceed)	100 (combination not to exceed)
Copper	250	2500	Rhodium		
Manganese	250	2500	Ruthenium		
Molybdenum	25	250	Iridium		

Accumulation and Action of Heavy Metals

'Poison' is defined as any substance, which when absorbed into the body, will cause adverse or deleterious effects. Several metals and their compounds have been stated to be toxic to animals. The As, Cu, Pb, Hg and Cd have been reported to be the most toxic heavy metals. It is believed that many toxic metals exert their bad effects by distressing the enzyme systems of animals. Many of them bind to specific enzymes and proteins necessary for cellular function and thus compete with other substances essential for maintenance and the continued function of cells. Thus, the poisons can also have the effect of inducing mineral deficiencies. Additionally, many toxic appear to assist in the formation of the paramagnetic anion, superoxide (O_2^-), which itself is toxic and seems widely responsible for the spontaneous cell death[8].

Severe toxicity and bioaccumulation of several heavy metals pollution are also related to aquaculture. By such aquacultures, the quality of fishes will be deteriorated, resulting into detrimental health of fish eating population. The methyl Hg is thousand times more soluble in fats compared to water. This methyl Hg is concentrated in tissues of muscles, brain and central nervous system (CNS). The concentrations of Hg in fishes can be more than 10,000 to 100,000 times of the original levels in surrounding waters. The deposition of Hg is rapid but its depuration is slow. Less polluted shrimps are slow for depuration of Hg, but the polluted oysters depurate faster. The depuration of Hg is also found much slower in fishes. The methyl Hg has its half-life of about 2 years in fishes. But there is no significant health effect of general population by such Hg pollution. The levels of Hg for saltwater fish averaged 0.35 to 70.02 ppm and the levels of Se averaged 0.37 to 70.01 ppm. The Hg concentrations in bluefish are more than sufficient to produce toxic effects in mammals and birds eating fishes. The fishes bigger than 50 cm fork length have been reported to have the average concentrations of higher than 0.3 ppm. This suggests that the pregnant women, children and others sensitive individuals should not eat such contaminated fishes. It means that fish consumption is the only chief source of methyl Hg for humans. The population that depends on daily fish intake can be more affected from long-term and high doses of methyl Hg and other organic pollutants. Likewise, high-end fish eaters are also severely exposed from Hg[7].

The heavy metals can have toxic effects on different organs. They can enter into water via drainage, atmosphere, soil erosion and all human activities by different ways. With increasing heavy metals in the environment, these elements enter the biogeochemical cycle. The heavy metals can enter from contaminated water into fish body by different routes and accumulate in organisms. These metals can be concentrated at different contents in organs of fish body. The Cu and Zn have been measured in sediments near aquaculture sites at concentrations in excess of sediment quality guidelines. These elements could be lethal to aquatic biota and persist in sediments[7]. In the body, the heavy metals enter through respiration, skin and intestinal absorption. The heavy metals of elemental forms are not completely absorbed, while organometallic forms are lipophillic and can soon enter through membranes, and even cross blood-brain barrier (BBB, the defense system of nervous system). The heavy metals after absorption into body can be widely distributed in different organs, including glands and CNS. Some of the heavy metals are called 'bone seekers' and they deposit into teeth and skeletal systems. The heavy metals then become toxic to enzyme system, and enhance the 'free radical' production and compete with essential elements which form the metallo-enzyme complexes to compete with nutritional minerals absorption10. Generally, all heavy metals cause toxicity to cells. After competing with the nutritional minerals, they render them unavailable to body, leading to ill-health. For example, in a hair analysis sample, the Al displaces Ca so the latter is not available for bone formation, teeth and muscle (including heart muscle) function. Thus, these body structures become weak. The decrease concentration of Ca can lead to osteoporosis, heart disease, dental caries, periodontal disease, muscle cramping and colic. Other abnormalities include decrease concentrations of Zn, P (phosphorous), Mn, Fe and Mg (magnesium). The Al (having double whammy) increases Zn and Cu to secondary toxic levels[11-12].

Some Studies of Heavy Metals Toxicity in Animals and Fishes

It has been observed that both humans as well as animals are daily contaminated by the heavy metals. The heavy metals like Hg and light metals like Al are poisoning us and animals every day in vaccines, from environmental pollution in air and water, and from the foods. The heavy metals are also being sequestered in the long bones of food animals in our country due to use of leaded fuels in the automobiles. The Pb and Cd are two but there are more[13]. The heavy metals toxicity (e.g., from drinking-water contamination) in domestic animals can occur from high ambient air concentrations near emission sources, or by eating contaminated food. These metals are toxic since they are bioaccumulated in biological organisms in due course of time. Manifestation of toxicity of individual heavy metal differs depending on dose and duration of exposure, species, gender, and environmental and nutritional factors. Major differences occur between the single exposure to a high level and long exposure to lesser doses. The environmental pollution by heavy metals is due to both the natural abundance of metals within earth's crust and human activities. The toxic effects usually associated with chronic exposure by pollutant heavy metals are mutagenicity, carcinogenicity, teratogenicity, immuno-suppression, poor body condition and impaired reproduction. Domestic and wild animals are used to assess the quality of environment and are sentinels of great importance for toxicological risk assessment in general. In particular, the pets (dogs and cats) who for years shared the same habitat with humans, are inevitably exposed to the same environmental pollutants. Though several experiments have been done to assess the exposure of heavy metals in wild animals, there is little information on exposure to pollutants of domestic animals. Three species of animals (dairy cattle, growing swine and laying chickens) revealed the residues of Pb and Cd, which were not increased significantly in main food products received from the long-term exposed animals with subtoxic dietary levels of these metals. Both these heavy metals are deposited in liver and kidney but Pb deposits in bone also. A moderate intake of liver and kidney from Pb-exposed animals cause no or less ill-health. However, the consumption of these organs from Cd-exposed animals should be avoided[14].

The toxicity of some heavy metals (e.g., Pb, Hg and Se) and lack of some essential trace elements (e.g., Cr) was found in some wild species from north-east India with the help of inductively coupled plasma spectroscopy of hair and bone, cellular and surface ultrastructural features of skin and hair and behavioural studies on toxicity. The elemental levels showing their toxicity or deficiency were found significantly. Electron microscopic studies on cellular and ultrastructural features of skin and hair revealed specific toxic and deficiency effects of some elements. The behavioural studies showed several symptoms related to certain elemental abnormalities, viz., loss of appetite, constipation, salivation, photophobia, tendency to wander in a circle, etc. The possible source of toxicity and deficiency of elements were evaluated by analyzing soil and water samples from the home range of animals, and also by studying the behaviour pattern regarding mobility, migration and sequence of movements of animals[14].

Fish diversity of any regime has great significance in assessment of that zone reference to environment and pollution, as well as it contributes to the necessary information for fisheries. Many fishes may be the bioindicators of environmental pollutants also[15-16]. Now, there is a great need to adopt rational methods and new technology in the fishing towards the conservation of fish diversity of several rivers. The management measures aimed at conserving freshwater fishes should be part of fishery policies. The broodstock maintenance centres and hatcheries should be established exclusively for endangered and critically endangered indigenous fishes for their in situ conservation[16-17]. However, in the conservation of fish diversity, it is essential to protect the fish from the environmental pollutants heavy metals, as the fish are most often contaminated by these pollutants. Several studies in this regard have been performed by various investigators. The heavy metals, e.g., As, Cd, Cu, Cr, Fe, Pb, Mn, Hg, Ni, Zn, tin (Sn), etc. are very important pollutants which cause severe toxicity to fishes. The studies performed in various fishes showed that heavy metals may alter the physiological and biochemical functions both in tissues and in blood Carpio. The As and inorganic As compounds, Cd compounds, Ni compounds, crystalline forms of silica, beryllium and its compounds have been said to be chemical carcinogens, resulting into the development of cancer in fishes. In a study on the spotted snakehead fish (Channa punctatus, Bloch), it was observed that when the high concentration (2 mM) of sodium arsenite (NaAsO) affected these fishes, they died within 2.5 hr. The chromosomal DNA of liver cells were fragmented which indicated that NaAsO might have caused death of those cells through apoptosis. The polluted marine organisms used as sea foods have caused health hazards, including neurological and reproductive disorders in both humans and animals. The chemicals of industrial effluents and products of ships and boats, such as heavy metals can cause toxicity in aquatic animals. The petroleum products are most relevant pollutants to aquatic ecotoxicology. Crude oil and derivatives can also cause different toxic symptoms in experimental animals. The petroleum hydrocarbons can act as a mediator in free radical generation in fishes. The studies also revealed coastal pollution due to many pollutants, including heavy metals[7].

The nutrient pollutions have been reported to cause outbreaks of fish diseases. The water contaminated with Hg can cause abnormal behaviour, slower growth and development, decreased reproduction, and death in fishes. The persistent organic pollutants can cause illness, deformities and deaths in fishes6. The high toxic levels of Hg (more than 0.05 ppm in a man weighing about 180 pounds) prevent the body's cells from transporting glucose, thus reducing energy available to body. This can produce convulsion, anorexia, tremor, swollen gum and behavioural disturbances in animals8. In a case report, a human victim was killed by 300 ppm of Hg. The Hg 'burn' was seen on the skin of the fishes. It is estimated that over 60,000 foetuses will suffer from methyl Hg toxicity in the utero from mothers eating swordfish, shark and tuna fish[11-12].

The Cr is present in the tannery effluent, and is known to cause various ill effects. Such health hazards are dependent on the oxidation state of Cr. Its hexavalent form is toxic than the trivalent form. The haematological changes produced on the exposure to sublethal concentration (1/10th of LC50/96 hr) of Cr have been observed in fresh water fish, Labeo rohita for 7 and 30 days, respectively. The decrease in haematological parameters suggested that the exposed fishes became anaemic due to exposure of Cr. Hence, this heavy metal is toxic which was discharged via the effluents into aquatic environments, and caused severe anaemia and alterations in haematological parameters in the L. rohita fish[5]. The decreased levels of glycogen, protein and cholesterol have been observed after the administration of potassium dichromate in L. rohita fishes[7].

In a study, the faeces as bioindicator of heavy metal contamination were evaluated in captive zoo mammals. The heavy metal, Cd in the mammals of Bikaner (India) zoo was in range between 2.46±0.08 (Axis axis) to 0.41±0.03 (Macaca mulatta) ppm. The Cr was in the rage of 91.68±2.28 (Oryctolagus cuniculus) to 1.36±0.36 (M. mulatta) ppm; Cu was in the range between 22.82±2.18 (Panthera pardus) to 6.15±0.45 (Boselaphus tragocamelus); and Zn was found in the range of 35.6±1.35 (Canis aureus) to 8.15±0.45 (B. tragocamelus) ppm.

The analysis of feed and water along with the soil in cages which received particulate air pollutants indicated that the air pollution was the primary cause (of high concentrations of these heavy metals) due to high density of traffic in the area[3].

Conclusion

The heavy metals, viz., As, Cd, Pb and Hg are most toxic to all human beings, animals, fishes and environment. The excess levels of heavy metals cause severe toxicity. Though some heavy metals are essential for animals, plants and several other organisms, all heavy metals exhibit their toxic effects via metabolic interference and mutagenesis. The Pb and Hg cause severe toxicity in all. Fishes are not the exception and they may also be highly polluted with heavy metals, leading to serious problems and ill-effects. The heavy metals can have toxic effects on different organs. They can enter into water via drainage, atmosphere, soil erosion and all human activities by different ways. With increasing heavy metals in the environment, these elements enter the biogeochemical cycle leading to toxicity in animals, including fishes.

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