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Heavy Metals Contamination in Fish: Effects on Human Health

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ABSTRACT

Fish is a rich source of nutrients, however, its nutritional value may be affected by the environment in which it exists. The threat of toxic and trace metals in the environment is more serious than those of other pollutants due to their non-biodegradable nature. This is coupled with their bio-accumulative and bio-magnification potentials. Within the aquatic habitat fish cannot escape from the detrimental effects of these pollutants. Heavy metal toxicity as a result of fish consumption can result in damage or reduced mental and central nervous system function, lower energy levels, and damage to blood composition, lungs, kidneys, bones, liver and other vital organs. Long term exposure may result in slowly progressing physical, muscular, and Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis. Allergies are not uncommon and repeated long term contact with some metals or their compounds may even cause cancer. Heavy metal toxicity is a chemically significant condition when it does occur. If unrecognized or inappropriately treated, toxicity can result in significant illness and reduced quality of life which can ultimately result in death. Recommended strategies to combat this menace involves environmental legislation, holistic planning, technological measures to improve the quality of waste discharges and environmental monitoring programs.

Keywords: *Heavy metals, fish, human health, contamination.*

INTRODUCTION

Fish, an important source of food for humans is also a key component in many natural food webs. Fats, fat-soluble vitamins and protein is obtained from fish. The high quality protein from fish is better for human health than that in meat and poultry. Fish consists of 15 – 24% protein; 1 – 3% carbohydrate; 0.1 – 22% lipid; 0.8 – 2% inorganic substances and 66 – 84% water [1]. Each of these is important for human health, growth and intelligence. Fish play an important role as it is an important source of trace minerals and calcium. It also provides calories, nutrients such as fat, vitamins (B complex and D), elements such as, phosphorus, sodium as well as trace elements. Fish may easily absorb pollutants from the ambient water and from their food and then deposit them in the tissue through the effects of bioconcentration and bioaccumulation. In this regard, heavy metals have long been recognized as an important pollutant due to their toxicity and ability to accumulate in marine organisms. Some of the identified toxic metals are arsenic, beryllium, cadmium, chromium, cobalt, tin, zinc, copper, iron, lead, manganese, aluminium, mercury, nickel and selenium [2].

SOURCES OF HEAVY METALS POLLUTION

Heavy metals differ widely in their chemical properties, and are used extensively in electronics, machines and the artifacts of everyday life as well as in high-tech applications. As a result, they are able to enter into the aquatic environment and food chains of humans and animals from a variety of anthropogenic sources as well as from natural sources [3]. The main sources of contamination include; mining wastes, landfill leaches, municipal wastewater, urban runoff, and industrial waste waters particularly from electroplating, electronic and metal finishing industries. Many aquatic environments face metal concentrations that exceed water quality criteria designed to protect the environment, animals and humans. The problems are exacerbated because metals have the tendency to be transported with sediments, are persistent in the environment and can bio-accumulate in the food chain [4].

Cadmium is used widely in electroplating industries, solders, batteries, television sets, ceramics, photography, insecticides, electronics, metal finishing industries, and metallurgical activities. It can be introduced into the

environment by metal-ore refining, cadmium containing pigments, alloys and electronic compounds, cadmium containing phosphate fertilizers, detergents, and refined petroleum products. Rechargeable batteries with nickel-cadmium compounds are also sources of cadmium [5]. Arsenic is found naturally in the deposits of earth's crust worldwide. The word "arsenic" is taken from Zarnikh in Persian literature, which means yellow pigment [6]. It was first isolated as an element by Albert Magnus in 1250AD. Arsenic exists in powdery amorphous and crystalline forms in the ores. In certain areas, the concentration of arsenic may be higher than its normal dose and creates severe health hazards to human beings and animals. It enters the environment through the natural weathering of rocks and anthropogenic activities, mining and smelting processes, pesticide use and coal combustion. The toxicity of arsenic as a result of the contamination of ground water bodies and surface waters is of great concern. Arsenic exists as arsenate, As (v), and arsenite, As (iii), in most of the groundwater [7]. Adsorption and solution pH commonly controls the mobility of arsenic in the aqueous environment. Metal oxides of Fe, Al, and Mn play a role adsorption of arsenic in aquatic bodies. The natural sources of mercury are volcanic eruption, weathering of rocks and soils, whereas anthropogenic mercury comes from the extensive use of the metal in the industrial applications, its mining and processing applications in batteries and mercury vapor lamps [7].

Extensive use of chromium compounds in industrial applications has discharged huge amounts of waste water containing toxic chromium species into water bodies. Chromium enters into the environment by natural inputs and anthropogenic sources. Volcanic eruptions geological weathering of rocks, soils and sediments are the natural sources of chromium whereas, anthropogenic contributions of chromium come from the burning of fossil fuels, production of chromates, plastic manufacturing, electroplating of metals and extensive use in leather and tannery industries [8]. Nickel occurs naturally in the soils and volcanic rocks. Nickel and its salts are used in several industrial applications such as in electroplating, automobile and aircraft parts, batteries, coins, spark plugs, cosmetics and stainless steel and is used extensively in the production of nickel-cadmium batteries on an industrial scale. It enters into the water body naturally by weathering of rocks and soils and through the leaching of minerals. The water soluble salts of nickel are the major problems of contamination in aquatic systems. Paint formulation and enameling industries discharges nickel containing effluents to the nearby water bodies. Nickel is also found in cigarettes as a volatile compound commonly known as nickel carbonyl [9].

Transport of Heavy Metals in the Environment

The atmosphere represents an active environmental compartment for heavy metals. The other environmental compartments are land surface, ocean, sediments and biosphere. It is known that heavy metals in the atmosphere originate from both natural and anthropogenic sources. Each year large quantities of potentially toxic metals are introduced into the world's ocean from both sources [6]. The atmosphere can also be viewed as a transient environmental compartment whereby heavy metals pass through at a rapid rate from stationary and mobile sources, on their way to other environmental compartments. Besides, human activities also result in the release of large quantities of different contaminants, which are dispersed along various pathways through the biosphere. Bradl [10] divided the transport of heavy metals in the marine environment into three parts:

Atmospheric Transport

In atmospheric transport, metals are emitted into the atmosphere and are transported by wind over vast distances, depending on their state (gaseous, vapor or particulate). The atmosphere is a major route for the transport of heavy metals to the open oceans [11].

Biological Transport

Transport of metals by living organisms also plays a role in the total transport. In biological transport, plankton in coastal areas may have a quantitative influence on metal transport. A large numbers of metals may be absorbed by phytoplankton and zooplankton and are brought to the coastal areas via the river systems. The metals may then settle and become incorporated in sediments instead of being transported further into the oceans [4].

Aquatic Transport

Generally, the greater part of metal load emitted into the environment is transported by water.

Most of it eventually reaches lakes and the coastal areas via river transport. Part of the total metal load carried into a lake systems are transported by absorption or adsorption onto particles of different types. The metals may then be released again into the systems through microbial activity or due to changes in various physical and chemical factors including pH and redox potential [4].Heavy metals transported into the marine environment may be incorporated into the marine food chain and eventually reach human consumers [10].

Transformation of Heavy Metals in Aquatic Environment

Berg *et al.* [7] clearly described that the physical and chemical form of metals in the aquatic environment is controlled by such environmental variables as pH, redox potential (dissolved oxygen, ionic strength), salinity, alkalinity and hardness, the presence of organic compounds and particulate matter, and biological activity. Six principal factors, which contribute to the movement and distribution of heavy metals, are polarity and water solubility, partition coefficients, vapor pressure, partition between different compartments of the environment and molecular stability and recalcitrant molecules [9].

There are considerable variations in heavy metals toxicity to the marine organisms because the uptake, storage, detoxification, and removal of the heavy metals vary greatly among different marine species. According to Peterson [11], intrinsic and extrinsic factors that may affect bioavailability and trace metal uptake by these organisms are:

- Intra- and inter-specifically variable intrinsic factors, e.g. nutritional state, stage of molt cycle, throughput of water by osmotic flux, and surface impermeability, and
- Extrinsic physical-chemical factors, e.g. temperature, salinity, dissolved metal concentration, presence or absence of other metals, and presence or absence of chelating agents. Heavy metals absorbed from the gastrointestinal tract are carried by the portal vein to the liver, where storage, metabolism, and biosynthetic activities take place [11].

Effects of Heavy Metals on Human Health

Fish is important for a healthy diet because they are rich in essential nutrients. However, when fish tissues accumulate metals in various concentration, and when that exceeds the safety levels, the toxic metals reach the human body and cause various forms of diseases. For this reason, fish consumption could become a major pathway to metal exposure and consequent risk for human health [12]. Heavy metals such as cadmium, mercury, lead, and arsenic pose a number of hazards to humans, these metals are also potent carcinogenic and mutagenic [13]. Heavy metal toxicity can result in damage or reduced mental and central nervous system function, lower energy levels, and damage to blood composition, lungs, kidneys, liver and other vital organs. Long term exposure may result in slowly progressing physical, muscular, and Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis. Allergies are not uncommon and repeated long term contact with some metals or their compounds may even cause cancer [14]. According to Ferner [15], heavy metal toxicity is a chemically significant condition when it does occur. If unrecognized or inappropriately treated, toxicity can result in significant illness and reduced quality of life. Acute heavy metals intoxications may damage central nervous function, the cardiovascular and gastrointestinal systems, lungs, kidneys, liver, endocrine glands and bones. Specific threats to human health associated with exposure to Cadmium, Lead, Mercury and Arsenic include the foregoing:

Health Effects of Cadmium

Cadmium (Cd), a by-product of zinc production is one of the most toxic elements to which man can be exposed to at work or in the environment. Once absorbed, Cd is efficiently retained in the human body in which it accumulates throughout life [16]. Cd is primarily toxic to the kidney especially, to the proximal tubular cells; the main site of accumulation. Cd can also cause bone demineralization either through direct bone damage or indirectly as a result of renal dysfunction [4].

Health Effects of Lead

Lead poisoning can happen if a person is exposed to very high levels of lead over a short period of time. When this happens, a person may experience the following: abdominal pain, constipation, tiredness, headache, irritability, loss of appetite, memory loss, pain or tingling in the hands and or feet and weakness [17]. However, lead poison can easily be overlooked because these symptoms may occur slowly or may be caused by other things. Exposure to high

levels of lead may cause anemia, weakness and kidney and brain damage. Very high lead exposure can cause death. Lead can cross the placenta barrier, which means pregnant women who are exposed to lead also expose their unborn children. Lead can damage a developing baby's nervous system[17]. Even low level lead exposures in developing babies have been found to affect behavior and intelligence. Lead exposure can cause miscarriage, stillbirths, and infertility (in both men and women). Generally, lead affects children more than it does adults. Children tend to show signs of severe lead toxicity at lower levels than adultsn [18]. A person who is exposed to lead overtime may experience abdominal pain, constipation, depression, distraction, forgetfulness, irritability, nausea. People with prolonged exposure to lead may also be at risk of high blood pressure, heart disease, kidney disease, and reduced fertility. The department of Health and Human Services (DHHS), Environmental Protection Agency (EPA), and the International Agency for Research on Cancer (IARC) in United States have determined that lead is probably cancer-causing in humans [4].

Health Effects of Mercury

Mercury has no known beneficial role in human metabolism, and its ability to affect the distribution and retention of other heavy metals makes it one of the most dangerous toxic metals [4]. The relatively high solubility and stability of certain mercury salts in water enables them to be readily taken up and bio-transformed to methyl-mercury by certain fish; these forms are readily absorbed through the gastrointestinal tract and are becoming a major source of mercury exposure in humans [11]. Although humans can excrete small amount of mercury in urine or feces as well as through exhalation or sweating, they lack an active robust mechanism for mercury excretion, allowing levels to accumulate with chronic exposures [19]. Mercury when ingested can be distributed to many organs, but may concentrate in the brain and kidneys, it can also cross the placenta and be found in breast milk [20]. Mercury exert its toxic effects by competing with and displacing iron and copper from the active site of enzymes involved in energy production, this include; mitochondrial dysfunction and oxidative damage. Mercury can also directly accelerate the oxidative destruction of cell membranes and LDL cholesterol particle as well as bind to and inactivate the cellular anti-oxidants N-acetyl cysteine, alpha-lipoic acid, and glutathione. Because of its effects on cellular defense and energy generation, mercury can cause widespread toxicity and symptoms in several organ systems; nervous system e.g. personality changes, tremors, memory deficits, loss of co-ordination., cardiovascular system e.g.; increased risk of arterial absorption, hypertension, stroke, atherosclerosis, heart attacks, and increased inflammation., gastrointestinal tract e.g.; nausea, diarrhea, ulceration., and kidney e.g.; failure [20]. Mercury may also accumulate in the thyroid and increase the risk of autoimmune disorders [22], and may cause contact dermatitis.

Health Effects of Arsenic

Arsenic occurs in inorganic and organic forms. Inorganic arsenic compounds (such as those found in water) are highly toxic while organic arsenic compounds such as those found in seafood) are less harmful to health. The immediate symptoms of acute arsenic poisoning include; vomiting, abdominal pain and diarrhea. This is followed by numbness and tingling of the extremities, muscle cramping and death in extreme cases. The first symptom of long-term exposure to high level of inorganic arsenic (e.g. through drinking water and food) are usually observed in the skin, and include; pigmentation changes, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis)[9]. These occur after a minimum exposure of approximately five years and may be a precursor to skin cancer. Long term exposure to arsenic can cause cancer in the skin, lungs, bladder and kidney [13]. Other adverse health effects that may be associated with long term ingestion of inorganic arsenic include; developmental effects, neurotoxicity, diabetes, and cardiovascular disease. In china (Province of Taiwan), arsenic exposure has been linked to "blackfoot disease", which is a severe disease of blood vessels leading to gangrene. However, this disease has not been observed in other parts of the world and it is possible that malnutrition contributes to its development [9].

RECOMMENDATIONS

The presence of heavy metals in aquatic ecosystems is a threat not only to the inhabitants of the ecosystems but also to the well-being of

humans. To combat this menace, the following measures are suggested:

- Environmental legislation: Environmental laws should be enforced to ensure that the aquatic environments are protected from exposure to toxic substances and from the risk associated with the use of chemicals.
- Anthropogenic activities should be regulated to ensure that heavy metals are net released into aquatic environments (either directly or indirectly).
- Holistic Resource Planning; This approach should ensure that relationships among land use, development, water flow, water quality, and aquatic ecosystems are considered prior to any land use designation.
- Technological measures to improve the quality of waste discharges and to lower both water demands and effluent loading should be implemented in response to environmental and water use concerns.
- Environmental monitoring programs should be set up and implemented to monitor chemicals in water, sediment, and organisms which would help to identify potential ecosystem problems and to track existing problems.
- Compensatory measures such as fish hatchery operation can produce young fishes that heavy metals contaminated habitats can no longer produce, and;
- Environmental sustainability education needs to be incorporated into the curricula of schools and universities, while awareness creation on environmental pollution needs to be given the seriousness it deserves.

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