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ENVIRONMENTAL MERCURY TOXICITY IN FISH: AN OVERVIEW

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ABSTRACT

Natural aquatic system may extensively be pollutated with mercury (Hg) released from domestic, industrial and other man-made activities. With increasing Hg in the environment, this heavy metal (element) enters the biogeochemical cycle. This can enter from the pollutated water into fish body by different routes and accumulates in the fish. The Hg is concentrated at different levels in the fish body. The fish may be more greatly affected by the water pollution sources. They are highly exposed from Hg, leading to severe toxicity. In this manner, the fish accumulate substantial concentrations of Hg in their tissues and so they are the single largest sources of Hg for humans through their eating. The organic forms of Hg (e.g., methyl Hg) are more toxic than the inorganic forms due to ease of absorption into the human system. The organic Hg compounds are most toxic to central nervous system (CNS), and may also affect the kidney and immune system. Main symptoms of Hg poisoning in human beings include kidney damage, disruption of nervous system, damage to brain function, DNA and chromosomal damage, allergic reaction, sperm damage, birth defect and miscarriage.

KEYWORDS: Aquatic environment, fish, heavy metals, mercury, pollution, toxicity.

1. INTRODUCTION

Nowaday, the pollution has become a serious threat and has brought hazards to the growing population as well as to the environment (or earth). 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. Hence, the industrial wastes are the main source of metal pollution for aquatic animals. The heavy metals constitute major pollutants in the environment. They are important pollutants for fish, because they are not eliminated from the aquatic systems by natural methods, such as organic pollutants, and are enriched in mineral organic substances. The metal contaminants are mixed in the aquatic environment through smelting process, effluents, sewage and leaching of garbage which cause severe harm to the aquatic systems. 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.[11,14]

In view of the above, the heavy metals are considered the most important form of pollution of the aquatic environment because of their toxicity and accumulation by marine organisms. The natural aquatic systems may extensively be polluted (contaminated) with heavy metals released from domestic, industrial and other man-made activities. With increasing heavy metals in the environment, these elements enter the biogeochemical cycle. The heavy metals can enter from pollutated water into the fish body by different routes and accumulate in the organisms. These metals are concentrated at different contents in the organs of fish body. Therefore, fish may be more greatly affected by the water pollution sources. They are highly exposed from the heavy metals, especially mercury (Hg) leading to severe toxicity, both in the fish and human beings.[11,13] 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 might be the bioindicators of environmental pollutants.[6]

The Hg is widespread in the environment as a result of natural and anthropogenic releases. Everyone is exposed to small amounts of Hg over the course of a lifetime. Most atmospheric Hg is elemental Hg vapor and inorganic Hg. The Hg present in waters, soils, plants and animals is typically present in organic or inorganic forms. The organic Hg is primarily in the form of methyl Hg. The Hg is released into surface waters from natural weathering of rocks and soils, and from volcanic activity. It is also released from human action, e.g., industrial activities, fossil fuel burning and disposal of consumer products (i.e., Hg thermometers, fluorescent bulbs and dental amalgams). The global cycling of Hg via air deposition occurs when Hg evaporates from soils and surface waters to the atmosphere. From the atmosphere, the Hg is redistributed on land and surface waters; then absorbed by soils or sediments. Once the inorganic Hg is released into the environment, the bacteria convert it into organic Hg, which is the primary form that accumulates in fish and shellfish.[1,4]

The Hg vapor is emitted to the atmosphere through both natural and anthropogenic sources. The natural sources of Hg vapor include volcanoes, as well as rocks, soils and water surfaces. The Hg is also found naturally in cinnabar, the major ore for the production of Hg. Anthropogenic sources of Hg vapor include emissions from coal-burning power plants, municipal incinerators and through the recycling of automobiles.[3] It is estimated that 50-70% of the total emission of Hg to the environment is a result of human activity. About 1,000 twice as much, about 2,600 tons, is emitted from anthropogenic sources.[9]

2. EXPOSURE AND ACCUMULATION OF MERCURY IN FISH

The Hg emitted from all sources is cycled through the ecosystem. Once in the atmosphere, Hg vapor is slowly converted by oxidative processes to divalent Hg, which is then returned to the earth's surface by rainfall, where it accumulates in soils and in surface waters. Some of the Hg load is then converted back into Hg vapor and returned to atmosphere. However, another fraction of Hg load is washed into rivers, streams and eventually the ocean, where it accumulates in aquatic sediments. It is here that inorganic. Hg is converted to methyl Hg by microorganisms living in the sediments by a process called 'methylation'. The methyl Hg then enters the food chain when it is absorbed by phytoplankton species. The phytoplanktons are eaten by plankton consumers, which then are eaten by larger fish and larger mammals. The methyl Hg accumulates in the tissues of fish and shellfish via a process called 'biomagnification', through which methyl Hg concentration increases as it moves up from one trophic level to the next. Within each organism, methyl Hg bioaccumulates as the organism consumes more and more organisms containing methyl Hg. Thus, smaller fish that are lower down in the food chain have lower concentrations of Hg in their tissues, while larger fish that are higher up in the food chain have higher concentrations. For example, sardines contain about 0.01 ppm of Hg, while sharks contain from 1-4 ppm. Fish with highest levels of Hg include sharks, swordfish and king mackerels. Large marine mammals like whales have levels similar to these fish. In aquatic food chain, methyl Hg biomagnifies as it is passed from lower to higher trophic levels through consumption of prey organisms. The fish at the top of food chain can biomagnify methyl Hg approximately 1-10 million times greater than concentrations in surrounding waters. About all of the Hg found in fish and other aquatic organisms are in methyl Hg form. Long-lived predatory ocean fish may have increased methyl Hg content because of exposure to natural and industrial sources of Hg.[3,12]

Fish accumulate substantial concentrations of Hg in their tissues, and thus can represent a major dietary source of this heavy metal for humans. So, fish are the single largest sources of Hg for humans. Primary source of Hg pollution in humans is through eating the fish.[4,17] Methyl Hg accumulation in seafood and fish products is a growing global concern that poses severe health risks to public. While Hg occurs naturally, large amounts enter the environment from anthropogenic sources. Human exposure to Hg begins with the production of many useful products. As only metal on earth that can be found in a liquid form at room temperature, Hg and its compounds have many uses. Due to its special properties, including high density and high rate of thermal expansion, Hg is often used in barometers and thermometers. It can also be combined with other metals to create special alloys called 'amalgams'. Gold (Au) and silver (Ag) amalgams have been used in dentistry for fillings, and tin (Sn) amalgams are used to make mirrors. The Hg can be found in many different lamps, including black lights, and is used in industrial production of chloride and sodium hydroxide. Some Hg compounds are used as ingredients in skin creams, antiseptics, diuretics, fungicides, insecticides, and as a preservative in vaccines. The Hg compounds were even once used in the treatment of syphilis.[3,12]

The Hg is a naturally occurring heavy metal and a waste product of industries such as coal-burning power plants. Once Hg enters the water, it is consumed by microorganisms, which are eaten by small fish, and these, in turn, by bigger fish. At each step of food chain, Hg is retained in the muscle meat of fish, resulting in the highest concentrations of Hg in large, long-lived predatory fish, such as swordfish and shark.[12]

3. MERCURY TOXICITY TO FISH

While some of the Hg compounds are fairly inert, many of them are extremely toxic. In USA, some of the Hg products containing have been banned, have limited use, or have special disposal requirements. These include dental fillings, vaccines, non-industrial thermometers, lamps, car starters and electronics. There are also many regulations regarding the disposal of Hg wastes. Most organic Hg compounds are readily absorbed by ingestion and appear in the lipid fraction of blood and brain tissue. The organic Hg readily crosses blood-brain-barrier

(BBB) and placenta. The foetal blood Hg levels are equal to or higher than maternal levels. The methyl Hg also appears in human milk.[12]

The organic Hg compounds are most toxic in the CNS, and may also affect the kidneys and immune system.[7] Methyl Hg is toxic to the cerebral cortex and cerebellum in the developing brain and is a known teratogen. The Hg has a toxic effect on human nervous system, and can cause problems with learning, coordination and several other severe disorders, leading to death. The Hg is particularly dangerous for pregnant women (who can pass the Hg to the foetus through the placenta), breastfeeding women (who can pass the Hg to the baby through breast milk) and young children, whose nervous systems are developing.[7-8] One form of Hg that is toxic and very harmful is elemental Hg. It is highly volatile and can easily be converted to Hg vapor, exposure to which can damage the nervous system, lungs and kidneys. For most people, exposure to Hg occurs when they eat fish or shellfish contaminated with methyl Hg. This is found in nearly all freshwater and marine fish.[7]

As body tries to rid itself of these toxins, gaseous Hg is oxidized to divalent Hg, which accumulates in kidney and can cause kidney damage. Brain, kidney and lung are the target organs of elemental (gaseous) Hg. The brain and foetal brain are also the target organs for methyl Hg.[9] Most people are not exposed to inorganic Hg but rather absorb methyl Hg through the consumption of fish and shellfish. The methyl Hg is easily absorbed in the digestive tract, where it forms a complex with the amino acid cysteine. This new complex resembles a large neutral amino acid found in the body, methionine, and can more easily gain entry into cells. As with inorganic Hg, once in the bloodstream, methyl Hg will accumulate in brain and cause damage to CNS. The methyl Hg is naturally removed from the body over time. Eventually, this methyl Hg-cysteine complex is transported to liver where it is secreted into bile, after which enzymes break the complex down into its amino acid and methyl Hg parts. Some of this methyl Hg then comes in contact with the bacteria in the intestine and is broken down into inorganic Hg and carbon. The inorganic Hg is poorly absorbed in the rest of the methyl Hg that does not interact with bacteria is reabsorbed by the body and goes through the process again. It takes about 30-40 hr for methyl Hg to be distributed to the tissues of the body. This cycle is the reason it takes so long to rid the body of Hg and how it can accumulate in the blood. It can take up to a year for Hg levels to drop significantly. Many adverse health effects are associated with the accumulation of Hg in body, though these vary depending on the amount of Hg one is exposed to, time of exposure, chemical form of Hg and age of the subject. Many toxic symptoms have been noted in people who consumed fish that were contaminated directly by methyl Hg from anthropogenic sources, not from methyl Hg that accumulated through natural methylation process.[3,12]

In the 1950's, one of the most severe incidents (known as the 'Minamata Bay Incident') of industrial pollution and Hg poisoning occurred in the small seaside town of Minamata, Japan. A local petrochemical and plastics company, Chisso Corporation, dumped an estimated 27 tons of methyl Hg into the Minamata Bay over a period of 37 years. The Hg was used as a catalyst in the production of acetaldehyde, a chemical employed in the production of plastics. The methyl Hg-contaminated waste water, a byproduct of the process, was pumped into the bay, creating a highly toxic environment that contaminated local fish. The residents of Minamata, who relied heavily on fish for food, were at risk of exposure to methyl Hg with every bite of fish they ate. The high contamination levels in the people of Minamata led to severe neurological damage and killed more than 900 people. An estimated 2 million people from the area suffered health problems or were left permanently disabled from the contamination.[10] This form of toxicity in humans is now called 'Minamata disease'. Symptoms of this disease include sensory disorders of the four extremities, loss of feeling or numbness, cerebellar ataxia, tunnel vision or blindness, smell and hearing impairments, and disequilibrium syndrome. More serious cases lead to convulsions, seizures, paralysis and possibly death. In addition to the outbreak among the townspeople, congenital Minamata disease was observed in babies born to affected mothers. These babies demonstrated symptoms of cerebral palsy.[9]

Methyl Hg is 1,000 times more soluble in fat than in water, and it concentrates in muscle tissue, brain tissue and CNS. The Hg levels in fish may be in excess of 10,000-100,000 times the original concentration in surrounding waters. Its accumulation is fast, while depuration is extremely slow. The half-life of methyl Hg in fish is estimated at 2 years. The Hg levels for saltwater fish average 0.35-70.02 ppm.[1] The methyl Hg content of fish varies by species and size of the fish as well as harvest location. Top 10 commercial fish species (i.e., canned tuna, shrimp, pollock, salmon, cod, catfish, clams, flatfish, crabs and scallops) represent about 85% of the seafood market and contain a mean Hg level of about 0.1 μg/g.[7,12] Based on the growing body of evidence concerning the health issues of methyl Hg accumulation in the body, the EPA and 'Food and Drug Administration' (FDA) of USA have issued advisories targeting consumption of fish for specific groups. Their advice to women who may become pregnant, pregnant women, nursing mothers and young children up to 6 years of age is to avoid certain types of fish high in methyl Hg, and limit the amount of fish consumed each week. Specifically, the EPA and FDA advise these groups not to eat shark, swordfish, king mackerel, or tilefish at all because they contain very high levels of mercury (>1 ppm). They also advise these groups to eat up to 12 ounces (or 2 average meals) a week of fish and shellfish that are low in Hg. Children should only eat 6 ounces of fish. The low Hg fish and shellfish include shrimp, canned light tuna, pollock, salmon and tilapia. *Albacore tuna* is a commonly eaten fish but contains moderate amount of Hg. The EPA and FDA advise eating only 6 ounces of albacore tuna a week. Also, if one exceeds the suggested amount of fish or shellfish in a week, simply cut back the amount consumed the next week or two. Lastly, the EPA and FDA advise the public to check for local advisories on fish caught from local lakes, rivers and streams. These fish may be more greatly affected by anthropogenic pollution sources (CFSAN, 2006). These guidelines are not aimed at adult men, or woman past child bearing age, but individuals concerned with possible exposure to Hg should follow them as well. The current action level of US FDA for Hg in fish tissue is 1 ppm.[5,12]

Levels of Hg in bluefish are high enough to cause potential adverse effects in sensitive birds and mammals that ate them and to provide a potential health risk to humans who consume them. Fish larger than 50 cm fork length with average levels of Hg above 0.3 ppm, suggest that eating them should be avoided by pregnant women, children and others who are at risk. Fish consumption is the only significant source of methyl Hg for public. Communities that relied on fish intake for daily nutrient sustenance may be at risk from chronic, high exposure to methyl Hg and other persistent organic pollutants. High-end fish consumers, whether recreational or subsistence, are also at risk from Hg exposure.[1]

While the danger of Hg poisoning may seem like a good reason to refrain from consuming fish, the benefits of eating fish may outweigh many of the risks. Fish is high in protein, low in saturated fats, and contains important nutrients such as heart healthy omega-3 fatty acids. Docosahexaenoic acid (DHA), one of the omega-3 polyunsaturated fatty acids found in fish oils, is important for normal brain development and function.[15]

It is possible that DHA may even counteract the negative effects of Hg though this relationship has not yet been proven scientifically. Eating fish has also been found to reduce the risk of heart attacks, lower blood pressure, and improve arterial health.[16]

4. CONCLUSION

Pollution has become a serious threat and has brought hazards to the growing population as well as to environment. Heavy metals constitute major pollutants in the environment. They are important pollutants for fish, because they are not eliminated from the aquatic systems by natural methods. The metal contaminants are mixed in the aquatic environment through smelting process, effluents, sewage and leaching of garbage which cause severe harm to aquatic systems. With increasing heavy metals in the environment, these elements enter the biogeochemical cycle. The heavy metals like mercury (Hg) can enter from pollutated water into the fish body by different routes and accumulate in the organisms. These metals are concentrated at different contents in the organs of fish body. Therefore, fish may be more greatly affected by the water pollution sources. They are highly exposed from the Hg, leading to severe toxicity. The Hg is widespread in the environment as a result of natural and anthropogenic releases.

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