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Review Article

Health Hazards Due to Heavy Metal Poisoning and other Factors in Sea Foods

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ABSTRACT

Mercury (Hg) is a heavy metal that is present in the earth's crust and it is methylated by bacteria in aquatic environments to methyl mercury (MeHg) in anaerobic conditions. It is then concentrated into the food chain, so predatory fish and other seafood animals may possibly consume to the highest levels. Thus, consuming fish and other seafood leads to human exposure. It is generally accepted that seafood represents one of the major sources of non-occupational mercury exposed by humans. MeHg readily crosses the placenta and the blood-brain barrier and acts as a neurotoxin. The developing fatal nervous system is especially sensitive to its effects, and chronic exposure causes Minamata disease in human. Controlling of methyl mercury in fish and seafood products is important for public health and there are some responsible organizations in the world, which are in charge of monitoring and controlling methyl mercury in fish and seafood products. Salmon is a kind of fish which has good nutrition for human but it can be contaminated by another heavy metal such as arsenic. In risk assessment, the provisional tolerable weekly intake (PTWI) for inorganic arsenic is 15 µg/kg b.w./week and the organic forms of arsenic present in sea foods need different consideration from the inorganic arsenic in water. There are no reports of toxicity in man or animals from the consumption of organoarsenicals in seafood. Organic arsenic compounds such as arsenobetaine and arsenocholine seems not to be converted to inorganic arsenic *in vivo* and are not genotoxic in mammalian cells *in vitro*. Therefore, arsenobetaine and arsenocholine from fish and sea food consumption are not considered to represent a significant health risk, but can cause toxicity if it exceeds the tolerable level of consumption. This article would have a review of materials and sources of mercury and arsenic, public health concerns due to it and other various methods of contamination in fish and seafood products with respect to various factors like parasites, pathogens and aqua culture drugs.

Keywords: Sea foods, metal poisoning, organoarsenicals.

INTRODUCTION

At present, a significant portion of the global diet consists foods of aquatic origin, either in fresh form or in processed form either from fresh or salt water sources. The more the consumption of sea foods have an economic impact on commercial fishing and the associated food processing industries, and each year a wide variety of manufactured seafood products are launched into the market. The need to include seafood, particularly fish, in the human diet has been emphasized with regard to its lower levels of saturated fat, cholesterol, and caloric intake compared with meat, poultry, and dairy products,[1] but we must investigate the attendance of environmental contaminants in fish and other seafood products. Both in terrestrial and aquatic food chains accumulation of certain environmental contaminants up to toxic concentrations are always possible. In general, few among the thousands of chemicals produced from the industries enter to the aquatic environment. Some of these chemical are basically considered as a part of seafood's natural environment while others have anthropogenic sources. Chemical contaminants can occur through industrial, municipal, or agricultural sources[2]. In terms of organic chemicals, the best known examples of bioaccumulation in aquatic food chains are the polychlorinated biphenyls (PCBs), dioxins, and organochlorine pesticides such as dichlorodiphenyl trichloroethane (DDT). Arsenic and Methyl mercury are the best documented example for metals of high bioaccumulation[3].

Methyl mercury is an organic material that conforms from inorganic mercury. The contamination of mercury in seafood such as fish, shellfish, oyster and other types of sea foods are the major concern in places where it is densely populated and pollution caused due to the population[4]. There are also sources of non-occupational mercury exposure caused in the fish and other seafood which can increase the level of mercury in the tissues of the fish[5]. In Japan, industrial discharge of mercury into Minamata Bay raised the concentrations of the metal in fish, resulting in serious human intoxication and deaths following consumption of the contaminated fish. The Hg discharged in Minamata continued to magnify until the values reached to 10-100 µg/g in sediments, 2000 µg/g at the discharge channel of the Chisso Corporation that used and dumped it, and 5-40 µg/g in fish and molluscs. The Minamata experience has indicated that the most serious source of mercury toxicity can occur due to the discharge from industrial plants and it was one of the most dramatic example of environmental contamination due to mercury and in turn affecting the human life[6].

Arsenic usually occurs in waters as inorganic oxides in the pentavalent form. Arsenic is a ubiquitous, naturally-occurring element. Increased levels of arsenic in water and soil can be found in certain areas as a result of leaching from rock into ground water, and possible geothermal activity[7]. Levels of arsenic are most constant in deep ocean waters, while levels in surface waters show seasonal variation[8]. Trivalent forms of arsenic are more toxic to humans and aquatic organisms and are usually only present under anaerobic conditions. Arsenic has a very complex chemistry in the marine environment, and occurs in various chemical forms and more than 20 different chemical forms have been identified and characterised. The inorganic arsenic compounds are the most toxic, particularly As_2O_3. Methylated arsenic compounds occur naturally in the environment as a result of biological activity[9]. Reduction and methylation by microorganisms occur in the more superficial photic zone which sufficient sunlight penetrates to support photosynthesis; levels of methylation correlate with photosynthetic activity[10,11]. Accordingly, in addition to As[V], surface waters contain small amounts of inorganic arsenite (As[III]), methyl arsenate (MA) and di-methylarsenate (DMA). The sequence starts with phytoplankton which readily take up arsenate from water via trans-membrane transport systems normally dedicated to the uptake of essential phosphate anions[12,13,14]. Following uptake, phytoplankton rapidly detoxify arsenate by reduction and methylation, resulting in the formation of arsenic containing sugars as well as minor amounts of DMA and other methylated arsenical compounds[15,16]. In addition to arsenobetaine, other organic and inorganic arsenic compounds have been found in fish that are common components of the human diet. The proportion of inorganic arsenic in those foods are generally low, less than 1–4% of total arsenic[17,18] .

MATERIAL AND SOURCES

Mercury

Fish and other seafoods can be exposed to a range of mercury contamination from the water table[19]. Mercury has a widespread occurrence in nature albeit, in trace quantities. Its principal mineral cinnabar (HgS) from the earth's crust can be found in abundant in the region of gold mining[19]. Mercury or its compounds are used in industries as catalysts (inorganic form) for the synthesis of important industrial compounds like (e.g. acetaldehyde, vinyl chloride), as fungicides in agriculture and horticulture, as anti liming agents in the paper and pulp industries, and as antifouling agents in paints. Trace quantities of mercury are also found in crude oil and coal, which is released to the environment during combustion such as coal burning, trash incineration, and industrial emissions. Mercury can enter into the aquatic environment and are carried into the aquatic animals such as fish, shellfish, shrimp, oyster and other types of seafood by absorption through the gills or by absorption into the body from the food upon which they are fed, but absorption into the body through the food is the major predominant source of entry, and mercury accumulates in organic form in the tissues of fish and other seafood animals[20, 3]. The measurement of mercury concentration among species of fish, cephalopods, crustaceans and molluscs in marine environment showed that fish and crustaceans had the highest accumulation levels of this element[21] with the mercury concentration in fish organs are observed in descending order such as the gills, intestines, head and muscles[22, 23]. The mercury concentrations will usually be low in the muscle and high in liver or the gills[23]. Inorganic mercury can be methylated and formed to organic mercury compounds when it is covalently bound to carbon, such as methyl mercury (Hg CH)[24]. This process occurs biologically, and more predominantly by microbiological process, and also by chemical processes in the aquatic environment, and this organic form is taken up by aquatic organisms such that the mercury concentrations in tissues can be greater than in the ambient water. The methyl mercury bio accumulates up the tropic chain so that the highest concentrations are found in predatory fish.

Arsenic

The epidemiological data found that arsenic has a little evidence with cancer risk[25]. Inorganic arsenic has been recognized as a human poison since ancient times, and large oral doses (above 60,000 ppb in water) can result in death. The most characteristic effect of long-term oral exposure to inorganic arsenic is a pattern of skin changes. These include patches of darkened skin and are often associated with changes in the blood vessels of the skin. Skin cancer may also develop. Swallowing arsenic has also been reported to increase the risk of cancer in the liver, bladder, and lungs. The Department of Health and Human Services (DHHS) has determined that inorganic arsenic is known to be a human carcinogen (a chemical that causes cancer)[26]. Inorganic arsenic is more toxic than organic forms and inorganic arsenic is classified by the International Agency for Research on Cancer (IARC) as "carcinogenic to humans" (Group 1) on the basis of "sufficient evidence" for an increased risk for cancer of the urinary bladder, lung and skin[27]. Besides cancer induction, chronic human exposure to arsenic in drinking water (mainly inorganic arsenic) has also been associated with peripheral vascular diseases, cardiovascular diseases and possibly with diabetes and reproductive effects[27]. Environmental Protection Agency (EPA) also has classified inorganic arsenic as a known human carcinogen. Almost no information is available on the effects of organic arsenic compounds in humans. Studies in sea foods show that most simple organic arsenic compounds (such as methyl and di methyl compounds) are less toxic than the inorganic forms[28]. In sea foods, ingestion of methyl compounds can result in diarrhoea, and lifetime exposure can damage the kidneys. Lifetime exposure to di methyl compounds can damage the urinary bladder and the kidneys[26]. Arsenic and its metabolite are chemicals that bio accumulate in tissues of aquatic organisms but do not bio magnify in the aquatic food chain. The bioaccumulation factor (BAF) for arsenic in salmon is 5.79[29]. The average biological half-life is about 60 days (rats/rabbits) due to the accumulation of arsenic in the erythrocytes. For humans, half-life is shorter because of a fast excretion of arsenic[30].

PARASITIC HAZARDS

Parasites (in the larval stage) consumed in uncooked or undercooked seafood can present a human health hazard. Among parasites, the nematodes or roundworms (Anisakis spp., Pseudoterranova spp., Eustrongylides spp., and Gnathostoma spp.), cestodes or tapeworms (Diphyllobothrium spp.), and trematodes or flukes (Chlonorchis sinensis (C. sinensis), Opisthorchis spp., Heterophyes spp., Metagonimus spp., Nanophyetes salmincola, and Paragonimus spp.) are of most concern in seafood. Most of these parasites cause mild-to-moderate illness, but severe symptoms can occur. Roundworms may embed in the intestinal wall and cause nausea, vomiting, diarrhoea, and severe abdominal pain and sometimes may penetrate the intestine. Tapeworms can cause abdominal swelling and abdominal cramps and may lead to weight loss and anaemia. Intestinal flukes (Heterophyes spp., Metagonimus spp., and Nanophyetes salmincola) may cause abdominal discomfort and diarrhoea. Some intestinal flukes may also migrate to and damage the heart and central nervous system. Liver flukes (C. sinensis and Opisthorchis spp.) and lung flukes (Paragonimus spp.) may migrate to the liver and lung and sometimes cause serious problems in other vital organs.

Some products that have been implicated in human parasite infection are the following: ceviche (fish and spices marinated in lime juice); lomi lomi (salmon marinated in lemon juice, onion, and tomato); Poisson cru (fish marinated in citrus juice, onion, tomato, and coconut milk); herring roe; sashimi (slices of raw fish); sushi (pieces of raw fish with rice and other ingredients); green herring (lightly brined herring); drunken crabs (crabs marinated in wine and pepper); cold-smoked fish; and, undercooked grilled fish[31]. A survey of U.S. gastroenterologists confirmed that seafood-borne parasitic infections occur in the United States with sufficient frequency to recommend preventive controls during the processing of parasite-containing species of fish that are intended for raw consumption.

Controlling parasites

The process of heating raw fish sufficiently to kill bacterial pathogens is also sufficient to kill parasites. Guidance concerning cooking and pasteurizing to kill bacterial pathogens is provided by hot smoking, cooking and pasteurization[32]. Regulatory requirements for retorting (i.e., thermal processing of low acid canned foods) are contained in the Thermally Processed Low-Acid Foods Packaged in Hermetically Sealed Containers regulation, 21 CFR 113 (hereinafter, the Low-Acid Canned Foods (LACF) Regulation). This guidance does not provide further information on retorting.

The effectiveness of freezing to kill parasites depends on several factors, including the temperature of the freezing process, the length of time needed to freeze the fish tissue, the length of time the fish is held frozen, the species and source of the fish, and the type of parasite present. The temperature of the freezing process, the length of time the fish is held frozen, and the type of parasite appear to be the most important factors. For example, tapeworms are more susceptible to freezing than are roundworms. Flukes appear to be more resistant to freezing than roundworms. Freezing and storing at an ambient temperature of -4°F (-20°C) or below for 7 days (total time), or freezing at an ambient temperature of -31°F (-35°C) or below until solid and storing at an ambient temperature of -31°F (-35°C) or below for 15 hours, or freezing at an ambient temperature of -31°F (-35°C) or below until solid and storing at an ambient temperature of -4°F (-20°C) or below for 24 hours are sufficient to kill parasites[5]. Note that these conditions may not be suitable for freezing particularly large fish (e.g., thicker than 6 inches).

Brining and pickling may reduce the parasite hazard in a fish, but they do not eliminate it, nor do they minimize it to an acceptable level. Nematode larvae have been shown to survive 28 days in 80° salinometer brine (21% salt by weight). Fish that contain parasites in their flesh may also contain parasites within their egg sacs (skeins), but generally not within the eggs themselves. For this reason, eggs that have been removed from the sac and rinsed are not likely to contain parasites.

Trimming away the belly flaps of fish or candling and physically removing parasites are effective methods for reducing the numbers of parasites. However, they do not completely eliminate the hazard, nor do they minimize it to an acceptable level.

PATHOGENS IN THE HARVEST AREA

The control of pathogens from the harvest area for both molluscan shellfish and fish other than molluscan shellfish.

Strategies for control of pathogens in fish other than molluscan shell fish

There are a number of strategies for the control of pathogens in fish and fishery products. They include: Controlling the source (i.e., harvest waters) of molluscan shellfish and the time from exposure to air (i.e., by harvest or receding tide) to refrigeration to control pathogens from the harvest area [31].

- Controlling the amount of moisture that is available for pathogenic bacteria growth (water activity) in the product by drying
- Controlling the amount of moisture that is available for pathogenic bacterial growth (water activity) in the product by formulation
- Controlling the amount of salt or preservatives, such as sodium nitrite, in the product
- Controlling the level of acidity (pH) in the product (covered by the Acidified Foods regulation, 21 CFR 114, for shelf-stable acidified products, and for refrigerated acidified products);

- Controlling the introduction of pathogenic bacteria after the pasteurization process

Managing the amount of time that food is exposed to temperatures that are favourable for pathogenic bacteria growth and toxin production for Clostridium botulinum, and for Staphylococcus aureus in hydrated batter mixes.

Killing pathogenic bacteria by cooking or pasteurization or retorting (covered by the Thermally Processed Low-Acid Foods Packaged in Hermetically Sealed Containers regulation) hereinafter, the Low-Acid Canned Foods (LACF) Regulation[31].

Molluscan shellfish

Pathogens found in waters from which molluscan shellfish are harvested can cause disease in consumers. For the purposes of this guidance, molluscan shellfish include:

(1) Oysters; (2) clams; (3) mussels; and (4) scallops, except where the final product is the shucked adductor muscle only. The pathogens of concern include both bacteria (e.g., Vibrio spp., *Salmonella* spp., *Shigella* spp., and *Campylobacte*r jejuni (C. jejuni)) and viruses (e.g., hepatitis A virus and norovirus).

Pathogens from the harvest area are of particular concern in molluscan shellfish because of

- Environment in which molluscan shellfish grow are commonly subject to contamination from sewage, which may contain pathogens, and contamination from naturally occurring bacteria, which may also be pathogens.
- Molluscan shellfish filter and concentrate pathogens that may be present in surrounding waters and
- Molluscan shellfish are often consumed whole, either raw or partially cooked.

AQUA CULTURE DRUGS

Use of unapproved drugs or misuse of approved drugs in aquaculture fish poses a potential human health hazard. These substances may be toxic, allergenic, or carcinogenic, and/or may cause antibiotic resistance in pathogens that affect humans.

To control this hazard, drugs for use in food animals, whether they are for direct medication or for addition to feed, generally must be approved, conditionally approved or index listed by FDA (Federal Food, Drug, and Cosmetic Act Section 512)[31]. Under certain conditions authorized by FDA, unapproved new animal drugs may be used in conformance with the terms of an Investigational New Animal Drug (INAD) application (21 CFR 511 and FDA's Center for Veterinary Medicine (CVM) Guide 1240.3025). Off label use in animals of approved human or animal drugs is permissible in certain circumstances[33]. Drugs on the Index of Legally Marketed Unapproved New Animal Drugs for Minor Species (the Index) may not be used in food animals except in early non-food life stages of food producing minor species in certain circumstances.

Reasons for the use of drugs in aquaculture include the need to

(1) Treat and prevent disease

(2) Control parasites

(3) Affect reproduction and growth and

(4) Provide tranquilization (e.g., for weighing).

Relatively few drugs have been approved for aquaculture. This factor may lead to the inappropriate use of unapproved drugs, general-purpose chemicals, or approved drugs in a manner that deviates from the labeled instructions.

CONCLUSION

Fish and seafood products are the main protein diet. They are very delicious and stable health diet and there are many consumers throughout the world. Therefore, they must be safe for human, but some of chemical contaminants enter aquatic environment and then accumulate in seafood animals. Today, the main source of exposure to chemical contaminants such as mercury, is from methylation of inorganic mercury in bodies of fresh and ocean water, the ensuing bioaccumulation in the aquatic food chain, and the consumption of fish or other sea foods by humans.

Mercury is one of the most toxic metals that can readily accumulate in tissues of fish and other seafood animals even if the concentrations in water and aquatic plants are low. The ingestion of seafood animals contaminated with methyl mercury is the leading cause of mercury poisoning in humans. Methyl mercury is taken up predominately from ingested food and in Marine culture systems generally, and in other systems the fish are fed formulated diets. The feed will, or should, have low mercury contents, and the harvested products will thereby have low concentrations of mercury in their tissues for being harvested at a young stage and would be expected to have less body burden even if their food contained mercury.

Nonetheless, fish and other seafood should be monitored for methyl mercury contaminant and arsenic and other sources like parasites, pathogens and aqua culture drugs for its human health hazards. Therefore, authorities responsible or sentinels of food and environmental pollution should give more attention to assuring clean and safe sea foods and aquatic environments. So, various contaminations affect not only the aquatic ecosystems which are exposed to it, but can also have an impact on human health. Consequently, fish and other sea creatures could be served as alarms regarding to risks for seafood consumers and they need to reduce or eliminate sources of this contamination.

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