Chapter 9

Chemical hazards and seafood safety

Dr. T.V. Sankar

Senior Scientist & Head
Division of Quality Assurance & Management
Central Institute of Fisheries Technology, Cochin - 682 029

Food is any substance consumed to provide nutritional support for the body (Wikipedia). Food is generally from plant or animal origin and provides body with all the essential nutrients like carbohydrates, fats, proteins, vitamins, or minerals. The substance is ingested by an organism and assimilated by the organism's cells in an effort to produce energy, maintain life, or stimulate growth. Animals are used as food either directly or indirectly by the products they produce. Food has two distinct roles to play in the consumer – provide nutrients that are essential for growth namely proteins, fat, vitamins and minerals as well as provide components necessary for prevention of certain diseases. Though food is generally recognized to be safe, some human illnesses can be traced to foods. The causes of these illnesses could be as a result of constituents of foods, such as contaminating pathogenic bacteria, or chemicals in minute amounts that have been added for other purposes, such as pesticides for insect control before harvest or food additives for enhancing food quality and safety.

Fish is a food of excellent nutritional value, providing high quality protein and a wide variety of vitamins and minerals, including vitamins A and D, phosphorus, magnesium, selenium, and iodine in marine fish. Its protein - like that of meat - is easily digestible and favourably complements dietary protein provided by cereals and legumes that are typically consumed in many developing countries. Even in small quantities, fish can have a significant positive impact in improving the quality of dietary protein by complementing the essential amino acids that are often present in low quantities in vegetable-based diets.

But recent research shows that fish is much more than just an alternative source of animal protein. Fish oils in fatty fish are the richest source of a type of fat that is vital to normal brain development in unborn babies and infants. Without adequate amounts of these fatty acids, normal brain development does not take place. But at the same time, most often, it is associated with the risk of several other unwanted chemicals which cause harm to the consumer.

Components of Foodborne Hazards

Foodborne illness, commonly called "food poisoning", is caused by the contamination of food from other food, more so in the case of cooked food as well as temperature abuse. Food poisoning also could be due to, to a lesser extent from improper storage, contamination from detergents or disinfectants. Adulteration is one possible source of contamination. The primary categories of foodborne pathogenic organisms are bacteria, viruses and parasites.

Intrinsic food components include nutritional factors and thousands of contaminant compounds naturally present in foods. The intrinsic component hazards in the food supply associated with nutritional factors can be either deficiencies or excesses. Pellagra, scurvy, goiter, rickets and beriberi are examples of the former, and toxicity from excessive fat-soluble vitamins and minerals illustrates the latter. On the other hand, natural contaminants include those occurring in foods of plant origin, such as the oxalates in spinach and the glycoalkaloids in potatoes. Eating a nutritious diet including mixed and varied components can minimize most of these problems.

Chemicals which are hazardous to the consumer but present in food include naturally occurring toxicants, agro-industrial contaminants and food additives. The naturally occurring toxicants are considered high risk components while food additives are considered as least risky. The naturally occurring toxicants include chemicals which are present in food and feeds including mycotoxins and algal metabolites, aquatic biotoxins, phytoalexins, intrinsic components of plants, bacterial toxins, cyanobacterial toxins and food decomposition components. Several organic and inorganic compounds can find their way into fish and seafood which include - inorganic chemicals like arsenic, cadmium, lead, mercury, selenium, copper, zinc and iron, organic compounds like poly chlorinated biphenyls (PCBs), dioxins and insecticides (chlorinated hydrocarbons). This is a very diverse group with a wide range of industrial uses and a chemical stability that allows them to accumulate and persist in the environment. Food additives pose relatively little risk because of intensive testing required by public health agencies before approval for food or animal feed use. Processing-related compounds are sulphites (used in shrimp processing), poly phosphates, nitrosamines and residues of drugs used in aquaculture (e.g. antibiotics or hormones).

Many of the inorganic chemicals are essential for life at low concentration but become toxic at high concentration. While minerals such as copper, selenium, iron and zinc are essential micronutrients for fish and shellfish, other elements such as mercury, cadmium and lead show no known essential function in life and are toxic even at low concentrations when ingested over a long period. These elements are present in the aquatic environment as a result of natural phenomena such as marine volcanism and geological and geothermal events, but are also caused by anthropogenic pollution arising from intensive metallurgy and mining, waste disposal and incineration, and acidic rain caused by industrial pollution. This is in contrast with organic compounds, most of which are of anthropogenic origin brought to the aquatic environment by humans. Increasing amounts of chemicals may also be found in predatory species as a result of biomagnification, which is the concentration of the chemicals in higher levels of the food chain. Similarly, they may be present as a result of bioaccumulation, when chemicals in the body tissues accumulate over the life span of the individual. In this case, a large (i.e. older) fish will have a higher content of the chemical concerned than a small (younger) fish of the same species. The presence of chemical contaminants in seafood is therefore highly dependent on geographic location, species and fish size, feeding patterns, solubility of chemicals and their persistence in the environment.

Risks from fish contaminants

Several studies indicate that in the open seas, which are still almost unaffected by pollution, fish mostly carry only the natural burden of these inorganic chemicals. However, in heavily polluted areas, in estuaries, in rivers and especially in locations that are close to industrial sites, these elements can be found at concentrations that exceed the natural load. Likewise, several studies have concluded that levels of these chemicals in fish intended for human consumption are low and probably below levels likely to affect human health. Nevertheless, they can be of potential concern for populations for whom fish constitutes a major part of the diet and for pregnant and nursing women and young children who consume substantial quantities of oily fish.

Risk Assessment

Risks associated with food hazards and chemical exposure, although not common, make the public more aware of foodborne hazards in their daily lives. Once a specified hazard has been identified as causing a particular health effect, a risk assessment is conducted. The goal of the risk assessment is to estimate the risk to humans caused by the potential hazard. A risk assessment is conducted following three basic steps: hazard evaluation, human exposure evaluation and risk determination or estimation. Once these have been determined, a risk management strategy is developed to reduce the risk to the lowest practical level, while trying to maintain an adequate, wholesome food supply.

Risk Management

Risk management is the process of using information obtained in the risk assessment procedure and weighing policy alternatives to select the most appropriate regulatory action. In principle, risk management involves the identification and appraisal of available management alternatives, the selection of the best alternatives, and the implementation, monitoring and enforcement of the selected alternatives. Some practical risk management alternatives contributing to food safety include: establishment of regulatory limits, monitoring of food products before and during harvest and processing, screening and testing of products in commercial channels, developing decontamination procedures and diverting products to less risky uses.

Globalization and further liberalization of the world fish trade, while offering many benefits and opportunities, also present new safety and quality challenges. Fish safety regulators have been applying a host of control measures, from mandating the use of the Hazard Analysis and Critical Control Point (HACCP) system to increasing testing, with varying degrees of success. Improved risk-based scientific tools must be adopted so that the fish safety standards reflect the most current and effective scientific methods available to protect public health.

In establishing maximum levels of fish pollutants, regulators need to ensure the highest level of consumer health protection, but they must also take into account the reality of the current background contamination of the environment in order not to endanger the food supply. Concurrently, strategies must be adopted to reduce gradually the contamination of the environment and lower progressively the maximum levels in feed and foods to follow this downward trend. In addition, consumer information and awareness programmes will be necessary in order to improve transparency and consumer education.

Environmental Chemical Contaminant and Pesticide Tolerances, Action Levels, and Guidance Levels (Source: USFDA)

Deleterious Substance	Level	Food Commodity	Reference
Aldrin/Dieldrin[a]	0.3 ppm	All fish	Compliance Policy Guide sec. 575.100
Benzene hexachloride	0.3 ppm	Frog legs	Compliance Policy Guide sec. 575.100
Chlordane	0.3 ppm	All fish	Compliance Policy Guide sec. 575.100
Chlordecone[b]	0.3 ppm	All fish & Crabmeat	Compliance Policy Guide sec. 575.100
	0.4 ppm	Crabmeat	
DDT, TDE, DDE[c]	5.0 ppm	All fish	Compliance Policy Guide sec. 575.100
Diquat[d]	0.1 ppm	All fish	40 CFR 180.226
Fluridone[d]	0.5 ppm	Fin fish and crayfish	40 CFR 180.420
Glyphosate[d]	0.25 ppm	Fin fish	40 CFR 180.364
	3.0 ppm	Shellfish	

Toxic elements:			
Arsenic	76 ppm	Crustacea	FDA Guidance Document
	86 ppm	Molluscan bivalves	FDA Guidance Document
Cadmium	3 ppm	Crustacea	FDA Guidance Document
	4 ppm	Molluscan bivalves	FDA Guidance Document
Chromium	12 ppm	Crustacea	FDA Guidance Document
	13 ppm	Molluscan bivalves	FDA Guidance Document
Lead	1.5 ppm	Crustacea	FDA Guidance Document
	1.7 ppm	Molluscan bivalves	FDA Guidance Document
Nickel	70 ppm	Crustacea	FDA Guidance Document
	80 ppm	Molluscan bivalves	FDA Guidance Document
Methyl Mercury[(f)]	1 ppm	All fish	Compliance Policy Guide sec. 540.600
Heptachlor	0.3 ppm	All fish	Compliance Policy Guide sec. 575.100 /
Heptachlor Epoxide[(e)]			
Mirex	0.1 ppm	All fish	Compliance Policy Guide sec. 575.100
Poly chlorinated Biphenyls (PCB's)[(d)]	2.0 ppm	All fish	21 CFR 109.30
Simazine[(d)]	12 ppm	Fin fish	40 CFR 180.213a
2,4-D[(d)]	1.0 ppm	All fish	40 CFR 180.142

[a] The action level for aldrin and dieldrin are for residues of the pesticides individually or in combination. However, in adding amounts of aldrin and dieldrin, do not count aldrin or dieldrin found at below 0.1 ppm; [b] Previously listed as Kepone, the trade name of chlordecone; [c] The action level for DDT, TDE, and DDE are for residues of the pesticides individually or in combination. However, in adding amounts of DDT, TDE, and DDE, do not count any of the three found below 0.2 ppm; [d] The levels published in 21 CFR & 40 CFR represent tolerances, rather than guidance levels or action levels; [e] The action level for heptachlor and heptachlor epoxide are for the pesticides individually or in combination. However, in adding amounts of heptachlor and heptachlor epoxide, do not count heptachlor or heptachlor epoxide found below 0.1 ppm.