

Training Modules on Food Safety Practices for Aquaculture

# Food Safety Practices for Aquaculture

# Introduction

This module is part of a training program on Food Safety Practices for the Aquaculture Industry.

This program was developed through a partnership facilitated by the Partnership Training Institute Network (PTIN) of the Food Safety Cooperation Forum (FSCF) of the Asia Pacific Economic Cooperation (APEC) Forum. The educational content was designed by faculty at Michigan State University. Funding for this effort was provided by The World Bank Group.

To learn more about the APEC FSCF Partnership Training Institute Network, please visit <http://fscf-ptin.apec.org/>.

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# Food Safety Hazards

Food Safety Hazards

## Module Overview

Food Safety is defined by the Codex Alimentarius General Principles of Food Hygiene as “Assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use.”

To ensure an appropriate level of food safety is assured for consumers, food producers, processors and others in the food chain must be able to identify and describe potential food safety hazards that might be present in their ingredients or finished products and use practices that control these potential hazards.

The following topics will be discussed in this section:

- Food Quality and Food Safety
- Definition of Food Safety Hazard
- Biological Hazards – Pathogenic Bacteria, Parasites and Viruses
- Chemical Hazards
- Physical Hazards

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## Food Quality and Food Safety

Food quality encompasses several characteristics that make a food acceptable to consumers. Quality characteristics include external factors as appearance (size, shape, color, gloss, and consistency), texture, and flavor; factors such as grade standards, conformance to standards of identity, and other credence attributes such as organic or conformance with religious standards; and internal characteristics including food safety attributes such as the presence of potential food safety hazards.

Many of the external food quality attributes can be readily observed by sight, smell, or simple measurement. Other quality characteristics such as credence attributes are often not quantifiable and therefore these products require careful chain of custody and traceability to give the consumer confidence in these characteristics.

Most food safety attributes can not be directly observed, but instead require specific analytical procedures for their measurement. The analytical tools available to quantify food safety attributes continue to evolve and become more sensitive and specific.



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# Definition of Food Safety Hazard

A food safety hazard is defined by the Codex Alimentarius as “a biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.”

Examples of compounds that could be food safety hazards include the following:

## Biological Hazards

Bacterial Pathogens  
(e.g. pathogenic *Escherichia coli* strains, *Salmonella*, *Listeria*)

Parasites  
(e.g. parasitic worms, protozoan parasites)

Viruses  
(e.g. Norovirus, Hepatitis A virus)

## Chemical Hazards

Natural Toxins  
(e.g. shellfish toxins, mushroom toxins)

Allergens

Heavy Metals  
(e.g. Mercury, Cadmium)

Veterinary Drugs  
(e.g. used in aquaculture or animal husbandry)

Pesticides, Insecticides, Fungicides, etc.

## Physical Hazards

Metal

Glass

Bone (when not expected)

Hard or sharp foreign objects



Food Safety Hazards

## Biological Hazards

Biological hazards can include three different types of organisms. These are:

Bacteria – Single-celled organisms that live independently.

Parasites – intestinal worms or protozoa that live in a host animal or human.

Viruses – small particles that live and replicate in a host.

Each of these classes of biological hazards will be briefly discussed in this module. For those seeking additional information on biological hazards that are of concern with fishery and aquaculture products, an excellent resource is the “Fish and Fishery Products Hazards and Controls Guide (Fourth Edition)” developed by the United States Food and Drug Administration.

This document is available online at:

<http://www.fda.gov/food/guidancecomplianceregulatoryinformation/guidancedocuments/seafood/fishandfisheriesproductshazardsandcontrolsguide/default.htm>



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## Pathogenic Microorganisms

Most species of bacteria and other microorganisms are not harmful to humans. In fact, many types of bacteria and other organisms such as yeast and molds are actually beneficial organisms. For example, several foods such as cheese, yogurt, sour cream, bread, sauerkraut and pickles are produced using specific strains of bacteria, yeast or molds to convey quality characteristics and help preserve the food.

Other microorganisms may cause spoilage of foods but otherwise are not directly harmful to humans. These organisms and the spoilage they cause are undesirable characteristics of foods but do not necessarily represent food safety hazards.

However, there are numerous strains of bacteria and other organisms that are pathogenic, or disease-causing, to humans or animals. We are particularly concerned about identifying these pathogenic bacteria and implementing effective food safety measures to control them in foods.



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## Bacterial Pathogens in Aquaculture

There are two broad groups of bacteria of public health importance that may contaminate aquaculture products at the time of capture: (i) those that are normally or incidentally present in the aquatic environment, referred to as indigenous microflora: and (ii) those introduced through environmental contamination by domestic and/or industrial wastes. Examples of these bacteria include the following:

### indigenous bacterial hazards

- *Aeromonas hydrophyla*
- *Clostridium botulinum*
- *Vibrio parahaemolyticus*
- *Vibrio cholerae*
- *Vibrio vulnificus*
- *Listeria monocytogenes*

### Non-indigenous bacterial hazards

- *Enterobacteriaceae*, including *Salmonella* spp., *Shigella* spp. and pathogenic strains of *Escherichia coli*.
- Other species that cause foodborne illness and that have occasionally been isolated from fish include *Edwardsiella tarda*, *Pleisomonas shigelloides* and *Yersinia enterocolitica*.
- *Staphylococcus aureus* may also occur and may produce heat resistant toxins.

Food Safety Hazards

## Bacterial Pathogens in Aquaculture

The level of contamination in fish at the time of capture will depend on the environment and the bacteriological quality of the water in which fish are harvested.

Many factors influence the microflora of finfish. The following are some of the most important factors:

- water temperature
- salt content
- proximity of harvesting areas to human habitations
- quantity and origin of food consumed by fish
- method of harvesting
- farming methods (e.g. density of fish, animal health management, biosecurity, etc.)

The edible muscle tissue of finfish is normally sterile at the time of capture and bacteria are usually present on the skin, gills and in the intestinal tract.



Photo: Agriculturasp / Flickr

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## Bacterial Pathogens in Aquaculture

Indigenous pathogenic bacteria, when present on fresh fish, are usually found in fairly low numbers. Consequently, the potential food safety hazard presented by these pathogens are usually insignificant for fishery and aquaculture products that will be adequately cooked prior to consumption.

During storage, indigenous spoilage bacteria will generally outgrow indigenous pathogenic bacteria, thus fish will usually spoil before becoming toxic and will be rejected by consumers.

Hazards from these pathogens can be controlled by:

- heating seafood sufficiently to kill the bacteria
- holding fish at chilled temperatures
- avoiding post-process cross-contamination

*Listeria monocytogenes*, *clostridium botulinum* and other bacterial pathogens can be a significant concern in aquaculture products that have been inadequately processed, subjected to post-process recontamination, or otherwise have been held under conditions permissive to their outgrowth.



Photo: Serfling US FDA

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## Factors Influencing Bacterial Growth

In order to proliferate (grow) in foods or the environment, bacteria need:

**Food:** Nutrients such as protein or carbohydrates are provided by most foods and can support bacterial growth.

**A favorable pH:** Most bacteria do not proliferate at pH values below 4.6, although they may survive at pH values below this.

**A favorable growth temperature:** Most bacteria prefer relatively warm temperatures for optimal growth (e.g. room temperature or a little higher). However, keep in mind that some bacteria such as *Listeria* and certain types of *Clostridium botulinum* can grow at refrigeration temperatures.

**Time:** Bacteria can grow very quickly. Under the right circumstances, some bacteria can double every 20 minutes.

**Oxygen:** Some bacteria, such as *Clostridium botulinum*, can only grow in anaerobic (oxygen-free) environments such as in canned or vacuum-packed products.

**Moisture:** Found in most foods, including fish and other aquaculture products including many processed products.

Food

Acidity

Time

Temperature

Oxygen

Moisture

Food Safety Hazards

## Parasites

The parasites known to cause disease in humans and transmitted by fish or crustaceans are broadly classified as helminths or parasitic worms. These are commonly referred to as nematodes, cestodes and trematodes.

Fish can be parasitized by protozoans, but there are no records of fish protozoan disease being transmitted to human beings.

Parasites have complex life cycles involving one or more intermediate hosts and are generally passed to human beings through the consumption of raw, minimally processed or inadequately cooked products that contain the parasite infectious stage, causing foodborne disease.

Freezing at  $-20\text{ }^{\circ}\text{C}$  or below for seven days or  $-35\text{ }^{\circ}\text{C}$  for about 20 hours for fish intended for raw consumption will kill parasites.

Processes such as brining or pickling may reduce the parasite hazard if the products are kept in the brine for a sufficient time but may not eliminate it.

Candling, trimming belly flaps and physically removing the parasite cysts will also reduce the hazards but may not eliminate them.

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## Parasites

Many species of nematodes are known to occur worldwide and some species of marine fish act as secondary hosts. Among the nematodes of most concern are:

- *Anisakis* spp.
- *Capillaria* spp.
- *Gnathostoma* spp.
- *Pseudoteranova* spp.

These nematodes can be found in the liver, belly cavity and flesh of marine fish.

An example of a nematode causing disease in human beings is *Anisakis simplex*; the infective stage of the parasite is killed by heating (60 °C for one minute) and by freezing (–20 °C for 24 hours) of the fish core.

Nematodes generally are not significant hazards in fish species that are most common in aquaculture.

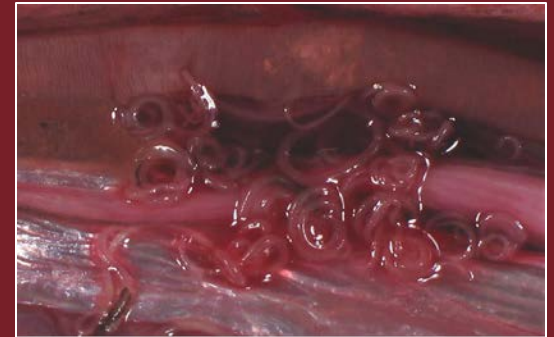


Photo: Wikipedia

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## Parasites

Cestodes are tapeworms and the species of most concern associated with the consumption of fish is *Diphyllobothrium latum* (formerly known as *Dibothriocephalus latum*).

This parasite occurs worldwide and both fresh and marine fish are intermediate hosts.

Similar to other parasitic infections, the foodborne disease occurs through the consumption of raw or underprocessed fish.

Similar freezing and cooking temperatures as applied to nematodes will kill the infective stages of this parasite.



Photo: Wikipedia

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## Parasites

Fish-borne trematode (flatworm) infections are major public health problems that occur endemically in about 20 countries around the world.

The most important species with respect to the numbers of people infected belong to the genera *Clonorchis* and *Ophisthorchis* (liver flukes), *Paragonimus* (lung flukes), and to a lesser extent *Heterophyes* and *Echinochasmus* (intestinal flukes).

The most important definitive hosts of these trematodes are human beings or other mammals. Freshwater fish are the second intermediate host in the life cycles of *Clonorchis* and *Ophisthorchis*, and freshwater crustaceans in the case of *Paragonimus*.

Foodborne infections occur through the consumption of raw, undercooked or otherwise under-processed products containing the infective stages of these parasites.

Freezing fish at  $-20\text{ }^{\circ}\text{C}$  for seven days or at  $-35\text{ }^{\circ}\text{C}$  for 24 hours will kill the infective stages of these parasites.



Photo: Sripa et al. PLoS Medicine 4(7): e201, adapted for presentation in Wikipedia

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## Viruses

Viruses are obligate intracellular parasites which invade living cells and then use the cell's machinery to replicate.

Viruses will not grow or multiply in foods or anywhere outside the host cell.

Persons who are infected with viruses will “shed” particles in their feces. An infected person may shed virus particles without realizing they are sick.

Foodborne viral disease generally results from poor personal hygiene of an infected food handler.

Contaminated water and ice also can serve as a vehicle for viruses.

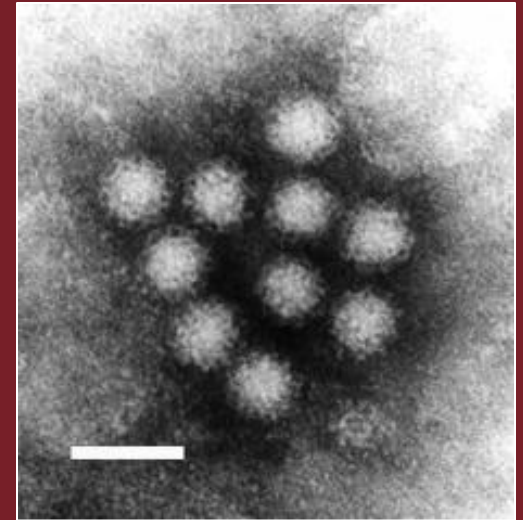


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## Viruses

Foodborne illness outbreaks associated with viruses are relatively uncommon for finfish and crustaceans, but are frequently associated with molluscan shellfish.

Molluscan shellfish harvested from inshore waters that are contaminated by human or animal feces may harbour viruses that are pathogenic to human beings. Enteric viruses that have been implicated in seafood-associated illness include the hepatitis A virus, caliciviruses, astroviruses and the norovirus. The latter three are often referred to as small round structured viruses. All of the seafood-borne viruses causing illness are transmitted by the fecal-oral cycle and most viral gastro-enteritis outbreaks have been associated with eating contaminated shellfish, particularly raw oysters.

There is no reliable marker for indicating the presence of viruses in shellfish harvesting waters. Seafood-borne viruses are difficult to detect, requiring relatively sophisticated molecular methods to identify the virus.

Occurrence of viral gastro-enteritis can be minimized by controlling sewage contamination of shellfish farming areas and pre-harvest monitoring of shellfish and growing waters as well as controlling other sources of contamination during processing. Depuration and relaying are alternative strategies, but longer periods are required for shellfish to purge themselves clean of viral contamination than of bacteria. Thermal processing (85–90 °C for 1.5 minutes) will destroy viruses in shellfish.

## Biological Hazards – Control Measures

Numerous measures can be used to control biological hazards in foods. The following is a list of example control measures that may be applied.

1. Microbiological criteria for raw materials – feeds used in aquaculture production and finished products that are intended to be consumed raw (e.g. sashimi) may be tested for biological hazards to help ensure safety. Another example would be conducting a sanitary survey of bivalve production areas.
2. Preservative factors (pH, water activity [ $a_w$ ], etc.) – Reducing pH and water activity (e.g. by drying or salting) are effective means to control the growth of most pathogenic bacteria.
3. Time / temperature (cooking, freezing, etc.) – Cooking and other types of thermal processing is effective in destroying most types of biological hazards. Freezing and refrigeration are effective controls for pathogenic bacteria and parasites.
4. Prevention of cross contamination – This is essential during production, packing and processing of seafood including aquaculture products.

## Biological Hazards – Control Measures

Numerous measures can be used to control biological hazards in foods. The following is a list of example control measures that may be applied. (Continued)

5. Food handling / employee hygiene – Employees must practice appropriate hygiene practices to minimize the risk of contaminating food.
6. Equipment / environmental sanitation – Appropriate cleaning and disinfection (sanitation) procedures are essential to minimize the risk of contamination of fishery and aquaculture products during production, harvest, post-harvest handling and processing.
7. Packaging integrity / storage, distribution – Maintenance of packaging integrity and using appropriate storage and distribution procedures will minimize the risk of product contamination.
8. Consumer directions for use – Appropriate consumer preparation (such as cooking) may be essential to ensure food safety. When the consumer must use specific preparation steps to ensure product safety, the preparation steps must be clearly indicated on the product label.



Food Safety Hazards

## Chemical Hazards

Chemical hazards can include:

- Naturally-occurring chemicals
- Intentionally-added chemicals
- Unintentional or incidental chemical additives

In the case of aquaculture, the primary potential chemical hazards of concern include intentionally added chemicals such as veterinary drugs used in aquaculture production and unintentional contaminants such as persistent environmental contaminants that might be present in the production areas. These hazards will be briefly discussed in the following sections.

In addition, certain types of marine fish naturally contain toxic compounds or may be particularly susceptible to contamination with naturally-occurring toxins. These also will be discussed although they generally are not hazards of concern in the predominant species used in aquaculture.



Photo: Serfling US FDA

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## Chemical Hazards

The following chemical hazards are examples of naturally-occurring compounds in fish and shellfish. These hazards are associated with marine fish, not the species most commonly used in aquaculture.

### Tetrodotoxin

Some fish species, mainly belonging to the family Tetradontidea (“puffer fishes”), may accumulate this toxin, which is responsible for several poisonings, often lethal. The toxin is generally found in the fish liver, roe and guts, and less frequently in the flesh.

### Ciguatoxin

Another important toxin to consider is ciguatoxin, which can be found in a wide variety of mainly carnivorous fish inhabiting shallow waters in or near tropical and subtropical coral reefs. The source of this toxin is dinoflagellates and more than 400 species of tropical fish have been implicated in intoxication. The toxin is known to be heat-stable.

### PSP/DSP/NSP/ASP

Paralytic shellfish poison (PSP), diarrhetic shellfish poison (DSP), neurotoxic shellfish poison (NSP), and amnesic shellfish poison (ASP) complexes are produced by phytoplankton. They concentrate in bivalve molluscan shellfish, which filter the phytoplankton from the water, and may also concentrate in some fish and crustaceans. Generally, the toxins are heat-stable. Hence, knowledge of the species identity and/or origin of fish or shellfish intended for processing is important.

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## Chemical Hazards

### Scombrototoxin

Scombroid intoxication, sometimes referred to as histamine poisoning, results from eating fish that have been incorrectly chilled after harvesting. The intoxication is rarely fatal and symptoms are usually mild.

Scombrototoxin is attributed mainly to histidine degradation by *Enterobacteriaceae*, which can produce high levels of histamine and other biogenic amines in the fish muscle when products are not immediately chilled after catching.

Fish implicated in scombrototoxic fish poisoning are characterized by the presence of high levels of free histidine in the tissue. The main susceptible fish are the scombroids such as tuna, mackerel, and bonito, although it can be found in other fish families such as Clupeidae.

Rapid refrigeration after catching and a high standard of handling during processing should prevent the development of the toxin.

The toxin is not inactivated by normal heat processing. In addition, fish may contain toxic levels of histamine without exhibiting any of the usual sensory parameters characteristic of spoilage.

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## Chemical Hazards

The following are examples of intentionally-added chemicals that could be potential hazards.

- Veterinary drug residues
- Residues of approved pesticides
- Food additives

Some chemicals are intentionally used in aquaculture production or in packing and processing of fishery products. When used, these compounds must be approved for the particular use and proper instructions for use (including any applicable withdrawal times in the case of veterinary drugs) must be followed.

In the global aquaculture industry, use of unapproved antibiotics and other chemotherapeutics in production are the leading cause of chemical contamination and subsequent rejection of products. Unapproved use of compounds such as malachite green, chloramphenicol, and nitrofurans has been particularly widespread in the industry and has led to hundreds of detentions and border rejections.

Food Safety Hazards

## Chemical Hazards

### Intentionally-added chemicals (continued)

Inappropriate use of veterinary drugs in aquaculture is particularly concerning. In addition for the potential of veterinary drug residues to cause adverse health effects in consumers of aquaculture products, there also is concern that inappropriate use of veterinary drugs such as antibiotics could lead to antimicrobial resistance by pathogens. For this reason, therapeutic antimicrobial drugs must be used judiciously. A key objective when using these drugs is to maximize therapeutic efficacy and minimize the potential for selection of resistant microorganisms.

It also is extremely important to note that the list of drugs approved or authorized for use in aquaculture differs from country to country (e.g. the US and EU have different lists of authorized drugs). This requires producers to be vigilant and comply with importing country requirements.

Use of food additives such as sodium nitrite, preservatives, or nutritional additives should always comply with applicable laws and regulations in the country of production (or destination country for exported products) and be included in any product formulations at concentrations that are not hazardous. Establishing and strictly following formulation specifications and standard operating procedures for product preparation are important controls for these additives.

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## Chemical Hazards

The following are examples of unintentional or incidental chemical additives that could be hazardous under certain conditions.

- Persistent pesticide residues
- Organochlorine compounds
- Heavy metals
- Detergents and disinfectants

Certain pesticide residues, such as DDT and DDE, continue to persist in the environment despite their use being phased out decades ago. These residues can bioaccumulate in the fatty tissue of fish. Of greatest concern are fish harvested from coastal and estuarine areas, which are more likely to harbor chemical contaminants, rather than fish harvested from the open seas.

Organochlorine compounds such as polychlorinated biphenyls (PCBs) and dioxins also are very persistent in the environment and can bioaccumulate in fish. More than 90% of human exposure to dioxins is through food, mainly meat and dairy products, fish and shellfish.

Heavy metals such as methylmercury also are a particular concern for fish and can bioaccumulate in tissues. This is particularly true for predatory fish species.

If appropriate hygiene and sanitation procedures are not followed, it is possible that approved chemicals such as detergents and disinfectants could contaminate fish during packing or processing.

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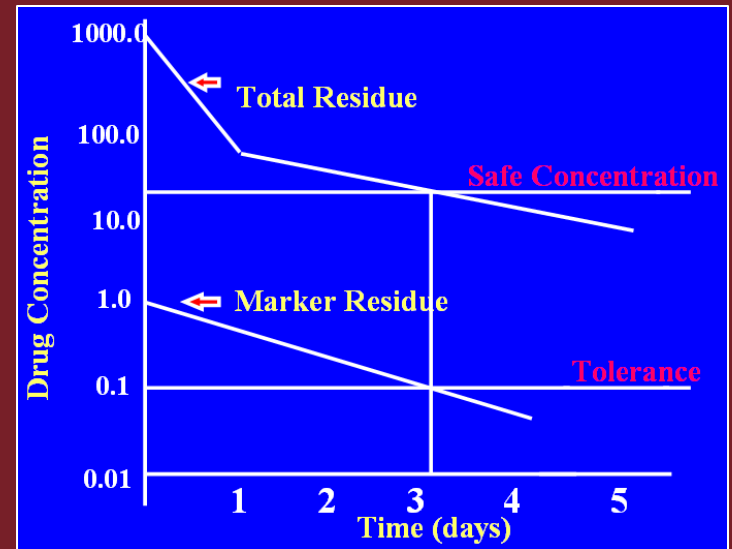
Food Safety Hazards

## Chemical Hazards

### Maximum Residue Limits (MRLs) and Tolerance Levels

Many potential chemical hazards do not cause acute toxicity, but rather may cause increased risk of cancer or other adverse effects through chronic exposures.

For certain potentially hazardous chemicals, particularly those that can not be completely avoided in the food, maximum residue limits or tolerance levels have been established by the competent food safety authorities in each country. Food producers and processors should take affirmative steps to ensure that their products do not exceed these maximum levels. Periodic analytical testing may be required to demonstrate compliance with MRLs.



Source: US FDA

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## Chemical Hazards

### Maximum Residue Limits (MRLs) and Tolerance Levels (continued)

Recommended MRLs or tolerance levels for many potential chemical hazards also have been developed by the Codex. These MRLs are useful guidelines in cases where MRLs have not been established by food laws and regulations in the country of production or importing country.

The MRLs and/or tolerance levels for the majority of chemical compounds and animal drug residues are not harmonized and therefore might vary from country to country. To illustrate this point, the Codex has only established three MRLs for drug residues in fish: oxytetracycline (all fish), flumequine (trout) and deltamethrin (salmon). However, neither flumequine nor deltamethrin has been approved by the U.S. Food and Drug Administration.

Consequently, exporters must be aware of specific requirements pertaining to their product's destination country or countries and comply with importing country regulations.

## Controls for Chemical Hazards

The following are examples of potential measures that can be used to control chemical hazards during production, harvest, packing and processing of fishery and aquaculture products.

Prior to receipt

- Specifications

Upon receipt

- Inspection before acceptance

During processing

- Use “Approved” chemicals

During storage

- Avoid cross contamination

During use

- Use approved procedures

Prior to shipment

- Pre-shipment inspection

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## Physical Hazards

Physical hazards include any potentially harmful extraneous matter not normally found in food. The following are some examples of common physical hazards encountered in the food industry.

- Metal fragments
- Glass particles
- Wood splinters
- Stones or rock fragments
- Brittle plastic
- Bones, shells, or their fragments (when not expected)

These physical hazards generally cause problems for relatively few consumers per incident, and typically result in personal injuries that are not life-threatening.

- Broken tooth, cut mouth,
- Some physical hazards can be a potential choking hazard



Photo: Serfling US FDA

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# Physical Hazards

Controls for physical hazards can include the following practices among others.

## Proper employee practices:

- Education on appropriate physical hazard prevention and controls
- “No metal above the waist” is a common company policy to control potential for physical hazards to fall into food.
- Personal jewelry typically is limited to a single plain wedding band.

## Equipment Preventative Maintenance Programs:

- Routine inspection and maintenance of equipment is an important component of a physical hazard prevention program.

## Detection and Segregation Equipment:

- Detection equipment such as metal detectors and X-ray machines
- Separation equipment such as magnets, screens, filters, aspirators, riffle boards, mechanical separators, etc. may be implemented if the product and process is amenable to this.

# Physical Hazards

Controls for physical hazards can include the following practices among others.

## Specifications:

- Raw material specifications may include requirements for physical defects if the product or ingredient is known to be susceptible to these hazards.

## Good Manufacturing Practices:

- GMPs for physical hazard control also can include appropriate facility and equipment and design to minimize the potential for metal parts or other hard materials to be shed by equipment

## Glass Breakage Program:

- If the product is being packed in glass, robust procedures should be designed and implemented to minimize the risk of glass particles being present in finished products. These procedures should include controls for glass container handling and inspection prior to and after filling with product, and standard operating procedures to be used in the event of breakage.



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