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# Review Article; Occupational Hazards in Fish Industry

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**Abstract:** The current review is directed to workers in aquaculture, fish handlers, consumers, private and governmental fish industry producers and researchers. They should consider the possible occupational hazards and follow regulations and legislations adopted. The occupational hazards, safety concerns and risks to health in the aquaculture industry are based on the types of operation, scale of production and the specific species of interest. Hazard is a biological, chemical, or physical agent with the potential to cause an adverse health effect. Fish grown in excreta-fertilized or wastewater ponds may be contaminated with pathogens. Transgenic fish is hazardous because of their potential allergenicity and toxicity. Awareness of the health hazards involved in the handling of industrial fish is important, particularly for those working in the vicinity of fishing communities. Farmhands and other workers in aquafarms are susceptible to many injuries, noise, sting from fish spines, sprain and fracture which are of physical hazards. Spoiled wet fish in storage may produce poisonous gases. Fish muscle can hold different concentration of Hg representing health risk to fertile women. Cadmium and lead concentrations are higher in fish scales and vertebral column than in the other parts of the fish. The author’s objective is to improve the health and safety of workers in aquaculture through the recognition, evaluation, control or mitigation of human health risk in the aquaculture industry. Focusing on the possible role of aquatic farming in the spread of communicable human diseases.

**Key words:** Chemical pollution % Microbial toxins % Occupational hazards % Risk assessment % Transgenic fish

## INTRODUCTION

The occupational hazards, safety concerns and risks to health in the aquaculture industry can vary considerably based on the types of operation, scale of production and even the specific species of interest [1]. The public health aspects of fish farm development are directed to the possible role of aquatic farming in the spread of communicable human diseases. Hazards are defined as the presence of a material or conditions that has the potential for causing loss or harm or a combination of the severity of consequences and likelihood of occurrence of undesired outcomes [2]. Risk is the harm or injury from a hazard that will occur to specific individuals or groups exposed to a hazard for every system or process. Farmhands and other workers in aquafarms are susceptible to many physical hazards in the course of their work as noise, injuries, sting from fish spines, cuts, sprain, fracture and snake bites. Biological hazards included parasitic infestation (weeds in ponds, nematodes and cestodes) and pathogenic infections (fungal, Vibrio in intensively manured ponds). The effluents from aquaculture facilities constitute significant sources of organic pollution that damage the water quality and generate unwanted algae [3]. Hazards can enter an aquaculture product at any time during production and processing because of using pesticide contaminated feed; inappropriate use of veterinary chemicals; pollution of the aquaculture environment by pathogenic bacteria or viruses contamination during the processing of aquaculture products. Molluscan shellfish have been implicated in numerous outbreaks of food-borne disease when they are consumed raw [4]. The occupational health and safety hazards (OHSH) related to the daily operations of the aquaculture sector can be grouped into three categories; 1-Physical hazards (heavy left) as refilling

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automatic feeders in the ponds handle them, grading the fish, electric shock as manifold, cover water pump and lighting installations. 2- Exposure to chemicals when used in treatment and / or control disease organisms or to facilitate production e.g lime, diluted chlorine, or salts and fertilizers. 3- Exposure to water-borne diseases where workers may be directly or indirectly exposed to water borne diseases due to frequent contact with water ponds and the close proximity of living quarters to surface water bodies [5]. Aquaculture occupational hazards and risks to health can generally be categorized into those concerning physical work hazards, chemical and toxic exposures and risks associated with infectious disease. There are occupational hazards and safety concerns in the aquaculture industry, some practices have caused environmental degradation. Some farmed fish have much higher body burden of natural and man-made toxic substances, e.g. antibiotics, pesticides and persistent organic pollutants, than wild fish. These contaminants in fish could pose health concerns to unsuspecting consumers, in particular pregnant or nursing women [6].

The current review is directed to aquaculturists, fish handlers, fish processing plant, fish consumers, private and governmental fish producers and researchers. They should be ever alert to the possible occupational hazards and follow regulations and legislations adopted regionally or nationally.

## Literature and Background

**Microbial Load of Aquaculture Used Water:** Streptococcus group was detected from a fresh water fish surface, swabs from gills, intestine and raw fish flesh caught from Nasser's Lake in Aswan. Coliform organisms were detected from skin, gill samples, intestine and raw fish flesh [7]. Cholera could be transmitted to farm workers if they irrigated with raw wastewater coming from an urban area where a cholera epidemic is occurring as in the outbreak of cholera in Jerusalem in 1970 [8]. Semi-organized and unregulated status create a situation where workers are exposed to innumerable hazards [9]. A twofold excess risk of clinical enteric disease in young children (0-4 years) living within 600-1000m from sprinkler irrigated fields could occur in summer irrigation months only [10]. The tentative bacterial guideline suggested a geometric mean number of *faecal coliforms* of $10^3$ per 100 ml in pond water [11]. Human pathogens including *Salmonella, E.coli and Clostridium botulinum,* found to survive in fish tissues and could serve as a vector for these pathogens thus infecting humans consumed or handle them [12]. The aquaculture production of finfish, crustaceans and molluscs may present a threat to public health if they are not grown and harvested under strictly hygienic conditions. The potential hazards from *Salmonella and Vibrio species* in farming of shrimp are conflicting. *Salmonella and Vibrio cholerae* are found to be present as part of the natural flora of brackish cultured shrimp and posed a major concern for processors and exporters. Aquatic microorganisms such as algae and detritus producing toxic compounds could present significant human health risks [13]. Individuals pricked by spines of *Tilapia spp*. infected with *Vibrio vulnificus* could cause amputation of their fingers [14]. Human who consume shellfish *Lobster and Carbs* that have ingested dinoflagellate and their toxins stand the risk of being afflicted with paralytic shellfish poisoning [15]. Many other fish pathogens are known to be contagious to humans, including several species of the genera *Mycobacterium and Vibrio* (especially *M. marinum, V. vulnificus and V. parahemolyticus*), as well as species of *Streptococcus, Aeromonas, Erysipelothrix and Pseudomonas*. A more inclusive list would also include parasites (nematodes, trematodes and flukes), protozoans and dinoflagellates [16]. Botulism, typhoid, hepatitis, cholera, nonspecific gastroenteritis and a host of other diseases might result from ingestion of raw or insufficiently cooked fish and shellfish. *Clostridium botulinum* was isolated from all the aquacultured fish except *pacu* and *tilapia* grown in a recirculating aquaculture system. The counts were very low, ranging from 0.0 to 2.3 MPN/g [17]. Streptococcus iniae was a serious public health threat associated with commercially raised fish, for old or immunocompromised people who incurred puncture wounds while handling and preparing fish [18]. FAO consider the public health and occupational health consequences of tilapia fish farming. *Streptococcus* sp. infections of fish are newly identified threat to humans and have been found in cultured tilapias, *S. iniae* and other *Streptococci* that infect fish may infect humans. Infections have been contracted when people market live fish, or consumers are cut or spined during handling or preparation of the fish."The disease appears most prevalent in intensive tilapia production systems, in which water quality is marginal and/or there is environmental stress or trauma to the fish [19]. Food-borne trematode such as *Cloronchis sinensis and Opisthorchis viverrini* are known to cause diseases particularly among Asians who ate their fish raw or poorly cooked. Enteric diseases caused by trematode parasites have been reported in Egypt and Republic of Korea [20].

The microbial quality of the tilapia indicated that all tissues except muscle tissues are contaminated with *fecal Coliform* [21]. In general, true zoonotic agents associated with fish, crustaceans and molluscs are few. Many commensally and pathogenic bacteria, viruses, fungi and parasites associated with fish have temperature growth limits that will not support their development in human. Viruses, bacteria, fungi and parasites in fish may cause disease or food-borne infections in human. In countries where fermented fish (both farmed and wild salmonids) is a specialty, unhygienic production conditions may result in intoxication with *C. botulinum* and death in humans. Scombroid or histamine fish poisoning, is caused by bacterial spoilage of a limited number of fish species. These comprise mainly: mackerel (*Scomber scombrus*), bonito (*Sarda spp*.), various tuna species (*Thunnus spp*.), swordfish (*Xiphias gladius*) and common dolphinfish (*mahi-mahi*) (*Coryphaena spp*.) [22]. Many pathogenic microorganisms and parasites could conceivably be transmitted to humans through fish. Fish and shellfish accounted for 5% of the individual cases and 10% of all foodborne illness outbreaks with most of the outbreaks have resulted from the consumption of raw molluscan shellfish (USCDC). Farmed fish originally found to carry *L. monocytogenes* became gradually Listeria-free after several months. *L. monocytogenes* isolates from the final products are often the same types found in the processing environment as well as on raw fish. Microflora in hybrid striped bass identified several human foodborne pathogens, including *P. shigelloides*, *Listeria monocytogenes*, *S. aureus*, *Shigella dysenteriae* and Vibrio species [23].

**Microbial Toxins:** The most common and hazardous cyanobacteria in the water bodies of the Czech Republic are the producers of microcystins. Microcyctins (MCs) which are peptide hepatotoxins that inhibit the regulatory protein phosphatases 1 and 2 A [24]. Considering the high toxicity of anatoxin-a to humans and vertebrates, beside the potential harm to ecosystems, the presence of cyanobacteria should always be considered as a potential health hazard. Acute toxicity is the most obvious concern of anatoxin-a although a long-term risk may be a problem [25]. Humans might be exposed to cyanobacterial toxins via different routes. Often, drinking water is seen as the main source of potential exposure (allocation factor 0.8). Regarding mussels and shellfish, the importance of food as exposure route may be undervalued in a number of settings. Concentrations of cyanotoxins in seafood sometimes reached levels at which it may be adequate to discourage consumption [26]. Fish standing at the top of the aquatic food chain, are likely to be affected by toxic cyanobacteria and the consumption of contaminated fish by humans might pose health risks [27]. Aflatoxicosis and resulting epizootic hepatoma has been reported among a wide range of fish where Aspergillus species-contaminated foodstuffs were incorporated into the diet. Aflatoxin $B_1$ ($AFB_1$) is among the most potent known hepatotoxins and carcinogens. Marine water sea bass is a species highly sensitive to $AFB_1$. In addition, consumption of sea bass reared on aflatoxin $B_1$ ($AFB_1$)-contaminated diet could has a negative health impact on human health [28]. In addition to increased seafood consumption and tourism, recent studies link global climate change with an apparent increasing incidence of the Marine Seafood Toxin diseases. However, the epidemiology of the human diseases caused by the harmful marine phytoplankton is still in its infancy [29].

**Genetic Interference:** The development of beneficial transgenic organisms requires the insertion of appropriate genes during the blastocyst stage of embryonic development. Genes that can provide highly desirable benefits include growth hormone, freeze protection and disease resistant genes [30]. Transgenic fish have been produced in *Atlantic salmon*, *Coho salmon*, *Chinook salmon*, *Rainbow trout*, *cut throat trout*, *tilapia sp*, *Striped bass*, *Channel catfish*, *common carp* and *Indian major carps* [31]. In the case of the transgenic salmon containing a recombinant gene and producing a protein of totally Salmonid origin, no foreign protein is produced. Therefore, there is no change in allergenicity [32]. Transgenic fish have been classified as hazardous in terms of food safety because of their potential allergenicity and toxicity [33]. There is a potential public concern regarding food safety due to potentially elevated levels of growth hormone and insulin-like growth factor (GH and IGF) in transgenic salmon [34]. Discussion of the safety of the consumption of transgenic salmon potentially containing elevated levels of GH and IGF. Safety is defined as the absence (minimal probability) of known harm [35]. Allergenicity is probably the most important and represents real potential health risk of transgenic fish [36].

**Chemical Pollution:** The health hazards posed by chemical compounds have been studied extensively by several authors. Several polycyclic aromatic hydrocarbons (PAHs) are known to be potential human carcinogens including benzo [a] anthracene, chrysene, benzo [b] flouranthene, benzo [k] flouranthene, benzo [a] pyrene and benzo [ghi] perylene [37]. Aquaculture operations and the farms that often adjoin them are usually dependant on properly used chemicals to minimize problems and maximize harvests. Serious threats to aquaculture water come from herbicides used to control aquatic vegetation in fish ponds, runoff of pesticides, herbicides and fertilizers from fields adjoining aquaculture ponds; and aquifer contamination due to pollution of the recharge water [38]. Many aquaculture chemicals are by their nature biocidal when released to the surrounding environment at toxic concentrations. Thus, there is a potential for mortality of non-target organisms. Three classes of aquaculture chemicals and their effects on non-target biota include: 1) use of a carbaryl pesticide and mortality of non-target invertebrates; 2) use of an organophosphate parasiticide and suspected effects on nearby biota; and 3) effects of antibacterial residues in aquatic sediments on the associated microbial community [39]. The most common substances used in pond aquaculture are chemical fertilizers and liming materials. Less frequently used chemicals as oxidants, disinfectants, osmoregulators, algicides, coagulants, herbicides, probiotics and chemotherapeutants with agricultural or industrial pollution. These chemicals could result in product contamination and food safety concerns. These compounds or biological products quickly are degraded or precipitated. They are not bioaccumulative and do not cause environmental perturbations in natural waters receiving pond effluents. Most substances used in pond aquaculture to improve soil or water quality presented little or no risk to food safety. They may be biomagnified in the animal tissue and so consumers are at risk of intoxication with the chemicals [40]. The potential health hazards of handling industrial fish are documented. Wet fish in a storage consumed oxygen would produce poisonous gases as they spoiled. Various noxious agents have been demonstrated in association with spoilage including carbon dioxide, sulphur dioxide and ammonia. A fatal case of methane and cyanide poisoning among a group of deep-sea trawler men was described. Cyanides are a further potential fatal complication of handling spoiled fish with noxious agent. The risk is especially high in industrial fishing because fish are stored in bulk without ice in closed spaces. Methane is a well-known product of putrefaction and a potentially fatal load of cyanide can build up in a catch of fish as a secondary metabolite by bacteria-*Chromobacterium violaceum* and *pseudomonas* which acted as a metabolic poison. A fatal case of inhalation of toxic fumes related to decaying fish was reported. Various noxious agents have been demonstrated in association with spoilage included carbon dioxide, sulphur dioxide and ammonia. Awareness of the health hazards involved in the handling of industrial fish is important, particularly for those working in the vicinity of fishing communities [41]. The unintentionally added chemicals may include organochlorine pesticides, PCBs and other persistent chemicals in feed, chemicals in construction materials and metabolites and degradation products of intentionally added chemicals [42]. Cadmium and lead concentrations are higher in fish scales and vertebral column than in the other parts of the fish. Cadmium and lead levels in High Dam lake water and fish (*Tilapia nilotica*) are present as a result of the pollution that is attained from aquatic plants, sediments and gasoline containing lead that leaked from fishery boats. Tilapia nilotica fish is used as a good bio-assay indicator for the lake pollution with cadmium and lead. The fish muscles are in the safety baseline levels for man consumption [43]. Fish muscles could hold different concentrations of Hg which represents health risk to fertile women when consumed *Piscivorous* fishes from Rio caida basin during dry season. The general population does not face a significant health risk from methyl mercury, although certain groups with high fish consumption may attain blood levels associated with a low risk of neurological damage to adults. Since there is a risk to the fetus in particular, pregnant women should avoid a high intake of certain fish, such as shark, swordfish and tuna; fish (such as pike, walleye and bass) taken from polluted fresh waters should especially be avoided [44]. Pesticides and piscicides (Chemicals to kill fish) present a risk to human health and their use has to be carefully monitored. High levels of polychlorinated triphenyls (PCBs), dioxins and other contaminants have been reported in farmed salmon [45]. The ability of a chemical to cause adverse health effects and thus its tolerable daily intakes (TDI) and/or tolerable weekly intakes (TWI) are established by risk assessments performed by international bodies [46]. US-Fish caught in highly polluted waters could cause cells of some kinds of cancers to multiply rapidly. The extracts from catfish caught from waters high in sewage and industrial waste caused breast cancer cells to multiply. Fish contained substances that mimic the actions of estrogen, the female hormone. As fish could concentrate some kinds of chemicals in water in their bodies, the results suggested that pharmaceutical estrogen and xeno-estrogenic chemical might be making their way into the region's waterways where the researchers exposed extracts of catfish to estrogen-responsive and estrogen non-responsive human breast cancer cells [47]. Chemical inputs to the marine environment from aquaculture activities generally fall into two categories: intentional and unintentional inputs. Intentional inputs include pesticides, drugs, antifoulants, anaesthetics and disinfectants. Unintentional inputs include contaminants from fish feeds additives and so-called inert ingredients in pesticide and drug formulations. The rapid expansion of the salmon aquaculture industry in the last decade and the intentional and unintentional use of many chemicals have resulted in wastes that might have a direct environmental impact. Pesticides, disinfectants, antibiotics chemotherapeutants and anesthetics are among medicinals commonly used. Construction materials included wood, plastics, paints, metal, antifoulants and preservatives. Unintentional inputs included contaminants from fish feeds additives and so-called inert ingredients in pesticide and drug formulations. Use of large quantities of antibiotics in aquaculture have the potential to be detrimental to fish health, to the environment, wildlife and to human health. Copper and zinc have been measured in sediments near aquaculture sites at concentrations in excess of sediment quality guidelines. These elements could be lethal to aquatic biota and persist in sediments. Copper-based antifouling paints are applied to cages and nets to prevent the growth of attached marine organisms on them. The buildup of these organisms ("epibiota") would reduce the water flow through the cages and decrease dissolved oxygen [48]. Metal pollution is of concern to aquaculture because of the potential toxic effects and the ability of many metals to bioaccumulate thus reducing product quality and causing public health risks. Methyl mercury is 1,000 times more soluble in fats than in water and concentrates in muscle tissue, brain tissue and the central nervous system. Mercury levels in fish may be in excess of 10,000 to 100,000 times the original concentration in surrounding waters. Accumulation is fast while depuration is slow. Slightly contaminated shrimp are slow to depurate mercury, while contaminated oysters depurated rapidly. Mercury depuration in fish is also extremely slow. The half-life of methyl mercury in fish is estimated at two years. The general population does not face a significant health risk from mercury. Mercury levels for saltwater fish averaged 0.35-70.02 ppm and selenium levels averaged 0.37-70.01 ppm. The levels of mercury in bluefish are high enough to cause potential adverse health effects in sensitive birds and mammals that ate them and to provide a potential health risk to humans who consume them. Fish larger than 50cm fork length averaged levels above 0.3 ppm, suggesting that eating them should be avoided by pregnant women, children and others who are at risk. Fish consumption is the only significant source of methylmercury exposure for the public. Communities that relied on fish intake for daily nutrient sustenance may be at risk from chronic, high exposure to methylmercury, as well as other persistent organic pollutants. Similarly, high-end fish consumers, whether recreational or subsistence, are at risk from mercury exposure [49]. Ozonation plays an important role in maintenance of water clarity in large display aquaria and can help decrease the number of infectious particles in solution. Excess ozonation is hazardous to humans as well as fish. Malfunctioning ozone generators may release ozone gas, which can be a serious health hazard to humans in the vicinity. Ozone gas that remains in solution and comes in contact with live fish is also toxic. Ozone damages epithelial surfaces (i.e., skin and gills) and will kill the fish. Before the installation of an ozone generator, professional advice has to determine if it is appropriate for the system in question and to determine the type of equipment necessary [50]. Some farmed fish have much higher body burden of natural and man-made toxic substances, e.g. antibiotics, pesticides and persistent organic pollutants than wild fish. Farmed fish can have higher concentrations of certain toxic chemicals, especially manufactured chemicals than wild fish. The main sources of chemical contamination come from fish feed bioaccumulation and from location of aquaculture in contaminated areas. The former problems can potentially be minimized by changing the fish feed and by advisories on limiting the consumption of farmed fish, especially for susceptible individuals such as pregnant or nursing women [6].

**Physical Hazards:** Regarding the physical work environment, risks concerning machinery and tool use are similar to that of terrestrial agriculture. High-torque capacity tractors used in aquaculture are subject to the same roll-over protection (Occupational Safety and Health Administration (OSHA) compliance standards) as farm tractors [51]. Electrocution and high-voltage electrical accident is so of concern, particularly due to the proximity of water [16]. Other hazards may include drowning, musculo-skeletal injuries from repetitive lifting of heavy cages and nets, over-use injuries like tenosynovitis from repetitive motion tasks, long-term exposure in extreme environments of sunlight, wind, cold and water [52].

Fishponds pose potential drowning, electrocution and slip (mud and slime) hazards. Nighttime work raises issues of fatigue and human error, lighting and visual acuity, awareness of co-worker presence and so forth. Other possible hazards include punctures or cuts from fish teeth or spines, exposure to low temperatures and infection of cuts or abrasions [53].

**Risk Assessment:** Risk analysis considers a tool that provides decision-makers with an objective, repeatable and documented method for assessing the risks posed by a particular action or event [54]. The use of risk assessment has gained steadily in importance and recognition as the scientifically-based approach for the development of food safety and quality standards. During recent years there has been increasing use of the word "risk" in connection with food safety, in general and seafood safety in particular. There are statements such as "regulations must be risk-based", "a risk analysis must be done," and "we need to communicate the risk to all stakeholders". Risks from microbiological and chemical hazards are of serious concern to human health [55]. As aquaculture is very diverse (in terms of species, environments, systems and practices), the range of hazards and the perceived risks are much greater. These include; intensified transboundary movement of aquatic species as a part of increasing trade and globalization, the sector's vulnerability to natural disasters and on-going climate changes and other management and operational issues. Foremost is for resource protection (human, animal and plant health; aquaculture; wild fisheries and the general environment) as embodied in international agreements and responsibilities. The principal components of the risk analysis process are; hazard identification, risk assessment, risk management and risk communication (a continuous activity that takes place throughout the entire process) [56]. Several methods are used for quantitative risk assessment of such chemicals. Recently, the European Food Safety Authority (EFSA) has recommended using the 'margin of exposure' (MOE) as a harmonized approach for assessing the risks posed by substances which are both genotoxic and carcinogenic [57]. Specific chemicals such as sodium hypochlorite are often included in environmental health impact assessments (EHIAs). A health impact assessment (HIA) has also been done for formaldehyde with regard to acute and short term effects of lowering occupational exposure limits [58]. Some chemicals are carcinogenic. For genotoxic carcinogens, it is not possible to establish a dose threshold below which there is no effect [23].

**Prevention and Control of Occupational Hazards in Marine and Freshwater Bodies:** The principles for controlling hazards in aquaculture would include the identification of hazards, control of the hazard and monitoring of the effectiveness of the control [2].

- Fish could act as asymptomatic carriers of disease. Sick, moribund (dying) and dead fish should be removed as soon as possible from a system and disposed of according to county, state, or federal regulations. In most instances, disposal could be as simple as placing the dead fish in a plastic bag and putting it in a trash receptacle.
- Water can act as a reservoir. Water can spread pathogens to anything it touches. The ground (e.g., concrete slab) could contain pockets of water that contains pathogens. Equipment, including nets, siphon hoses and buckets, could also contain pockets of disease-causing organisms. For this reason, disinfection of floors and use of footbaths (either small containers or mats containing disinfectants) placed at entrances and exits to system rooms is recommended, as well as disinfection of all equipment when used with fish in different tanks or vats or systems. Nets should be kept off the floor and placed in an appropriate clean location to avoid contamination [59]. Chlorination of aquaculture ponds to remove pathogens could be performed. The chlorine dose would vary depending on pH and the concentration of organic matter and ammonia. When chlorinating aquaculture ponds, one has to be careful that the concentrations of chlorine are reduced below toxic levels before the fish are exposed to the disinfected water [60].
- Causes of hardness, it was caused by limestone, the $CaCO_3$ value reflected a mixture of free calcium and magnesium with calcium being the predominant divalent salt. Agricultural limestone could be used to increase calcium concentrations (and carbonate-bicarbonate alkalinity) in areas with acid waters or soils. At a pH of 8.3 or greater, agricultural limestone would not dissolve. Agricultural gypsum (calcium sulfate) or food grade calcium chloride could be used to raise calcium levels in soft, alkaline waters [61].
- On employment, workers; a) they should be well-instructed and trained on the associated risks and hazards of their vocation; b) there should be a re-orientation of old staff so as to inculcate safety consciousness; c) Personal protective gear should be provided and strictly enforced for all categories of

staff to reduce risks of accidents or other workplaces hazards; d) laboratory workers and other staff using chemicals should be subjected to regular medical checks for early detection of adverse impact of chemical intoxication; e) there should be first aid kits at all aquaculture facilities and adequate instructions on their pages. Specialist occupational medical clinical service with access to specialized diagnostic and management resources should be established.

- Guidelines should be provided by relevant stakeholders on how to achieve a basic level of environmental protection within the vicinity of aquafarms. Countries should adopt the Hazard Analysis Critical Control Point (HACCP) framework which is an innovation intended to improve food safety [2].
- The traditional procedures for aquaculture waste treatment, mainly based on physical and chemical means, should be overcome by more site-specific approaches, taking into account the characteristics and resistibility of the aquatic environment. Further research needed to improve or optimize the current methods of wastewater treatment and reuse. Proposed new treatment technology should evaluate their feasibility at a larger scale for practical application [62].
- ‘end of pipe’ technologies are needed to reach adequate effluent qualities for further production expansion. The pollution emitted per ton of fish produced have decreased successively over the last 20 years. Partial water reuse could improve effluent discharge. Physical, chemical and biological technologies could be used to treat trout farm effluents. The commonly used physical (mechanical) treatments in trout aquaculture are a) screening and sedimentation only remove suspended solids, containing up to 7-32% of total nitrogen and 30-84% of total phosphorus; b) the remaining soluble nutrients could only be removed by either the application of chemicals or biological effluent treatments. The possible applications of biological technologies are manifold, but practical and upscale experience is lacking [63].
- Biosecurity could be applied to aquaculture production systems through a variety of management strategies and by following internationally agreed upon policies and guidelines. In addition, there are a variety of risk assessments that could be used for aquatic animal diseases of finfish, molluscs and crustaceans [64].
- Providing better environmental and biological conditions to the infected population to increase its ability to resist diseases. This might be achieved via the following steps: a) effective physical measures (increased aeration, controlled temperature, improved the feeding regime, removed sludge and organic matter and treated wastewater) to improve the environmental conditions, b) effective chemical measures, including control of pH and salinity, reduction of ammonia and nitrite and application of antibiotics and c) to use effective biological measures, consisting mainly of the use of probiotics containing a mix of bacterial species to establish beneficial microbial communities under culture conditions [65].

In order to limit any risk of the transmission of fish diseases to fish or humans via the feeding of fish by-products processed into fishmeal/fish feed and in light of the issue of intra-species recycling, it is recommended that:

- The by-products of farmed finfish should not be fed to farmed finfish.
- The by-products of farmed invertebrates should not be fed to farmed invertebrates.
- The feeding to fish of 'wet' diets containing fresh or frozen but otherwise unprocessed fish byproducts is not recommended.
- Processes used for the production of feed or fertilizers from by-products of wild or farmed fish should be validated with regard to their ability to inactivate representative model organisms.
- Current procedures used to process mortalities from fish farms ('morts') should be validated in terms of their ability to inactivate fish pathogens and also in terms of the microbiological safety of the end-product [66].
- Proper handling is necessary for fertilizers (corrosive and some are highly explosive) to prevent accidents. Some liming materials are caustic and could be hazardous to workers if proper precautions are not exercised.
- Aquaculturists could minimize the risks to their food products by adhering to regulations relating to the distribution and use of chemicals. Several of the "chemicals" used in aquaculture appeared to be subject to various pieces of basic and subsidiary legislation. The best way for the careful aquaculturist to avoid the risk of chemical pollution is to follow strictly the instructions for use of fertilizers and chemical pesticides.

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