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Health risk from contaminated aquaculture fish

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ABSTRACT

Fish growing in aquaculture system can be contaminated with chemicals, pathogens and toxins. The use of various pharmaceutical products, anti-fouling paints, and fish food are all potential sources of chemical contaminants from commercial aquaculture operations such as fish farms. Products that are highly water soluble, break down readily, and do not bind to sediments are less likely to cause significant impacts. Integrated fish farming with livestock production can cause microbial, chemical contamination from livestock sources. Animal manure is shed directly into a fish pond as fertilizer and supports the growth of photosynthetic organisms. The livestock, mainly chickens and pigs, is often fed feed containing growth promoters. Integrated fish farming seems to favor antimicrobial-resistant bacteria in the pond environment. The fish with zoonotic pathogens can cause significant threat to human health though consumption of contaminated or affected fish. The situation is going worse in low and middle income countries due to unplanned and improper aquaculture system. The paper demonstrates the possible ways of contamination of fish and attribute to the selective pressure of chemicals and antimicrobials in the pond environment and/or to the introduction of antimicrobial-resistant bacteria from different sources. The review will help for scientific communities and stakeholders for building awareness and conducting research by addressing the issues for improved risk assessments, clinical management and prevention and control of these hazards.

INTRODUCTION

Fish is a major source of protein for the increasing world population especially in the developing countries of Africa, Asia and South America (FAO, 2006; Gabriel et al., 2007) and the major solution to the dietary protein shortage in such countries is increased fish production (Nnaji et al., 2009). Although fish are a valuable source of food, their consumption may contribute to food poisoning and infections as they contain pathogenic bacteria and /or their toxins, parasite and chemical residues (Musaiger and D'Souza, 2008; Christopher et al., 2009).

The need for a low-cost system of fish production that will meet the food needs of the rural and urban poor and at the same time maximize the utilization of resources becomes pertinent. This need is provided for by integrated fish farming which combines fish farming and other types of human activity (mainly agricultural activities). Such combination ensures that waste products from one activity become an input into the fish farming activity and this leads to reduction of production costs. Integrated chicken-fish farming involves the combination of chicken farming with fish culture where the wastes (manure and spilled feed) from the chicken sub-system become an input into the fish sub-system (Sinha, 1985).

According to FAO (2003), the practice of livestock-fish farming needs to be placed in perspective with the likely health risks. One of the risks involved in livestock-fish farming is the role of cultured fish in the possible transfer of pathogens between livestock and humans. Parasites may also affect the health of fish since they can reduce fish growth rate, resistance to disease and cause fish mortalities. Another important but neglected health risk is the possibility of transfer of toxic heavy metals from fish to man in the livestock-fish system. According to Alinnor and Obiji (2010), the contamination of water bodies and aquatic animals by heavy metals have been a global problem and constant monitoring of the environment for heavy metal contamination is important. This is concern is

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largely due to the persistence, toxicity, bio-accumulative and non biodegradable nature of such metals (Azmat et al., 2008; Bhattacharya et al., 2008). Poultry litter and indeed animal wastes in general contain high concentrations of some trace elements (Jackson et al., 2003).

Heavy metals are contained in both the spilled chicken feed and manure and these are consumed by fish with the possible accumulation of these metals to high levels if fish is cultured in such systems, especially for long periods of time. This study makes a review of the possible health risks from heavy metal deposition and accumulation in chicken-fish farming and makes some recommendations on possible ways of reducing these risks.

Chemical contamination

In fish culture inorganic fertilizers, lime, pesticides, formaldehyde, etc are used extensively in enriching fish ponds. Acute and chronic pollution of water ways are increasing risk of human health. Pesticides, oil spills, and other xenobiotics can pollute ponds and water sources which can also pose risks for workers that work in such farms. Fish pond can also be polluted by flocculants those are applied to ponds to precipitate suspended clay particles (WHO, 1999). Examples are aluminium sulfate (alum), calcium sulfate (gypsum). Disinfectants are used to disinfect equipment and holding units - e.g. formalin, hypochlorite, etc.

Fumes from water pumping machines feed mill and other machines; and smoke inhaled by workers smoking fish or drying feed are considered serious health risks. However, the increasing use of a range of technologies, chemicals and feed ingredients in both livestock and fish production poses a relatively new set of risks. Products such as antimicrobials, pesticides and a range of chemotheropeutants are often used with little idea of either indirect or long-term risks. Prophylactic use of antibiotics and growth promoters in intensive fish feeds rival their use in the livestock industry. Similar problems, in terms of public health and consumer resistance, have arisen with legislation governing the use of these compounds in different countries threatening international trade. The development of genetically modified organisms, either as feeds of livestock and fish, or the animals themselves has been raised as both a moral and public health issue.

Heavy metals may accumulate in fish either through direct consumption of water or by uptake through epithelia like the gills, skin, and digestive tract (Burger et al., 2002). Eventually, dietary intake of these metals poses risk to human health as fish occupied a significant part of human diet (Turkmen et al., 2005). For these reasons, heavy metals load in fish has become an important worldwide concern, not only because of the threat to fish but also due to the health risks associated with fish consumption (Begum et al., 2013).

Many contaminants accumulate in the edible fatty tissues of fish. Concentrations of these contaminants can vary considerably in individual fish of the same species from the same location, depending on factors such as their fat content, size, age, and gender. In the case of components or extracts of whole fish (e.g., dietary supplements, dietary ingredients, and flavors), the component or extract may contain higher or lower concentrations of environmental chemical contaminants and pesticides than the whole fish from which it was derived. For example, organochlorine contaminants, such as PCBs, are oil soluble. When producing fish oil and fish meal, any PCBs present will become more concentrated in the oil fraction and less concentrated in the water fraction, as compared with the levels in the whole fish. The hazard is most commonly associated with exposure over a prolonged period of time (chronic exposure). Illnesses related to a single exposure (one meal) are very rare. Concern for these contaminants primarily focuses on fish harvested from aquaculture ponds, freshwater bodies, estuaries, and near-shore coastal waters (e.g., areas subject to shoreside contaminant discharges), rather than from the open ocean.

Heavy metals accumulate more in the visceral tissues (liver, kidney, intestines etc) of fish than in other organs and least in the muscles (Cheung and Wong, 2006; Gbem et al., 2001). Benson et al. (2006) stated that fishes are important bio-indicators of heavy metal loads in aquatic systems.

According to Uzairu et al. (2008), sediments are important sinks for heavy metals from water in aquatic systems and are also crucial in the remobilization of trace metals to the water column under suitable conditions. The accumulation of metals in an aquatic environment has direct consequences on man and the ecosystem. Fish tend to bioaccumulate heavy metals which enter through their body surface, the highly permeable gill epithelial membranes and through ingestion/gastrointestinal absorption. The environment created by integrated fish farming systems is conducive for the accumulation of metals in water, fish and sediments. This is due to the fact that these metals are contained in chicken feed and manure which ensures that these metals get into the system and may reach dangerous levels after prolonged deposition of feed and manure into the system.

Among the chemical contaminants some have only small environmental impacts, while others can be significant, especially for shellfish species that are filter feeders (this makes them much more susceptible to contamination than non-bivalve species). Heavy metal concentrations in sediment (e.g., copper, lead, and zinc) are often locally elevated around built up human settlements. Recent overseas studies have highlighted the potential for bioaccumulation of persistent chemicals in farmed fish. (Dioxins, polychlorinated biphenyls (PCBs), and heavy metals like mercury, are compounds that accumulate in animal tissue, including humans, via the food chain.) These impacts should be eliminated from any aquaculture systems.

Different chemical and biological products including disinfectants, antibiotics, pesticides, fertilizers and feed additives and probiotics were reported to be applied in aquaculture specally in different countries of Asia (Ali et al., 2016). In a study shows that, despite rapid expansion of commercial aquaculture in Bangladesh, use of chemical and biological products is still relatively low compared to other aquaculture producing countries in Asia. Assessment of trace metals (lead, cadmium and chromium) in foodstuffs including fish grown around the vicinity of industries in Bangladesh suggesting that people may be exposed these metals due to the consumption of fish from the Buriganja river near the industrial area (Islam et al., 2015). However, in Bangladesh pollution of surface water, agricultural soil by unscientific industrial effluent disposal and application of chemical fertilizers, pesticides are the major ways of heavy metal contamination. Consumption of these heavy metals with food above safe limit causes various organ dysfunctions including cancer (Hezbullah et al., 2016).

Biological contamination

Biological contamination includes parasitic infestation and pathogenic infections. Humans suffer from numerous pathogenic food-borne zoonoses. Although the fish borne zoonoses are prevailing worldwide but the problem is more concern in middle and low income countries.

Parasites

Worldwide the number of people at risk with zoonotic fish parasite, including those in developed countries, is more than half a billion (WHO, 1995, 2004). The fish-borne parasitic zoonoses have been limited for the most part to populations living in low- and middle-income countries, but the geographical limits and populations at risk are expanding because of growing international markets, improved transportation systems, and demographic changes such as population movements. Livestock and fish are involved in both passive and active transfer of a range of parasites and diseases to humans, broadening the need for risk assessment. The role of fish and warm-blooded livestock as intermediate hosts for a range of human parasites and control strategies are well known.

Parasitic infections can affect a large number of fish species, especially in countries where untreated human and animal waste is used as fish feed in fish production. The list of potential fish-borne parasitic zoonoses is quite large. However, in this review, emphasis has been placed on important parasitic diseases from four main groups: digenetic trematodes, nematodes, cestodes and protozoa (Table 1).

Trematodes

It has been estimated that the number of people infected with fish-borne trematodes exceeds 18 million worldwide. Moreover, the number of people at risk, including those in developed countries, is more than half a billion (Chai et al., 2005). Notwithstanding 33 species of digenetic trematodes having been registered as transmissible to human through the consumption of fish, crustacea or molluscs, only a few represent zoonotic threats (Butt et al., 2004). Chlonorchis sinensis, Opisthorchis spp., Heterophyes spp., Metagonimus spp., Nanophyetes salminicola and Paragonimus spp. are the most important among trematodes from the public health point of view (Köse 2010) . The members of the Heterophyidae family are among the most significant and the most important are Heterophyes heterophyes and Metagonimus yokogawai (Butt et al., 2004). People become infected by eating raw, marinated or improperly cooked fish. Human infections are frequently reported in the Middle East and Asia, especially the Philippines, Indonesia, Thailand, China, Japan and the Republic of Korea (Chai et al., 2005). The accumulation of large numbers of these digenetic trematodes in the small intestine may cause inflammation, ulceration and necrosis (Stauffer 2004).

Liver fluke infection caused by *O. viverrini*, *O. felineus*, and *C. sinensis* is a major public health problem in East Asia and Eastern Europe, while O. viverrini is endemic in Southeast Asian countries, and C. sinensis infection is common in rural areas of Korea and China (Sripa et al., 2007). Cyprinidae fish species are the major intermediate hosts of parasites *C. sinensis* and *Opisthorchis* spp., and more than 100 species of freshwater fish have been shown to be naturally infected with C. sinensis and more than 35 with Opisthorchis spp. (Lima-dos-Santos et al., 2011) . Most people with opisthorchiasis or clonorchiasis have no symptoms, while non-specific symptoms such as abdominal pain, flatulence, and fatigue occurs in 5-10% of people (Stauffer et al., 2004) . Further, enlargement of the gall bladder can be detected as well as heavy, longstanding infection including cholangitis, hepatomegaly, fibrosis of the periportal system, obstructive jaundice, cholecystitis, and cholelithiasis (Sripa et al., 2007). Moreover, the pathology caused by all species is similar and the risk of cholangiocarcinoma may be high in chronic cases (Sripa et al., 2007).

Cestodes

Fish-borne cestodes capable of infecting humans. The members of the order Diphyllobothriidea, the large-sized human tapeworms have three host life-cycles, in which teleost fishes (except in the case of Spirometra) play a role of the second intermediate hosts and represent a source of human infection. Current (re)-emergence of diphyllobothriosis and the introduction of its agents into new geographical regions are mainly fuelled by: (i) increased preference of human societies to consume raw food, (ii) globalized trade with fish products, (iii) humanmigration. Dozens of nominal species have been described so far, but only 15 species currently recognized as valid have been reported to infect humans. Although the broad fish tapeworms (genera Adenocephalus, Diphyllobothrium and Diplogonoporus) have been recognized as human parasites for a long time, many aspects of their biology and epidemiology, including species composition of individual genera, their clinical relevance and geographical distribution have been noticeably understudied.

Nematodes

Some nematodes are zoonotic. Among these parasites, *Anisakis* spp. has the highest medical importance because of the severe allergic reactions and gastrointestinal symptoms it causes in humans after eating or handling infected fish or crustaceans (Lima-dos-Santos et al., 2011). Humans are infected with larval *A. simplex* by eating raw, inadequately cooked, poorly salted or smoked salmon, herring, cod or mackerel, while *P. decipiens* is commonly present in cod, halibut or flatfish5. In humans who have consumed raw or undercooked fish, *Eustrongylides* spp. have produced gastritis and intestinal perforation (Mitchell et al., 2009). Human infections with Eustrongylides spp. occur after ingestion of raw or poorly cooked fish meat, since fishes act as intermediate and paratenic hosts in the development of their lifecycles. The pathogenicity to humans can be different to and, most times, more conspicuous than that observed in birds, the natural definitive hosts for this species (Barros et al., 2004).

Protozoa

Protozoal pathogens are arguably the most prevalent and damaging form of disease in ornamental piscine aquaculture.15 Protozoal organisms like *Cryptosporidium* spp, *Giardia lamblia*, *Balantidium* spp, malarial trypanosomes, and *Toxoplasma gondii* are capable of infecting human from fish sources.

Cryptosporidium, a protozoan parasite that can cause severe diarrhea in a wide range of vertebrates including humans, is increasingly recognized as a parasite of a diverse range of wildlife species, including fish (Ryan and Power, 2012). Although the epidemiology of cryptosporidiosis has been widely reported worldwide for different groups of animals, little biological, epidemiological and molecular data are available on Cryptosporidium infection in fish, even though the parasite has been already described and genetically characterized in more than 20 species of both freshwater and marine fish. *Cryptosporidium molnari*, the only currently recognized species infecting fish, was first identified in sea bream (*Sparus aurata*) and European sea bass (*Dicentrarchus labrax*) (Alvarez et al., 2002). Cryptosporidium scophthalmi was detected in turbot (*Psetta maxima*, syn. *Scophthalmus maximus*) (Alvarez-Pellitero et al., 2004) but this species is still considered a nomen nudum due to a lack of genetic data (Ryan et al., 2014). *Cryptosporidium* species found in other groups of vertebrates have also been identified in fish, including *C. parvum, C. hominis, C. scrofarum* and *C. xiaoi*. Additionally, eight Cryptosporidium fish genotypes, and one Cryptosporidium rat III-like genotype, have been described in fish (Ryan et al., 2014). Recently, the species name *Cryptosporidium huwi* has been proposed for the piscine genotype 1 from the guppy (*Poecilia reticulata*) to reflect its genetic and biological differences from gastric and intestinal Cryptosporidium species (Ryan et al., 2015).

Very little is known about the prevalence, genetic diversity and effect of species of *Giardia* in marine environments and the role that marine animals play in transmission of these parasites to humans (Olson et al., 1997; Dixon et al., 2008).

There are serious safety concerns related to the consumption of raw fish meat due to the presence of parasitic hazards. Because of all the mentioned facts, good knowledge and management of parasitic hazards associated with the consumption of fish meat is of major health and economic significance. Despite their huge social costs and global impacts, information is generally lacking regarding just where these parasites come from, how they live in the human body, and – most importantly – how they make us sick.

Disease pathogens

Bacteria

It should be assumed that all water used in aquaculture is potentially contaminated with pathogens, whether or not livestock wastes are used. Evident showed that faecal coliforms, *Salmonella* and bacteriophage (used as an indicator of viruses) are sometimes present before input of wastes, suggesting that surface water is often contaminated (Edwards et al., 1983). Microbial levels increased with loading level for buffalo manure added to the ponds daily, but not for the wastes from egg laying ducks raised over the pond. In both cases, the concentration of the different microorganisms increased in the water during the early part of the experiment before falling to a constant level thereafter.

The zoonotic diseases associated with fish contact are primarily bacterial infections. These include *Mycobacterium, Erysipelothrix, Campylobacter, Aeromonas, Vibrio, Edwardsiella, Escherichia, Salmonella, Klebsiella and Streptococcus iniae. Aeromonas* is more common is freshwater species and *Vibrio* is more likely in saltwater species. Contact may result in wound infections and ingestion can result in gastroenteritis with vomiting and diarrhea. More severe & potentially life-threatening disease and septicemia may occur in immunosuppressed persons. Often these infections do not make fish appear ill but can cause serious illness in humans. Persons with specific medical conditions such as a chronic illness, immunodeficiency and pregnancy may be at higher risk of developing disease or complications from a zoonotic disease and should consult with their physician before working with animals.

Antimicrobials and antimicrobial resistance

Antibiotics are used in aquaculture as a prophylactive or therapuetic measures or as feed additives and gain access to the pond environment through using human and animal wastes or integrated fish farming system. There has been a surge in the number of foodborne infections caused by antibiotic resistant bacteria (Subasinghe et al., 2005). Recently, a few studies have shown a direct relationship between antibiotic use in food animals and the emergence of antibiotic resistance in human and animal pathogens Teuber M (1999) and Van den Bogaard et al., (2002).

Integrated fish farming is practiced throughout Southeast Asia. These systemns include duck-fish integrated farming in India, poultry-fish in Thailand, rice-fish in the Philippines, and crop-livestock-fish-homestead integrated farming in Vietnam. Manure from livestock production is administered to fish ponds; the manure is either directly consumed by fish, or release of nutrients that supports the growth of mainly photosynthetic organisms (Tapiador et a., 1976). The integrated fish farming system produces high yields with low input, with the fish receiving limited, if any, supplementary feed. In contrast, the livestock on the integrated farms, which includes chickens and pigs, is reared intensively, and antimicrobial agents are used as growth promoters and for prophylactic and therapeutic treatment. Within integrated fish farming systems, antimicrobials, their residues, and antimicrobial-resistant bacteria enters the fish ponds through animal manure and/or excess feeding and are potential sources of antimicrobial-resistant bacteria. However, the impact of the use of animal manure in integrated fish farm environments on the occurrence of antimicrobial resistant bacteria has to our knowledge not been investigated previously. Antimicrobial resistance in traditional fish farming systems in temperate waters has been intensively studied (Mitchell and James (2008). A high incidence of bacteria resistant to the antimicrobials used in aquaculture, including multiply resistant bacteria, has been found in fish farms and the surrounding aquatic environments (Alderman and Hastings, 1998). Furthermore, residues of antimicrobials have been found in the sediments of marine fish farms (Samuelsen et., 1992).

Environmental contamination with antimicrobial residues of antimicrobials in the aquatic environment can have a negative impact on the environment, e.g. by altering the microflora, which again indirectly can have a negative effect on public health. Such environmental contamination with antimicrobial can select for resistance in environmental microflora, and resistance genes can be disseminated further and eventually reach e.g. human pathogens. Aquatic environments can be a source of resistant bacteria that can be transmitted to and cause infections in humans, and due to the resistance traits results in treatment failures. Such direct spread of resistance from aquatic environments to humans may involve human pathogens such as *Vibrio cholerae, Vibrio parahaemolyticus, Vibrio vulnificus, Shigella* spp. and *Salmonella* spp. or opportunistic pathogens such as *Aeromonas hydrophila*, *Plesiomonas shigelloides*, *Edwardsiella tarda*, *Streptococcus iniae* and *E. coli*. The spread of such resistant bacteria to humans may be through direct contact with water or aquatic organisms, through drinking water or through the handling or consumption of seafood. Several recently found genetic elements and resistance determinants for quinolones, tetracyclines, and b-lactamases are shared between aquatic bacteria, fish pathogens, and human pathogens, and appear to have originated in aquatic bacteria (Report on food safety).

Risk assessment

An understanding of the main risk factors and how to reduce them is therefore essential for developing best management practice. Moreover, in order to obtain a holistic view of risk, any comparison of public health and aquaculture produce derived from different environment and systems should be compared to those from other production systems.

The risk associated with contamination of heavy metals, antibiotics and other harmful chemicals from industries, agriculture and livestock should be compared with alternative uses that may present greater risks to public health in developing countries. Fundamentally a fish pond is a treatment system for pathogens present in organic wastes; large diurnal variations in temperature, pH and dissolved oxygen in shallow tropical fish ponds tend to cause rapid attenuation of pathogens (Somnasang et al., 1990). The health risk assessment is necessary before marketing the fish from the aquaculture system otherwise therefore continuous consumption of contaminated fish may create health risk in the long run.

In aquaculture systems, the main risk factors for parasitic infection and transmission include contamination of pond environments with their eggs from infected hosts, i.e., humans, cats, dogs, pigs, and fish-eating birds. Factors that promote the diversity and population growth of snail intermediate hosts (families Thiaridae and Bithynidae) and aquatic arthropods (etc. cyclops, copepods) also increase risk (Thu et al., 2007; Thien et al., 2007; Phan et al., 2011). Whilst the levels of micro-organism in manure or pond water are important in understanding risks to the producer, the level of pathogens contained in the fish at harvest is of key importance in determining risk to those preparing and consuming the fish. Levels of microorganisms found in the digestive tract of fish are much higher than in the water illustrating a likely route to infection is via contamination of hands and surfaces during preparation and cooking of fish. However, conditions are such in waste-fed ponds that even heavier microbial loads from introduction of livestock manure are rapidly attenuated. *Salmonella* has also been found in shrimp pond sediment and shrimp throughout Southeast Asia however, and the cause attributed to the use of large amounts of fresh chicken manure and supplementary feeds (Reilly and Twiddy, 1992). In contrast to bacteria, indicators for pathogenic viruses, such as bacteriophage give a measure of faecal contamination rather than the presence of pathogens. It is thought that enteric viruses are also rapidly attenuated in waste-fed ponds but their low infective dose suggest that serious attention be given to their persistence in fish ponds.

Table 1
List of biological hazard that causing human health risk.

Disease	Causative Organism	Animals Involved	Probable Means of Spread to People
Arcobacter infections	*Arcobacter butzleri*, *A cryaerophilus*, *A skirrowii*, possibly others	Poultry, cattle, pigs, sheep, horses, shellfish; some studies detected these organisms in dogs and/or cats	
Erysipeloid (see *Erysipelothrix rhusiopathiae*	*Erysipelothrix rhusiopathiae*	Swine, sheep, cattle, rodents, marine mammals; many other domestic and wild mammals and marsupials, birds (including poultry), reptiles, fish, mollusks, crustaceans	Contact with animal products; via skin, usually after scratch or puncture wound; contaminated soil (survives for weeks to months)
Listeriosis (see Listeriosis)	*Listeria monocytogenes*(types most often associated with disease are ½a, ½b, 4b), *Listeria ivanovii*(rare)	Numerous mammals, birds, fish, crustaceans	Foodborne, especially unpasteurized dairy products, raw meat and fish, vegetables, processed foods contaminated after processing; ingestion of contaminated water, soil; direct contact with infected animals; nosocomial in hospitals, institutions
Melioidosis	*Burkholderia*	Sheep, goats, swine; occasional cases in	Wound infection,

(Pseudoglanders, see Melioidosis)	*pseudomallei* (other species of soil-associated *Burkholderia*, such as *B oklahomensis* sp *nov*in North America, rarely linked to human infections)	many other terrestrial and aquatic mammals; also reptiles, some birds including parrots, tropical fish	inhalation, and ingestion; organisms live in soil and surface water; most cases are acquired from environment, but direct transmission from animals is possible
	Mycobacteria other than tuberculosis (includes *M simiae*, *M kansasii*, *M xenopi*, *M scrofulaceum*, *M szulgai*, *M chelonae*, *M marinum*, *M ulcerans*, others)	Cattle, other ruminants; swine, cats, dogs, koalas, other mammals, amphibians, reptiles (uncommon), fish; predominant *Mycobacterium* spp vary with host	Environmental, from water and/or soil
Streptococcal infections	*Streptococcus* spp, including *S suis*, *S equi zooepidemicus*, *S canis*, *S iniae*, possibly others	*S suis* in swine; *S equi zooepidemicus* in horses; *S canis* in dogs, cats; *S iniae* in fish; each species can also be found in other animals	Ingestion, especially of unpasteurized dairy products, pork; direct contact often through broken skin; the human pathogen *S pyogenes* can also colonize bovine udder and be transmitted in milk
Tularemia (see Tularemia)	*Francisella tularensis*subsp *tularensis* more virulent, *F tularensis*subsp *holarctica* (*F tularensis* type B) less virulent, *F tularensis*subsp *mediasiatica*, *F tularensis* subsp *novicida*	Rabbits, rodents, cats, sheep, other mammals, birds, reptiles, fish; often in wild animals	Contact with mucous membranes, broken skin; insect bites (tabanids, mosquitoes, hard ticks); fomites; ingestion in food or water; inhalation
Vibriosis	*Vibrio parahaemolyticus*	Marine and estuarine shellfish, fish; also environmental in aquatic environments	Ingestion; wound infections
	V vulnificus	Marine shellfish, crustaceans (eg, shrimp), fish; also environmental in aquatic environments	Ingestion (often raw oysters); wound infection from water or handling hosts
Sennetsu fever	*Neorickettsia sennetsu*	Uncertain, possibly fish	Thought to be ingestion of raw fish
Spotted fever group of *Rickettsia*			
Cryptosporidiosis (see Cryptosporidiosis)	*Cryptosporidium parvum*, *C canis*, *C felis*, *C meleagridis*, *C cuniculus*, *C viatorum*, *C muris*, and other species (*C hominis*and likely some genotypes of *C parvum* are adapted mainly to people)	Cattle and other ruminants, dogs, cats, rabbits, other domestic and wild mammals, birds, reptiles, fish	Fecal-oral; ingestion of contaminated food and water; inhalation
Giardiasis	*Giardia intestinalis*, also known as *G*	Many domestic and wild mammals, including dogs, cats, ruminants, aquatic	Ingestion of water and less often food; direct fecal-oral

	duodenalis (formerly *G lamblia*); only some genotypes seem to have zoonotic potential	mammals such as beavers	(hands or fomites)
Microsporidiosis	Microsporidia of *Enterocytozoon bieneusi*, *Encephalitozoon cuniculi*, *E intestinalis*, *E hellem*, others; both zoonotic and anthropnotic transmission reported for some agents	Widespread in vertebrates, including primates, rabbits, rodents, dogs, cats, cattle, pigs, goats, birds, fish; also in invertebrates	Fecal-oral; direct contact; ingestion of contaminated food or water; aerosols; possibly vector-transmitted
Rhinosporidiosis	*Rhinosporidium seeberi*; some strains may be host specific	Natural hosts thought to be fish and amphibians; also found in various mammals, including horses, cattle, mules, dogs, and cats; birds	Environmental exposure, probably water
Clonorchiasis	*Clonorchis sinensis*(Chinese liver fluke)	Dogs, cats, swine, rats, other mammals are definitive hosts; fish (and snails) are intermediate hosts	Feeding small, raw fish to pigs as a protein source could encourage re-infection Use of cooked small fish for livestock feed instead of direct consumption by humans could reduce risk Replacement of overhung latrines/use of fresh nightsoil with livestock manure could reduce risk Increased productivity of waste-fed ponds could result in more fish eaten preserved rather than fresh, increasing risk
Echinostomiasis	*Echinostoma revolutum*, *E ilocanum*, *E hortense*, and other *Echinostoma* spp; *Echinochasmus japonicus* and other members of Echinostomatidae can also be zoonotic	Cats, dogs, rodents, pigs, other mammals; birds, including poultry, are definitive hosts; fish, shellfish, tadpoles, snails are intermediate hosts	Ingestion of undercooked fish, shellfish, snails, or amphibians (frogs)
Heterophyiasis	*Heterophyes* spp, *Haplorchis* spp, other heterophids	Cats, dogs, foxes, wolves, cattle, other mammals, fish-eating birds are definitive hosts (host varies with species of parasite); fish (and snails) are intermediate hosts	Ingestion of undercooked fish containing encysted larvae
Metagonimiasis	*Metagonimus yokogawai*, *M miyatai*, *M takahashii*, and other *Metagonimus*spp	Cats, dogs, rats, other fish-eating mammals, possibly birds are definitive hosts; fish (and snails) are intermediate hosts	Ingestion of undercooked freshwater fish containing encysted larvae
Metorchiasis	*Metorchis conjunctus*, Canadian liver fluke	Dogs, foxes and other canids, cats, raccoons, muskrats, mink, other fish-eating mammals are definitive hosts; fish (and snails) are intermediate hosts	Ingestion of undercooked freshwater fish containing encysted larvae

Nanophyetiasis	*Troglotrema salmincola* (also called *Nanophyetus salmincola*)	Raccoons, foxes, dogs, cats, skunks, and other fish-eating mammals and birds are definitive hosts; salmonid and some non-salmonid fish (and snails) are intermediate hosts	Ingestion of undercooked fish or roe
Opisthorchiasis	*Opisthorchis felineus*(cat liver fluke)	Cats, dogs, foxes, swine, seals, other fish-eating mammals are definitive hosts; fish (and snails) are intermediate hosts	Ingestion of undercooked freshwater fish containing encysted larvae
	O viverrini (small liver fluke); zoonotic transmission can occur, but people are important hosts	People, dogs, cats, rats, pigs, fish-eating mammals are definitive hosts; fish and snails are intermediate hosts	Ingestion of undercooked freshwater fish containing encysted larvae
	Amphimerus pseudofelineus	Various mammals, birds, reptiles are definitive hosts; fish suspected as intermediate hosts	Undetermined but probably ingestion of undercooked fish
Paragonimiasis (Lung fluke disease)	*Paragonimus westermani*, *P heterotremus*, *P africanus*, *P mexicanus*, and other species	Dogs, cats, swine, wild carnivores, opossums, and other mammals are definitive hosts; snails and freshwater crustaceans are intermediate hosts; wild boars, sheep, goats, rabbits, birds, other animals are paratenic hosts	Ingestion of undercooked, infected freshwater crustaceans (crabs, crayfish); metacercariae on contaminated hands, fomites after preparing crustaceans, or undercooked meat from paratenic hosts such as wild boars
Schistosomiasis	Gastrodiscoides *Schistosoma* spp.	Monkeys, pigs, rats Some species have water buffalo, cattle, dogs and rats	Water plants Freshwater snails
Diphyllobothriasis (Fish tapeworm infection)	*Diphyllobothrium latum*(*Dibothriocephalus latus*), *D nihonkaiense*, *D pacificum*, *D dendriticum*, and other *Diphyllobothrium* s pp	Dogs, bears, seals, sea lions, gulls, and other fish-eating mammals and birds are definitive hosts; freshwater or marine fish (and copepods) are intermediate hosts	Ingestion of undercooked infected fish
	Angiostrongylus cantonensis, also called *Parastrongylus cantonensis*	Rodents (rats, including *Rattus* and *Bandicota* spp) are definitive hosts; snails, slugs are intermediate hosts; land planarians, crustaceans (crabs, shrimp, prawns), amphibians, fish, reptiles are paratenic hosts	Ingestion of raw/undercooked intermediate or paratenic host (or accidental ingestion on vegetables); possibly ingestion of plants contaminated by secretions of intermediate host
Anisakiasis	*Anisakis*, *Pseudoterranova*, and *Contracaecum* spp	Marine mammals (cetaceans and pinnipeds) and fish-eating birds are definitive hosts; fish, crustaceans, and cephalopod mollusks are intermediate or paratenic hosts	Ingestion of undercooked marine fish, squid, octopus
Intestinal capillariasis	*C philippinensis* (also called *Paracapillaria philippinensis*)	Aquatic birds, people can be definitive hosts; freshwater fish are intermediate host	Ingestion of undercooked infected fish
Dioctophymosis (Giant kidney worm	*Dioctophyma renale*	Mink, dogs, and other carnivores are definitive hosts; annelids are	Ingestion of infected fish, frog, or annelid

infection)		intermediate hosts; frogs, fish are paratenic hosts	
Gnathostomiasis	*Gnathostoma spinigerum*, *G binucleatum*, and some other *Gnathostoma* spp	Dogs, cats, wild carnivores are definitive hosts (*G doloresi* and *G hispidum* in pigs and wild boars); copepods, freshwater fish, eels, frogs, snakes, chickens, snails, pigs are intermediate or paratenic hosts	Ingestion of undercooked fish, poultry, or other intermediate or paratenic host, drinking water contaminated with copepods containing larvae; handling meat that contains larvae
Acanthocephaliasis, Macracanthorhyn-chosis	*Macracanthorhynchus hirudinaceus* and other species	Hosts vary with parasite species; definitive hosts include domestic and wild pigs, rodents, muskrats, arctic foxes, dogs, sea otters, other terrestrial and marine mammals; intermediate hosts are beetles, cockroaches, crustaceans; fish are paratenic hosts	Ingestion of infected beetles, other intermediate hosts, or fish

Reducing risks

The most effective and simple preventive measure to control the disease is avoiding consumption of raw fish, i.e. to eat fish that have been boiled, cooked or frozen before consuming (Kuchta et al., 2015a; Scholz et al., 2009). Improved sanitation or human waste disposal is a key element in the control of parasites, as is the control of pond-side vegetation that provides cover for snails which are often intermediate hosts. Education and the availability of anti-helminth drugs are also prerequisites for successful improvement of public health at the community level. Poorly-managed fish ponds often become mosquito-breeding sites (Birley and Lock, 1998). Removal of surface and emergent vegetation, as a part of intensified aquaculture, reduces shelter for mosquito larvae. Introduction of aquaculture has actually decreased the incidence of disease through reduction of the habitats of the vectors or intermediate hosts such as mosquitoes and snails in Israel and China respectively.

Although most fish species have been found to be relatively ineffective at biological control of snail intermediate hosts (McCullough, 1990), snail-eating black carp (*Mylopharyngodon piceus*), and ducks can be managed to control them to a limited extent. The Louisiana red swamp crayfish (*Proambarus clarkii*) is being used in an attempt to control freshwater snails in Kenya (Hofkin *et al*., 1991). Abandoned or poorly managed fish ponds have been associated with schistosomasis in Africa (McCullough, 1990) but well managed, productive systems in which aquatic weeds and molluscs are removed or managed are probably less of a problem.

The most important risk factor for all fishborne parasitic zoonoses is the consumption of raw or undercooked fish. It is noteworthy that the numbers of cases in outbreaks of food-borne diseases caused by consumption of fish are generally small when compared to those caused by poultry, dairy and meat products (Newell et a 2010). Visual inspection and removing visible parasites are suggested to prevent this hazard21. According to the EU (EC 2004), fish food producers must ensure that fishery products have been subjected to a visual examination for the purpose of detecting visible parasites before being placed on the market. Murrell (2002) also suggested several control measures for preventing parasite infection originating from freshwater, such as environmental control of surface water where fish are caught, hygienic aquaculture, and the control or elimination of the first intermediate hosts (snails). FDA (FDA, 2001) indicated that the effective methods to kill parasites are freezing, heating, and adequate combination of salt content and storage time or hot smoking. On the other hand, brining and cold smoking may reduce the parasite hazard in fish, but they do not eliminate it or minimize it to an acceptable level (Murrell 2002). The recommendation to avoid consumption of raw or poorly cooked fish is still the best preventive procedure. The consumption forms and the preparation of fish food should be modified in such a way that hazards to human health due to these zoonotic parasites and other pathogens would be avoided. Health education is a key factor in combating fishborne zoonotic infections.

Risks of passive transfer of pathogens through handling of live fish during production, harvest and processing can be reduced if physical exposure is minimized through use of appropriate clothing, especially gloves. Attention to minimise the risk of cross-contamination during processing should be avoided, as the digestive tract is the major source of pathogens. Depuration, the holding of fish in clean water without feeding, facilitates this task by reducing the amount of digestive tract contents. Consumption of raw, certain types of processed, or undercooked fish should be avoided. Removal of visera and major organs, in addition to the digestive tract, prior to marketing 'whole fish' would also reduce risk.

The health risk from parasites is far less than the risk from "unseen" illness causing bacteria which are present in almost all foods.

Pre-treatment or processing of livestock waste prior to its use as a fishpond fertilizer or feed ingredient also reduces risks associated with transfer of pathogens. A comprehensive study of shrimp farms in Southern Thailand found no evidence of *Salmonella* (Dalsgaard and Olsen 1995). A critical factor for the survival of *Salmonella* appears to be adequate moisture. In a subsequent analysis, *Salmonella* was not found in chicken manure samples used in shrimp farms, as they tended to be sun-dried or dry pelletized (Dalsgaard and Olsen, 1995). *Streptococcus* sp. infections of fish are a relatively newly identified threat to humans. Increasingly found in cultured tilapias, *S. iniae* and other *Streptococci* that infect fish may also 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 (Plumb, 1997). It has not yet been associated with fish from integrated culture systems.

Depuration in clean water for a six week period was more effective with tilapia raised in optimal growth conditions in wastewater-fed ponds as they contained initially lower concentrations of bacteria, with none present in organs or muscle.

Freeze the fish to an internal temperature of -4°F for at least 7 days to kill any parasites that may be present. Home freezers are usually between 0°F and 10°F and may not be cold enough to kill the parasites.

If fish is to be eaten raw, it should preferably be frozen at -30 degrees Celsius. If storage is at -20 degrees Celsius, the fish should be frozen for at least five days. It is preferable to use farmed fish for raw dishes as these fish appear to be virtually free of infection. Marinating or smoking the fish will not necessarily kill Anisakis.

Commercially frozen fish is almost risk free from any parasite. During commercial freezing fish is frozen solid at a temperature of -35°F and stored at this temperature or below for a minimum of 15 hours to kill parasites. Most home freezers have temperatures at 0°F to 10°F and may not be cold enough to kill parasites because it can take up to 7 days at -4°F or below to kill parasites, especially in large fish. Good handling practices on-board fishing vessels and in processing plants can minimize nematode infestation.

Fish is also safe to eat after it is cooked to an internal temperature of 145°F for 15 seconds. Normal cooking procedures generally exceed this temperature. If a thermometer is not available to check the internal temperature of the thickest portion of the fish, the fish should be cooked until it loses its translucency and flakes easily with a fork.

Prevention and control: • By creating awareness among the people through conducting seminars and training programmes. • Provision of laboratory facilities for identification of the causative agents (parasites). • Diseases can be controlled also by proper investigation and monitoring. •By educating the fish eating people regarding the parasitic diseases occurred through consumption of fishes. • Thorough and proper cooking of fishes also plays a key role in controlling the diseases.

Conventional farming systems in developing countries have severely neglected the negative impact of hazardous chemicals on human health and nature, but the environmental health awareness and concern are rapidly growing now. To overcome the problems of integrated farming system (IFS) it is required 1. Registration of all IFS units 2. Training in inspection for official inspectors for quality of water at regular intervals 3. Training in good agricultural practices (GAP)/Code of Conduct (CoC) for IFS farmers 4. Training in good hygiene practice (GHP), good manufacturing practices (GMP) and Hazard Analysis Critical Control Point (HACCP) System for IFS farmers to process and handle the products 5. Technical assistance for all IFS farmers to follow GAP, CoC, GHP, GMP and HACCP 6. Monitoring IFS units for production standards through regular testing of samples of feed, drugs, chemicals used on IFS and also fish, shelfish, ducks and livestock at IFS and their products 7. Controlling the IFS product movement 8. Documentation and certification of hatcheries; farms; feed, drug and chemical suppliers and handlers; and the suppliers and processors party to IFS for meeting the SPS requirements

To counter the bad effects of chemical use, IFS with integrated pest management (IPM) is the only way to maintain ecological balance in nature i.e. through organic farming. FAO and UNDP have initiated many different types of programmes in many countries to attain the objectives of safe ecological balance. The projects target demonstrations on farms using organic farming approach in order to promote this approach and train farmers on using its techniques (SADP 2008).

There is also urgent need to study the dynamics of pathogenic bacteria and hazardous chemicals circulating in various components of different types of IFS units (fish-duck, fish-pig, fish-cattle, fish-fodder-livestock, fish-vegetablelivestock etc.) to identify the possible intervention points to evolve of appropriate methodology for hygienic and safe food production from IFS in an eco-friendly manner.

The avoiding chemical contamination government should strictly monitor the sources of chemical contamination from industries or esles wehe and imply the existing laws to control the sources. Fish should not be reared near or connected water bodies to industries outlet and farms.

CONCLUSION

The eating of raw or partially cooked fish is the main risk factor for these pathogens. If fish consumption increases globally as is predicted, the importance of these zoonoses may increase. The infective stage of parasite or pathogens may be found in many varieties of fishes. Misuse of antimicrobials or using of manure as a fertilizer in aquaculture may not only carry and disseminate some pathogenic food borne or zoonotic bacteria in a pond environment that could be also transmissible to human during culturing, rearing, harvesting, marketing, processing or consumption with health hazard but also may create multidrug-resistant strains and may produce fish of low quality and of shorter shelf-life.

RECOMMENDATIONS

- Frequent diagnosis of foodborne and zoonotic bacteria in pond environment is essential.
- Cultured fish should be checked for containing heavey metals and harful chemicals commonly used industries and agriculture.
- Prevention and control of bacterial diseases in aquatic organisms is essential.
- Surveillance for antimicrobial resistance in humans and food animals is important.
- Detection to the changes in susceptibility of bacteria to the antimicrobials is essential.
- Control measures on the use of antimicrobial drugs should be implemented.
- He routine prophylactic use of antimicrobials should never substitute better hygiene.
- Prophylactic use of antimicrobials should be used only upon vaccination failure.
- Only non-human antibiotics may be available for performance enhancement.
- Overuse and misuse of antimicrobials in aquaculture should be restricted.
- He use of manure in aquaculture should be avoided or treated whenever possible.

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