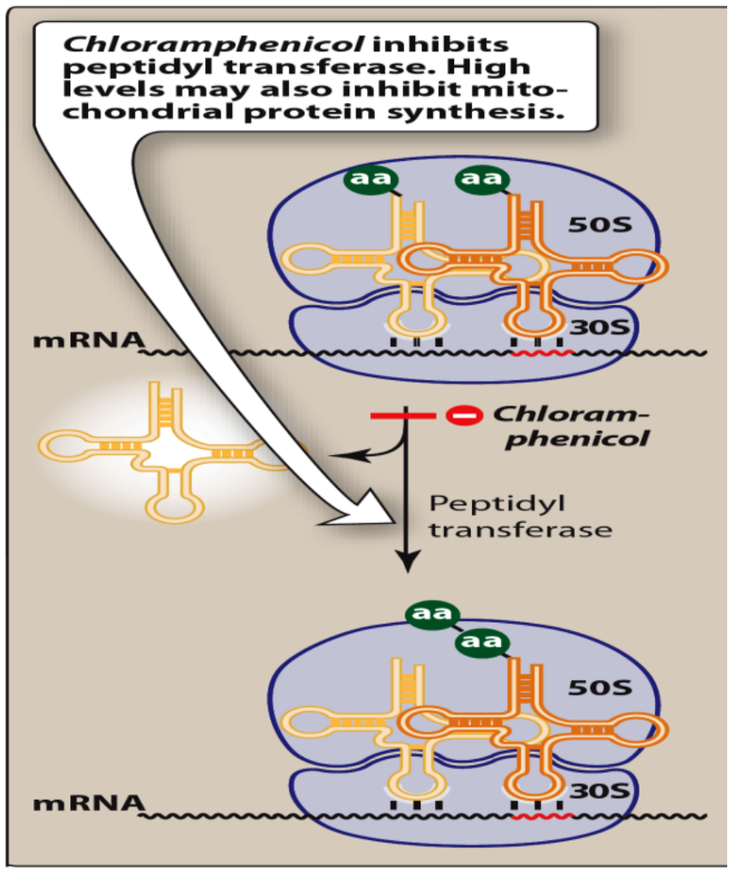

Fig. 4 Mechanism of Chloramphenicol
(Source: https://player.slideplayer.com/20/6230353/data/images/img3.jpg)

the introduction of pathogens and to prevent disease outbreaks and should include control measures to be implemented if the disease occurs.

WHO estimated that by 2050, antimicrobial resistance will be responsible for 4.7 million deaths in the Asia region (WHO 2015). Sri Lanka developed the National Strategic Plan (NSP) 2017-2022 with the collaboration of WHO in 2016 (National Strategic Plan-2017-2022). The NSP is developed under five key strategies which are aligned with the strategic objectives of the Global Action Plan. Those strategies are; improve awareness and understanding of antimicrobial resistance through effective communication, strengthen the knowledge and evidence base through surveillance and research, Reduce the incidence of infection through effective sanitation, hygiene and infection prevention measures, optimize the use of antimicrobial medicines in human and animal health and prepare the economic case for sustainable investment and increase investment in new medicines, diagnostic tools, vaccines and other interventions. Further studies that provide clear evidence of the link between inappropriate antibiotic use in aquaculture, and antibiotic residues and antibiotic resistance in bacterial pathogens, are needed to develop the appropriate control strategies.

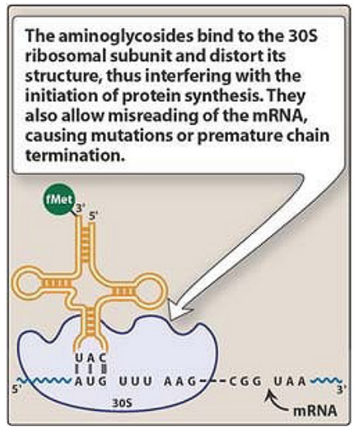

Fig. 5 Mechanism of Aminoglycosides
(Source: https://player.slideplayer.com/20/6230353/data/images/img16.jpg)

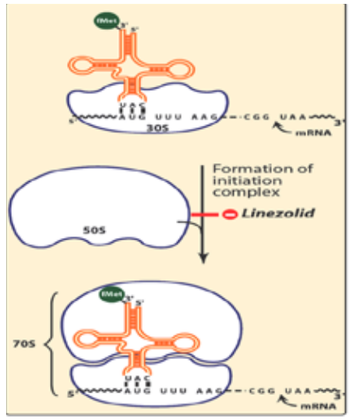

Fig. 6 Mechanism of Linezolid
(Source: https://www.slideshare.net/saminathankayarohanam/3-antibiotic-protein-synthesis-inhibitors-51450665)

Conclusion

The protein synthesis inhibitors are one of the branches and most commonly used antibiotics in aquaculture which is often used to treat the parasitic infections and bacterial diseases and avoid the horizontal transmission of infections in cultured fishes. It should be used at recommended dosage to avoid the bioaccumulation of antibiotics or drugs in fishes.

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Heavy metal contamination in seafood

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Introduction

Global population is depending upon seafood as a healthy diet choice because of its richness in high value proteins, health beneficial vitamins, minerals and poly unsaturated fatty acids. Fish is also a primary protein source in most parts of the world.

Even though fish supplies many health benefits, seafood can be compromised by different chemical contaminants which areharmful to consumers. Among the environmental chemical contaminants, heavy metals are reported as the most commonly occurring one in seafood mainly lead, cadmium, arsenic and mercury.

These metal contaminants are coming to the environment from industrial sources and pollution. Toxic nature of heavy metals with high persistence in the environment along with bioaccumulation and biomagnification through food chain makes a serious issue. Fishes can uptake and concentrate metals from water, other small fishes and vegetation. Accumulation in the tissue can depend upon environmental concentration and exposure period. Also in an aquatic ecosystem fishes are the most important biomonitor for estimation of heavy metal contamination (Rashed, 2001).

It is significant that all the metals are not hazardous and toxic to fish and humans. While essential metals like copper (Cu), zinc (Zn), iron (Fe), iodine (I) and selenium (Se) play important role in biological

activity and can affect the human health condition during their deficiency or at higher concentration.Cadmium (Cd), mercury (Hg), tin (Sn), arsenic (As) and lead (Pb) etc generally make harmful effect in living organisms. Based on the degree of toxicity, maximum allowable limit (MAL) is determined which is a limit above which the consumers are exposed to harmful contamination. MALs of toxic elements have been decided by different countries and regulatory bodies based on the fish consumption pattern of specific population group (Table 1).

Mercury

Mercury is the metal of most concern with respect to seafood consumption and human health as it is the most toxic among heavy metals. Fish is considered as the most important source of mercury in case of humans. Although forest fires and volcanic activity act as natural source of Hg, major part is from anthropogenic origin such as from industries of paint, electrical equipments, battery, fungicide, wood pulping etc. Even though the industrial use of Hg has decreased due to continuous awareness on Hg toxicity, the environmental Hg level is still in the higher side.

Speciation of mercury and toxicity

Elemental mercury (Hg) and mercuric ions (Hg^{2+}) are the main forms present in the natural environment, but it will not accumulate in fish. It can be converted into other soluble forms such as inorganic and organic mercury. Mercuric chloride ($HgCl_2$), mercurous chloride (Hg_2Cl_2), mercuric sulfide (HgS) are common forms of inorganic mercury occur in nature.

Although inorganic forms are non-toxic, they can be methylated to form organic mercury called methylmercury (MeHg) which is the chronic toxic form of mercury (Hempel et al., 1995). The process of methylation occurs either by photomethylation or microorganisms such as anaerobic sulfate reducing bacteria, iron reducers and methanogens. Among microorganisms sulfate reducing bacteria are the major contributors of Hg methylation in natural waters. Dimethymercury (DMHg) and ethylmercury (EtHg) are the other organic Hg forms other than methyl Hg. But MeHg is the main form absorbed into the food chain which is most toxic. Also half life of MeHg is longer than inorganic Hg and has good correlation on the percentage of MeHg on total Hg (Forsyth et al., 2004). The contribution of MeHg to total Hg is reported to be 10% in water, 15% in phytoplankton, 30% in zooplankton and 95% in fish flesh (Watras and Bloom, 1992). Fish at higher trophic levels accumulate more amount of Hg than at lower levels due to its significant absorption.

It creates a greater risk to consumer health as Hg can associate with protein fraction

of fish meat by binding with thiol group complexes. After consumption 95% of MeHg is getting absorbed through the intestinal tract. It can reach and accumulate in the brain via blood and result loss of cells in specific brain areas and also affect other target organs like pituitary gland, liver and kidney. The major symptoms of MeHg in humans are impaired vision and hearing, headache, paraesthesia, difficulty in movement, less coordination, fatigue, tremors and ataxia (Grandjean et al., 2010). Prenatal exposure of children to Hg can result developmental disorders. As seafood is the major source of beneficial poly unsaturated fatty acids consumption of predatory fishes like shark, sword fish, king mackerel etc can be avoided or consume in smaller quantities. As per the international safety guideline, the maximum tolerable weekly intake of Hg is 1.6 µg/Kg body weight (EC 2006).

Arsenic

Arsenic (As) is widely distributed in the environment due to natural and anthropogenic sources. It has the ability to deposit in huge quantities in sediments of water bodies and reservoir systems. The major agricultural source of As is from industries manufacturing defoliants and pesticides. Arsenic is present in both organic and inorganic form and the most toxic one among them is inorganic As which is stable and highly soluble and can be absorbed into the body easily. Organic form As cannot accumulate in the body and it is getting quickly excreted.

Inorganic Arsenites (As^{3+}) is more toxic and get easily absorbed into fish compared to arsenates (As^{4+}). Although total As is measured instead of inorganic As (Arsinite), 90% of As present in fish and crustaceans is in non toxic arsenbetain form. While in case of mollusks and algae it is present in the form of arsenocholine and arsenosugar respectively. The inorganic As trioxide is known as rat poison. It is reported that organic arsenic compounds and their metabolites can produce cytotoxic effects. Content of inorganic arsenic in seafood is very negligible generally lower than 0.2 mg/Kg in fish and shellfish.

As per the European Commission Scientific Cooperation Project (SCOOP), consumption of arsenic from marine origin foods may be in excess of 50%. As per EFSA, (2009a), seaweed has highest total As concentrations in the marine food web. Shellfishes usually have high content of arsenic than finfishes. Demersal fishes often contain higher As level compared to pelagic fishes (Wu et al., 2014). As concentration in fish are normally less than 5 mg/Kg. The reference value proposed

Heavy metals	Permissible limit (mg/Kg)			
	EU	USFDA	Codex	India
Mercury	*Fishery products* -0.5 *Certain fishes*- 1	*All fishes(methyl mercury)* - 1	*Fishes* – 0.5 *Predatory fishes* - 1	*Fishes* – 0.5 *Predatory fishes* - 1
Cadmium	*Crustaceans* – 0.5 *Bivalves* – 1 *Cephalopods* – 1 *Fishes* – 0.05 *to* 0.1	*Crustaceans* –3 *Bivalves* –4	*Bivalves* –2 *Cephalopods* – 2	*Fish* – 0.3 *Crustaceans* – 0.5 *Bivalves* –2 *Cephalopods* – 2
Lead	*Crustaceans* – 0.5 *Bivalves* – 1 *Cephalopods* – 1 *Fishes* – 0.2*to* 0.4	*Crustaceans* – 1.5	*Fish* - 0.3	*Fish* – 0.3 *Crustaceans* – 0.5 *Bivalves* – 1.5 *Cephalopods* – 1
Arsenic	*NIL*	*Crustaceans* – 76 *Bivalves* – 86	*NIL*	*Fish* – 76 *Crustaceans* – 76 *Bivalves* – 86

for intakes of inorganic As from seafood products is 0.3–8 mg/kg bw/day (EFSA, 2009a).

The various symptoms of As exposure in humans include abdominal pain, vomiting, diarrhea, muscle weakness and skin flushing. Continuous exposure to As can result deposition of As in keratin containing tissues like nails, hair and skin. In chronic cases it leads to skin defects and cancer. International Agency Research on Cancer (IARC) has classified inorganic As a carcinogen to human. Seaweeds can contain un-extractable or residual As linked with its structural components.

Cadmium

Cadmium (Cd) is a highly toxic heavy metal to all living organisms of plant and animal origin including microorganisms. Although Cd is a non essential trace element in nature, it can bioaccumulate at hazardous levels in living organisms and it has no known beneficial function in humans. In addition to sources from industries manufacturing-batteries, electroplating, plastic stabilizers, pigment, use of agricultural chemicals and fertilizers also contribute to the environmental contamination of water resources.It is also a naturally occurring nonessential trace element. It is comparatively soluble toxic metal which can make many adverse effects including chromosomal damage. It can also affect the nervous system, kidneys, bones, lungs, and cardiovascular system.Cd can be long-term stored in the human being, with an average biological life of 17 to 30 years (Tokar et al., 2015). It is normally seen in inorganic form in seafood with higher contents in shellfishes-pecially in bivalves which may reach 10 mg/Kg.

Bivalves can accumulate this toxic metal and act as suitable bioindicator for

pollution monitoring. It can also bio accumulate in plants, invertebrates, and vertebrates with a long half-life. Cadmium concentrates in freshwater and marine animals to concentrations hundreds to thousands of times higher than in the water ATSDR (2008). Biomagnification of Cd also happen in the food chain and increased concentration will reach the end of food chain. The bioaccessibility of Cd from seafood products is high (>50%) (Gao and Wang, 2014). The tolerable weekly intake established by EFSA's panel is 2.5 mg/kg bw (EFSA, 2009b)

Lead

Lead (Pb) is a highly toxic metal in aquatic system in which fish are at the top of food chain. It is also a naturally occurring metal, but anthropogenic sources from mining, manufacture of battery, paint and pesticides etc also contribute in environmental contamination. Inorganic lead occurs in soil, dust and many consumer products as lead carbonate, lead chromate, lead acetate etc. Organic form of lead or tetra ethyl lead is extremely poisonous which can affect brain and nervous system more severely than inorganic form of lead. Lead poisoning or toxicity due to lead is common in people associated with its industrial usage.Although acute toxicity due to occupational exposure is comparatively less, chronic toxicity due to prolonged exposure at lower concentration is common. The International Agency for Research on Cancer classified inorganic lead as probably carcinogenic to humans (Group 2A) in 2006.

The major sources for dietary exposure include cereals, vegetables and tap water. Pb accumulation in fish mainly occurs from contaminated water rather than diet, mainly inorganic form. In addition to fish, the other sources of Pb include bivalves, cephalopods, crustaceans and oysters. Provisional Tolerable Weekly Intake (PTWI) suggested by Joint FAO/WHO Expert Committee on Food Additives (JECFA) for lead intake was 25 µg/kg b.w.

Conclusion

Analysis of toxic forms of methyl mercury and inorganic arsenic in seafood has to be done using precise and robust analytical methods with prime importance. Data of these toxic contaminants can give the human exposure level in different geographical locations and the risk associated.

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