AQUACULTURE WATER REUSE AND HEALTH

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Summary

Fish and other aquatic animals captured either from fresh water or seawater provide essential protein sources for humans. Fish cultivation, including artificial hatching needs a great amount of water, and water reuse is therefore a necessary measure for economical benefit and conservation of limited water resources. It is important, however, to pay attention to water quality, not only for preventing adverse effects on fish but also for protecting the health of people who consume cultivated fish.

The effects of water pollution on fisheries can be classified into acute effects and long-term chronic effects. One of the obvious features of water pollution is the death of aquatic life, but, more often, pollution causes deterioration or abnormalities of physiological functions. This can be progressive, and the development can be either acute or chronic. One of the methods of estimating the toxicity in water is bioassay—this uses the life and death of organisms as the judgmental standard. Toxicity

to fish is represented by LC_{50} value (50% lethal concentration: Median Lethal Concentration).

In the nitrogen cycle, nitrifying bacteria detoxify ammonia (NH_4^+) by producing nitrate (NO_3^-) and nitrite (NO_2^-). In aquaculture, ammonia originates from food residues and excreta of cultured fish. Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle, but if they occur in excessive amounts in aquaculture water, the water becomes a serious threat to public health.

Marine cultivation systems were traditionally set up in bays, which offered a calmer environment than open seas. Often, however, there is little water circulation in bays, and the build-up of large amounts of fish-food residue can cause a severe decline in water quality.

This polluted water contains large amounts of nitrogen in the form of NH_4^+ and NO_3^-, and phosphorus in the form of PO_4^{3-}.The presence of these ions can cause eutrophication of the aquatic ecosystem and can lead to increased incidence of disease in marine products.

Even if a specific organism dies, a species survives as long as reproduction takes place. The effects on reproduction are evaluated on the basis of production of the gonads (reproductive cells), obstruction of normal development of the gonads, and genetic effects at the level of chromosomes or DNA.

For example, endocrine chemicals disrupt the hormonal system of aquaculture organisms so as to disturb the reproduction mechanism. Estradiol-17β, nonylphenol and bisphenol-A are typical and major endocrine disrupting chemicals in aquatic environments in many industrialized countries. Their distribution and effect on aquatic organisms were examined using the Japanese medaka, *Oryzias latipes*.

1. Introduction

Fish and other aquatic animals captured either from fresh water or seawater are essential protein sources for humans. Although there are differences between countries, people who live in areas with easy access to water environments consume more fish as a proportion of their total animal protein.

Fish generally have a life cycle of egg, larva, adult fish and spawning, each with its own life style and ecological requirements. The impact of water pollution depends on the kind of organism and the stage in the life cycle. While many organisms may be living in the water, each species or individual is not living independently; together they constitute an ecosystem in which there are close relations with other species or individuals.

Fish cultivation including artificial hatching needs a great amount of water. Water reuse is, therefore, a vital measure for both economic benefit and conservation of limited water resources. It is necessary to pay attention to water quality not only for preventing adverse effects on fish but also for protecting the health of people who consume cultivated fish.

2. Effects on physiological function of aquatic life

2.1. Death and disease of aquatic life

The effects of water pollution on fisheries are classified into acute effects and long-term chronic effects. One of the obvious features of water pollution is the death of aquatic life, but more often it is a matter of deterioration or abnormalities of physiological functions, and the development may be either acute or chronic.

Death of aquatic organisms is mainly caused by poisoning, asphyxiation due to oxygen deficit, or destruction of epidermal tissue by corrosive poisons such as acid and alkali. A large number of agents including heavy metals such as copper, cadmium, zinc, lead, and chromium, agricultural chemicals, and synthetic chemicals such as phenol and cyanogens, are categorized as toxic agents. Organisms can be poisoned to death by assimilating these toxic agents.

Death from suffocation is mainly caused by decrease of dissolved oxygen as a result of excessive organic materials in water systems. Fish sometimes have difficulty in respiring because the surface of the gills develops a covering from turbid components in the water, e.g. sediment, fabrics from pulp mill effluent, or oil. They often die of suffocation, and their body surface can be damaged by corrosive poisons such as alkali, organic acid, hydrogen sulfide or metals.

The most vulnerable parts of the epidermal tissues are the eyes, nostrils and inside of the oral cavity and alimentary canal. It is obvious that extreme damage to these tissues will cause the death of the organisms. It frequently happens that fish captured in waters polluted with industrial waste do not have fins, and the scales of their bodies are badly damaged.

Even though the physiological functions do not come to a stop, many cases of functional deterioration and development of abnormalities or diseases are reported. Outbreaks of malformed fish with abnormal bones are one type of case. It is known that pulp mill effluent affects the circulatory functions, especially blood characteristics of aquatic life, which subsequently causes histological or cytochemical change in liver and other organs. Blue-green algae, suspended matter and chemicals in water can cause damage and assimilation inhibition in the gills, which can subsequently lead to functional deterioration or diseases of internal organs.

2.2. Toxicity test and lethal limits of pollutants

It is often happens that insufficient information is available on the effect of industrial waste on aquatic organisms, even if its complex chemical analysis is undertaken. This is because it is not so simple to detect, separate and determine the various chemical components in wastewater. Even if detection, separation and determination can be conducted, the toxicity of individual components or compounds of various components mixed in various proportions can often not be determined.

One of the methods of estimating toxicity in water is bioassay—a technique that uses the life-and-death of organisms as the judgmental standard. Toxicity to fish is represented by LC_{50} value (50% lethal concentration, Median Lethal Concentration). This generally indicates the toxic density that causes the death of 50% of test fish within 24 to 48 hours. This corresponds to LD_{50} (Median Lethal Dose: a specific observation period is not required), as used in toxicological fields. The former represents the toxic density in the water, while the latter represents the dosage to the body of the organisms. It should be noted that LC_{50} value is a mere index of relative toxicity of specific materials under specific test conditions and that the value does not figure out the level of concentration that is considered to be safe or harmless in the contaminated water.

Water quality standards should be set so as to allow fish and other aquatic life to live and propagate normally, to secure stable operation of fisheries and not to reduce the economic value of fish catches. It should be noted, however, that water for aquatic life cannot be defined in terms of concentration of a single substance. It is affected by the variation between different types of life and even within a species, as well as between various environmental conditions, seasons, and antagonistic or synergistic effect of coexisting elements. In general terms, the limiting conditions for water quality are given in Table 1.

Water quality	**Unit**	**Limit of concentration**	**Remarks**
BOD	mg L^{-1}	5	
	mg L^{-1}	3	for salmon
DO	mg L^{-1}	5	for 16 hours in a day
	mg L^{-1}	3	at all times
pH		6.5 - 8.5	
SS	mg L^{-1}	10	of artificial applied
Phenols	mg L^{-1}	0.01	
Mineral oil	mg L^{-1}	0.01	
Hg	mg L^{-1}	0.004	
Cu	mg L^{-1}	0.01	
Cd	mg L^{-1}	0.03	
Zn	mg L^{-1}	0.1	
Pb	mg L^{-1}	0.1	
Al	mg L^{-1}	0.1	
Cl2	mg L^{-1}	0.02	
Flouride	mg L^{-1}	1.5	
NH4-N	mg L^{-1}	1	at pH 8
Ni	mg L^{-1}	0.1	
Cr	mg L^{-1}	1	
Mn	mg L^{-1}	1	

Sn	mg L^{-1}	1	
Fe	mg L^{-1}	1	
CN	mg L^{-1}	0.1	
Br	mg L^{-1}	1	
Sulfide	mg L^{-1}	0.3	

Table 1. Limit concentrations for fish

3. Water quality for aquatic life

3.1. Problems of consuming aquatic products as food

Although there are some differences between countries, people of island countries such as the United Kingdom and Japan obtain a high proportion of their animal protein from fish or other aquatic products. Therefore, even though toxic components in the water do not directly harm the physiology and biology of the aquatic organisms, many problems can arise from the viewpoint of human beings who consume aquatic organisms. For example, odorized fish or laver is one common problem.

It is said that the concentration limits to odorize fish are 1.7 ppm in petroleum ether extracts, 0.86 ppm in creosote, 1.89 ppm in fuel oil and 0.89 ppm in waste oil. It is recognized that 0.01 ppm of oil odorizes water, and the water odorizes the marine fish there within 24 hours. It is known that petroleum refining waste, phenol-included waste, and pulp mill effluent also odorize aquatic organisms. It is clear that the components of the odorant are not single materials, but compounds of several components such as saturated hydrocarbons, unsaturated hydrocarbons, aliphatic, aromatic hydrocarbons and thiophene compounds.Consumption of aquatic organisms living in polluted water that contains pathogenic bacteria or toxic components, can seriously affect the health of human beings. More than 90% of food poisoning caused by eating aquatic products is linked to bacterial contamination. For example, there have been many cases of typhoid epidemics as a result of eating polluted shellfish, particularly farmed oyster in water polluted with domestic sewage.

In addition, many cases have been reported of toxic agents in aquatic organisms threatening human health. Other than toxin *in vivo* such as Tetrodotoxin and Ciguatera type toxin, the important thing in relation to water pollution is bioaccumulation of toxic components in water and subsequent intoxication. Once a pollutant enters the water system, it is accumulated in the organisms or at the bottom of the water through biological or physico-chemical process. Bioaccumulation is generally thought to progress through the food chain of plankton, small animals and large animals. The degree of accumulation of a specific component in an organism is closely associated with its physiology and metabolic machinery. It is often the case, therefore, that a specific component is accumulated in one organism, but not in another, even in the same waters. Furthermore, even within an organism, the cumulative dose generally depends on the organs and tissue. Oysters, for example, tend to concentrate copper and zinc in their bodies.

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Bibliography and Suggestions for further study

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Biographical Sketches

Shosaku Kashiwada obtained a B.S. and M.S. degree in Bioresource Science from Shimane University (Japan), and holds a Ph.D. in Bioenvironmental Science from Tottori University (Japan). His specialties are ecotoxicology and environmental biochemistry, with an emphasis on the effects of pesticide exposure on aquatic organism. From 1996-2000 Dr Kashiwada worked for an environmental consulting company in Japan researching the influences of endocrine-disruption chemicals on medaka fish, “Development of Bioassays Evaluating Biological and Environmental Risk of Chemicals”. A Fundamental Research Grant from the Environmental Agency of Japan supported this research. Since 2001 he has been a research associate in the laboratory of Dr David Hinton at Duke University (USA) and focuses on endocrine modulation of environmental chemicals in fish. His main interest is effects of chemical contaminants on aquatic organisms. He has focused on effects of pesticide exposure to zooplankton in natural lakes, endocrine disruption chemicals in fresh water fish, and environmental risk of these chemicals. He is continuing his investigations on biological effects of endocrine disruption chemicals on Japanese medaka in Duke University, USA.

Yasumoto Magara is Professor of Engineering at Hokkaido University, where he has been on faculty since 1997. He was admitted to Hokkaido University in 1960 and received the degree of Bachelor of Engineering in Sanitary Engineering in 1964 and Master of Engineering in 1966. After working for the same university for 4 years, he moved to National Institute of Public Health in 1970. He served as a Director of the Institute from 1984 for the Department of Sanitary Engineering, then the Department of Water Supply Engineering. In the meantime, he also obtained a Ph.D. in Engineering from Hokkaido University in 1979 and was conferred an Honorary Doctoral Degree in Engineering from Chiangmai University in 1994. Since 1964, his research subjects have been in environmental engineering and have included advanced water purification for drinking water, control of hazardous chemicals in drinking water, management and treatment of domestic waste including human excreta, management of ambient water quality, and mechanisms of biological wastewater treatment system performance. He has also been the member of governmental deliberation councils of several ministries and agencies including Ministry of Health and Welfare, Ministry of Education, Environmental Agency, and National Land Agency. Meanwhile he performs international activities with JICA (Japan International Cooperation Agency) and World Health Organization. As for academic fields, he plays a pivotal role in many associations and societies, and has been Chairman of Japan Society on Water Environment.

Professor Magara has written and edited books on analysis and assessment of drinking water. He has been the author or co-author of more than 100 research articles.