The Use of Chemicals in Aquaculture in the People's Republic of China

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ABSTRACT

Aquaculture in China has developed very rapidly in recent years. Chemicals have become important tools in the control of disease and prevention of losses in various culture systems. The occurrence of diseases stimulated the development and production of drugs for aquatic culture systems, and promoted research on chemicals and their applications. Meanwhile, there exist some problems in the application of chemicals; and there are some potential risks in their usage in aquaculture which should not be neglected.

This paper describes the use of chemicals for the prevention and control of diseases in aquaculture in China. Their production, marketing, and usage, as well as associated problems and adverse impacts are also discussed. Approaches and practices to prevent diseases are also given. National regulations, on-going research and other aspects of the use of chemicals in aquaculture in China are also highlighted.

INTRODUCTION

Aquaculture in China has experienced rapid development in recent years. In 1993, the area of freshwater culture was 4.16 million ha, including 2 million ha of ponds and 200,000 ha of industrial fish farms. The area for marine culture in 1993 was 588,000 ha. Aquatic production from freshwater culture was 6.48 million t, and 3.09 million t were produced from marine culture. In 1995, production from these areas increased to 9 million and 4 million t, respectively.

Following the increase in aquatic production, risks due to diseases became more serious. Estimates of losses due to disease in freshwater culture range from 20% to about 30% when diseases reach epizootic proportions, while in marine culture, estimated losses range from 30% to 50%. Chemical application plays an important role in the control of disease and reduction of losses. The occurrence of diseases has created an extensive market for chemicals and has stimulated the production of drugs for aquatic culture systems. This development has promoted studies on chemicals and their applications to aquaculture.

At the same time, this use of chemicals in Chinese aquaculture has led to some problems in their application, a result of immature technology and poor management of drug use. The potential risks inherent in the use of chemicals in aquaculture should not be neglected. This paper describes the use of chemicals in aquaculture for the prevention and control of diseases in China.

PRODUCTION AND MARKET SUPPLY OF CHEMICALS FOR AQUACULTURE SYSTEMS IN CHINA

Before the 1980s, there were no Chinese factories producing chemicals specifically for use in aquaculture. The chemicals used by farmers originated from chemical and pharmaceutical factories catering to other animal production industries. By 1990, however, there were already about 30 factories producing chemicals for use in aquatic systems. In 1995, there were 69 aquatic drug factories and 558 veterinary drug factories in China. Many of the factories producing veterinary drugs also produce substances that can be used in aquaculture. For example, 121 of these factories produce furazolidone, 168 produce chloramphenicol and 242 produce Terramycin for veterinary use. There are also many other factories producing these drugs for use in human medicine. Fish farmers may buy drugs from any of these factories, so that directly or indirectly, drugs from all of these factories might be used for control of aquatic diseases.

The output from these factories varies from several tons to hundreds of tons. However, due to the vastness of China, and the wide variety of aquatic species, culture practices and technical levels of culture, there still exist limitations in production capacity and transportation. Thus, it is not possible for the existing factories to meet the industry's overall need for chemicals. As a result, in recent years a number of specialized factories have been set up to produce chemicals for aquatic culture systems. The research institutes have provided prescriptions or formulas, and the factories prepared these into commodities for the market. Usually, one factory produces a series of chemicals and drugs with a large number of commercial names. For example, Guangdong Fisheries Bio-pharmaceutical Factory produces a series of drugs including 12 kinds of fish drugs, 20 kinds of fish hormones and 14 kinds of other veterinary drugs trade marked "Fish Happiness." Many of these drugs are produced only in small batches and used in a limited area. The output for these drugs varies continuously along with the fluctuation of market demand.

Different drugs on the local market often have the same trade name, or the same drug may have different trade names in various regions. Most locally produced drugs have no English name, making it very difficult to identify them using standard references. Besides, the factories often like to maintain secrecy as to the composition of their products. In some cases, different brands of drugs have the same or similar compositions, with only differing proportions of active ingredients. For example, there are many kinds of chlorine-based disinfectants and at least 20 kinds of anti-bacterial drugs containing various percentages of chloramphenicol.

According to estimates as of April 1995, there are 2,900 kinds of registered drugs in China, of which 134 are marketed especially for aquaculture, and 683 are for veterinary use. Both types are being used in aquaculture. In total, these include 235 antibacterials, 16 anti-parasite drugs, 43 disinfectants, 23 Chinese traditional medicines, 271 feed additives, 55 imported drugs, and 40 other drugs for various applications. Although these chemicals can be registered in national, provincial or city administrative agencies, some of them, like bleaching powder, $CuSO_4$ and other all-purpose disinfectants, are not listed as aquatic drugs. It is very difficult to come up with a comprehensive list of the drugs currently being used in Chinese aquaculture because some unregistered drugs are sold in the market illegally.

In China, there are no specific routes or outlets for selling chemicals for use in aquaculture. Fish farmers can purchase drugs and chemicals directly from factories or from drug sales agents without knowing whether the drugs are designated for humans, poultry, or fish. They need not obtain a prescription from a veterinarian or a license from any administrative authority before they can buy chemicals. Farmers can buy any kind of chemical if they believe that the product may relieve the clinical signs of a disease. As the chemicals used in aquaculture originate not from specialized outlets, but are available at conventional or regular sources, it is very difficult to estimate the volume of consumption per year for the entire country.

In recent years, some chemicals have been imported from such countries such as Hong Kong, Germany, the United States, Switzerland, England, Japan, Canada, France, and Norway to the coastal provinces in the southern part of China. Some foreign companies have begun to promote the sale of chemicals for aquaculture (for example, Astos, produced by Pfizer of the USA; and Flavomycin, produced by Hoechst Veterinary Company of Germany). The volume of their sales may increase in the future; however, China is a developing country with a wide aquacultural area, so for economic reasons, it is not possible to depend upon imported chemicals to meet the huge need. These imported drugs will probably not play an important role in the control of fish diseases in China.

USE OF CHEMICALS IN AQUACULTURE

The purpose of chemical use in aquaculture is to prevent and cure diseases affecting cultured commodities. Preventive measures include disinfecting water, ponds and rearing facilities, as well as eggs and other stages of fish before stocking. These measures improve the rearing environment and reduce the numbers of pathogens in the water or on the body surface of fish. The common ways of administering drugs to cure diseases are by oral application (used especially to eradicate intestinal parasites and systemic diseases), by immersion in short or long baths (to eradicate external infections), and by injection (to treat disease in broodstock and other valuable fish). Experienced fish farmers use chemicals mainly for prevention, but most farmers apply chemicals whenever fish become sick or when mortality is encountered.

Chemical application is a popular measure employed to prevent and control diseases because of the following reasons:

- Chemicals are convenient and simple to use. Most fish farmers prefer pathogen eradication by using disinfectants or medicated feed, rather than by improving the rearing environment or readjusting the culture structure to prevent disease occurrence.
- Chemicals are effective. They produce rapid results under certain conditions (e.g., arresting disease outbreaks or remedying the absence of oxygen in the environment), while other measures are unable to achieve immediate effects. For example, when bacterial disease breaks out and causes high mortality, measures such as vaccination or improvement in the environment are unable to produce instant results as compared to those achieved by chemicals.
- Chemicals are economical to use. Although building optimal culture conditions is good for reducing losses, the investment for re-structuring the culture system to conform to an ideal condition is comparatively higher than the cost of using chemicals.

Table 1 lists some common chemicals used at various stages of fish culture in China with their generic names, dosage and method of use. In practice, several kinds of drugs are often used as mixtures, such as the combination of furazolidone and rhubarb to produce a synergistic curative effect.

Table 1. The common chemicals used in aquaculture in China.

Usage: Chemical	Pond Disinfection	Fish or Egg Disinfection	Bath Treatment	Injection	Oral Administration
Quick Lime	250-1000 ppm		15-20 ppm		
Bleaching Powder	20-50 ppm	10-30 ppm	1-2 ppm		
Chlorine	0.5-1 ppm				
$KMnO_4$	20-50 ppm	10-20 ppm	0.5-5 ppm		
Povidone-iodine		50-100 ppm			0.2 gm/kg
Formalin		20-40 ppm	1-10 ppm		
Dipterex		2 ppm	0.2-0.5 ppm		5-10 mg/kg
Malachite Green		70-100 ppm	0.02 ppm		
Methylene Blue			1- 3 ppm		
$CuSO_4$		3-10 ppm	0.5-0.7 ppm		
$CuSO_4/FeSO_4$			0.7 ppm		
Dipterex/$FeSO_4$			1.4 ppm		
$K_2Cr_2O_7$			20-40 ppm		
$CuCl_2$			0.7-1 ppm		
TCCA(DCCA)	5-10 ppm		0.2-0.8 ppm		
NaCl		2-5%			
EDTA			2-10 ppm		
Bromo-geramine		100 ppm			
Nystatin		20000 μg/L			
Furazolidone		3-10 ppm	0.1-1.0 ppm		20-200 mg/kg
Sulfonamide					50-100 mg/kg
Terramycin		25 ppm	2-3 ppm		50-100 mg/kg
Aureomycin		12.5 ppm			0.01-0.05 mg/kg
Penicillin			4-30 i.u./mL	10^5 i.u./fish	
Streptomycin		1.5 ppm	8-30 μg/mL	10^5 μg/fish	
Doxycycline					20-50 mg/kg
Erythromycin			0.05-0.1 ppm		10-30 mg/kg
Chloramphenicoal			1-1.8 ppm	20 mg/kg	25-100 mg/kg
Oxolinic Acid					100-300 mg/kg

The price of drugs varies with season, location, and market supply. For example, the price of furazolidone ranges from 60 to 150 Yuan/kg, depending on whether the farmers buy it from factories or from shops.

Although a great variety of drugs are used in aquaculture, most of them are not widely applied as yet. If we calculate the amount of applied chemicals by weight, bleaching powder and quick lime account for more than half of the total used. Other commonly used chemicals are furazolidone, sulfonamide, $CuSO_4$, Dipterex, and iodine compounds. Antibiotics are used mainly to treat valuable broodstock, larval shrimp, and other aquatic species of high value, such as eel and softshelled turtle. Antibiotics are much less used to treat freshwater fish because they have relatively lower economic value. For freshwater applications, furazolidone is the chemical that is most widely used.

PROBLEMS AND ADVERSE IMPACTS OF CHEMICAL USE IN AQUACULTURE

Aquaculture in lakes and reservoirs is being conducted at very low stocking density. During disease outbreaks, no chemicals are applied and the usual option is to terminate the culture because it is not economical to apply drugs to large water bodies. Therefore, very little impact of chemicals is felt in these culture systems.

In contrast, in the coastal regions of central and south China where most high-density fish culture operations are located, diseases spread very rapidly and can reach epizootic proportions. Chemicals and drugs are commonly used in these areas, and as a result, the problems and adverse impacts of chemical application to fish culture are focused there.

The main adverse impact of drug use in aquaculture in China is the development of drug-resistant strains. In some farms in southern China, for example, the dosage of drug needed to cure bacterial disease in eels is now 10 times higher than that previously required. Overcoming drug resistance not only requires an increase in dosage, but may also endanger human health, as most of the chemicals applied in aquaculture are also used to treat human diseases. Some chemicals also cause damage to the skin of fish. It has been observed that fish previously treated with formalin to kill parasites on the body surface become susceptible to secondary bacterial infection. The use of antibiotics often reduces the immunity of fish and shrimp to infectious agents.

The following problems have been recognized in connection with the use of chemicals in aquaculture systems:

- Owing to a lack of adequate knowledge on disease control, some farmers cannot apply chemicals properly. Information is lacking on the proper choice of chemicals, correct dosage, optimal time for treatment, and condition of application. For example, the action of Dipterex varies with environmental quality: it is highly poisonous at high pH and ineffective in environments with very high organic load. Because of the high cost of most drugs, farmers apply them using levels lower than the recommended effective dosage. This not only results in undesirable outcome of treatment, but also in the development of drug-resistant strains. In some cases, farmers use those chemicals readily available to them, while disregarding the nature of the disease and even lacking a prior diagnosis.
- Abuse and over-use of chemicals often occurs in farms culturing high-value aquatic species like shrimp, eel, turtle and various marine fish. Some drugs are used continuously for one month or longer. In some farms, several kinds of drugs are used at the same time or by rotation, each drug application lasting for one or two days. It is obvious that the farmers are not clear as to whether or not these drugs are actually useful and effective. This ignorance may also lead to poisoning of fish, impairment of their immune capacities, overgrowth of secondary pathogens like fungi, and eradication of beneficial bacteria.
- There are some problems related to the quality of drug products and their commercial advertisement. Some low quality drugs are sold in the market. For example, the chlorine content of bleaching powder varies from 12% to 36% due to improper transportation, packaging, storage, and the poor quality of the product itself. As a result, farmers use dosages several times higher than that recommended without getting good results. On the other hand, fish poisoning takes place when an overdose of chemicals is given. Some factories advertise their products as possessing properties for curing a wide range of diseases. These false claims lead farmers to misuse the drugs.
- A few farmers still use some prohibited chemicals like mercury-based compounds because no

better drugs can be obtained as replacements.

- In connection with the use of feed additives, some cases of illness in fish were observed to be caused by the improper usage of chemicals. For example, Olaquindox ($C_{12}H_{13}N_3O_4$), a kind of growth promoter, was used for fish and increased growth rate by 15-20% when applied at 20-50 mg/kg of food. However, some feed mills increased the amount of Olaquindox to 200 mg/kg. Common carp that received feeds with high doses of Olaquindox were prone to hemorrhage, especially during netting and transporting. The condition observed was fatal.
- In high-density culture, farmers use drugs administered through feeds and simultaneously add chemicals to the water to reduce losses. This practice leads to pollution of the environment and plankton die off. Although the condition is temporary and the environment recovers after a few days, repeated use of some heavy metal-based salts like $CuSO_4$ may pollute the pond bottom.

Despite the above problems, the direct and indirect adverse effects to the environment of chemicals used in aquaculture are relatively less than those caused by chemical wastes from industries and factories. There have been very few reports of environmental pollution by aquatic chemicals or of events of drug poisoning of fish farmers because the total amount of chemicals used in aquaculture in China is not very great. In contrast, there have been some reports of poisoning of aquatic animals due to chemical wastes from factories or run-off from agricultural lands.

None the less, potential risks associated with chemical application in aquaculture still exist. Since chemical usage is expected to increase in the future, the search for non-polluting and non-persistent drugs and chemicals specialized for use in aquaculture should be intensified.

APPROACHES AND PRACTICES TO DISEASE PREVENTION

There are a number of practices and methods to prevent and cure fish diseases without the use of chemicals. A few examples are given below:

Vaccination

There are several kinds of fish vaccines available in China. Vaccine against viral hemorrhage disease of grass carp can reduce mortality of fingerlings from 70% to 30% and has been widely applied. China produces at least 300 t of vaccine, and several billions of fish are vaccinated every year. Prof. Chen Changfu of Huazhong Agriculture University prepared vaccines against bacterial gill-rot disease caused by *Cytophaga columnaris* and bacterial hemorrhagic septicemia caused by *Aeromonas hydrophila* in Chinese perch. In 1994, 600,000 fingerlings in Zhongshan, Xinhui and Hainan counties, Guangdong Province were tested with vaccine by injection or by bath for 5-10 min. The vaccinated fish remained healthy throughout culture, while unvaccinated fish in an adjacent area became ill and suffered mortalities of more than 80%. Vaccination may be the practical way to control diseases in Chinese perch because they feed only on live fish and thus do not eat medicated pellets. In addition, vaccines against bacterial hemorrhagic septicemia of freshwater fish caused by *Aeromonas punctata* provided a 70% protective rate to silver carp after immunization by bath. The vaccine against bacterial gill-rot of grass carp, given orally and by immersion, successfully controlled the disease and is now produced commercially. As a preventive and control measure against disease, vaccines are timely, effective and clean, as no residues are left after treatment.

Application of Chinese Traditional Medicines

The use of medicinal herbs to treat fish diseases has great potential. In fact, fish farmers in various regions have their own recognized prescriptions using herbs. However, it is not easy to identify the effective ingredients and mechanisms of action of these herbs, so that very few of them have been approved for use. Table 2 shows some common herbs applied to treat fish diseases.

Improvement of the Pond Culture System

In the traditional method of polyculture of grass carp and silver carp, the stocking ratio is one grass carp to three silver carp (or, sometimes, bighead carp). However, it has been observed that this ratio does not give the optimal yield. The pond water has to be fertilized often to meet the natural food demands of the silver carp or bighead carp, such that the water quality deteriorates rapidly and induces sickness among the grass carp. With this finding, the stocking ratio was changed from 1:3 to 1.5-2.5:1. This modification in the rearing system resulted in increased survival, improved production, and better water quality. The output in the modified ponds was three times higher as compared to traditional ponds.

Positive results have also been observed in shrimp (*Penaeus monodon*) culture systems using water with lower salinity. The environmental modification may have reduced stress among the shrimp, which prefer a brackishwater environment.

Although it is clear that chemicals can kill pathogens, the question remains as to whether they can control diseases under field situations, where various conditions come into play. This example from the field illustrates the need to consider many factors before a treatment option is chosen and successful treatment can be achieved. A case of bacterial hemorrhagic septicemia broke out in two ponds with similar conditions in the Honghu Lake area. Details about the fish and pond conditions are presented in Table 3. In pond 1, fish were fed with unmilled rice grain, and the sharp seed coats caused abrasions in their intestines, resulting in bacterial infection. At first, the disease spread

Table 2. The common medicinal herbs used in aquaculture in China.

Names of Herbs	Target Diseases
Acalypha australis	Bacterial enteritis and gill-rot
Acorus calamus	Bacterial enteritis, gill-rot, and septicemia
Allium sativum	Bacterial diseases
Andrographis paniculata	Bacterial enteritis
Artemisia argyi	Bacterial enteritis and gill-rot
Cayratia japonica	White head-mouth disease
Chenopodium ambrosioides	Nematode infections
Cyrtomium fortunei	Nematode infections
Duchesnea indica	Bacterial enteritis
Euphorbia humifusa	Bacterial enteritis and gill-rot
Fructus quisoqualis	Tapeworm infections
Galla chinensis	White head-mouth, septicemia, furunculosis
Melia azedarach	Trichodiniasis, Lernaeosis
Perilla frutescens var. *crispa*	Bacterial enteritis
Pinus massoniana	Bacterial enteritis, and gill-rot
Piper sarmentosum	Lernaeosis
Polygonum hydropiper	Bacterial enteritis and gill-rot
Portulaca oleracea	Bacterial enteritis
Ricinus communis	Bacterial enteritis, gill-rot, and septicemia
Sambucus javanica	Bacterial enteritis and gill-rot
Sapium sebiferum	Bacterial gill-rot
Thysanospermum diffusum	Bacterial enteritis, and gill-rot

among common carp and Chinese bream which ate the rice grain. Upon observing this and acknowledging the adverse effect of unmilled rice grain on the fish, the farmer stopped giving them this feed and administered furazolidone orally through artificial feeds. The fish responded well to the treatment. In pond 2, the count of pathogenic bacteria in the water was too high for the fish to resist infection, and the majority of the stock became ill. The farmer had to give medicated feed and also applied disinfectants to remedy the bad condition of the water. Thorough analysis of the culture condition is needed so that appropriate solutions can be applied.

Table 3. Comparison of curative methods applied in two fish ponds.

	Pond 1	**Pond 2**
Area	6.5 ha	6.8 ha
Total fish	267,000	280,000
grass carp	41,000	100,000
silver carp	161,000	50,000
bighead carp	25,000	50,000
Chinese bream	15,000	80,000
common carp	15,000	few
Inducing factor:	intestines were hurt by rice	high count of bacteria in water
Treatment:	change food oral medicine	oral medicine disinfect water

The comprehensive use of drugs is also important. Culture systems for pearl oyster are very susceptible to bacterial infection in summer, and infections usually result in high mortality. Application of 0.2 ppm furazolidone can effectively control the disease, but the sick oysters can easily become re-infected after several days because their resistance to disease becomes very low following illness and chemotherapy. It has been observed that furazolidone becomes more effective for oysters if it is given in combination with rhubarb, as rhubarb has the ability to enhance the immunity in these animals. This method has been tested in more than 300 ha of pearl farms in Ezhou County, Hubei Province.

Since the 1950s, research on fish diseases developed very rapidy in China and some practical methods on the use of chemicals have been obtained. Two popular methods of disinfection involve the use of quick lime to disinfect ponds, and the application of hanging baskets filled with bleaching powder or bags filled with $CuSO_4$ at the feeding sites. These methods are easy to administer and effective against fish diseases. Supplying drugs using hanging bags or baskets is an ideal and practical method, as it allows the drug or disinfectant to dissolve slowly. Toxicity due to overdose is also avoided because fish can voluntarily keep away from areas near the bags if the concentration of drugs near the site is too high.

In addition, farmers also carry out disinfection for the following purposes:

- To disinfect juveniles and fingerlings, either 3-4% salt, 10 ppm bleaching powder, 8 ppm $CuSO_4$, or 20 ppm $KMnO_4$ is applied for 20 min.
- To disinfect feeds and feeding sites, sites can be kept clean by hanging baskets filled with bleaching powder in their vicinities or by broadcasting the disinfectant around the feeding sites.
- To disinfect manure before application in the ponds as fertilizer, 120 gm of bleaching powder

is applied to 300 kg manure. Alternatively, the bleaching powder may be applied into the water after the manure has undergone complete fermentation.

Proper feed management may also help prevent disease. The basic feed management rules such as strict adherence to good feed quality, determination of the exact feed requirements of the animals, and verification of the feeding sites and time of feeding are important measures to keep the fish healthy.

NATIONAL REGULATIONS ON THE USE OF CHEMICALS IN AQUACULTURE

The National Control Administration of Veterinary Bioproducts and Pharmaceuticals is in charge of management of production and authorization of sales of chemicals for aquaculture. Before a new drug is produced, the factory must submit an application and report the information regarding technology development, and the data from test results on safety and characteristics of the drug. After this procedure is completed, the drug is registered and approved. However, the aquaculture industry developed very rapidly in China and, as a result, chemical requirements increased very quickly. As a result, some drugs for aquaculture were produced and marketed illegally, even without licenses; and thus, some untested drugs were able to enter the market. This development aroused the attention of the government, so that at the end of 1994 an investigation of the development, production and marketing of chemicals used in aquatic systems was conducted, and all factories producing these chemicals were inspected. Unlicensed facilities were closed or their production and sales were stopped until their registration was approved. Some measures taken to strengthen the regulation of aquatic chemicals include formulating a licensing system for production, monitoring and supervising quality of products, and setting up of a specialized panel on aquatic drugs within the Veterinary Drugs Commission. Several research institutes were designated as certified clinical testing agencies for aquatic drugs. These regulations were, however, mainly embodied to control drug production and assure product quality. No regulations on the purchase and use of chemicals by consumers have been formulated.

The standards for allowable residues of chemicals in aquatic products were formulated and promulgated by the Surveillance Institute of Food Hygiene, Ministry of Public Health, and are monitored by the Food Hygiene Departments of Anti-epidemic Stations at various levels. Some processing plants and import and export corporations have their own laboratories to examine for chemical residues in exported aquatic products according to the standards prescribed by the importing country.

China has specified standards of allowable residues of hazardous materials in aquatic products (Table 4), but there are no set standards for antibiotic residues. In this case, the standards set for other food products are used as a reference. For example, the allowable terramycin residue in honey is limited to below 0.05 mg/kg.

The environmental monitoring system in China is implemented by the environmental protection agencies in the provinces and cities. They determine the types, concentrations, and origins of toxic chemicals and monitor changes in their levels. The National Bureau of Environmental Protection formulates the standards of quality for surface water (Table 5) and the standards of water quality for aquaculture in China (Table 6).

Table 4. Allowable limits for hazardous materials in aquatic products.[1]

Hazardous Material	Allowable Limit (mg/kg)
Organophosphate compound	< 0.1 mg/kg
Mercury	< 0.3 mg/kg
Methyl mercury	< 0.2 mg/kg
Arsenic	< 0.5-1.0 mg/kg
BHC	< 2 mg/kg
DDT	< 1 mg/kg

[1] From Chinese national standards GB-2733-81 to GB 2745-81.

Table 5. Environmental quality standards for surface water in China.[1]

Item	Class 1	Class 2	Class 3
Appearance	no visible foam, oil film and substances		
Smell	no peculiar smell	no peculiar smell	no peculiar smell
Temperature (°C)	35	35	35
pH	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Color	< 10°	< 15°	< 25°
DO	> 90% saturation	> 6 ppm	> 4 ppm
BOD_5	1 ppm	≤ 3 ppm	5 ppm
COD	2 ppm	4 ppm	6 ppm
Volatile phenol	< 0.001 ppm	< 0.005 ppm	< 0.01 ppm
Cyanide	< 0.01 ppm	< 0.05 ppm	< 0.1 ppm
Arsenic	< 0.01 ppm	< 0.04 ppm	< 0.08 ppm
Total Hg	< 0.0001 ppm	< 0.0005 ppm	< 0.001 ppm
Cd	< 0.001 ppm	< 0.005 ppm	< 0.01 ppm
Cr	< 0.01 ppm	< 0.02 ppm	< 0.05 ppm
Pb	< 0.01 ppm	< 0.05 ppm	< 0.1 ppm
Cu	< 0.005 ppm	< 0.01 ppm	< 0.03 ppm
Petroleum	< 0.05 ppm	< 0.3 ppm	< 0.5 ppm
E. coli	< 500 cfu/L	< 10000 cfu/L	< 50000 cfu/L
Total nitrogen	≤ 1.0 ppm	≤ 1.0 ppm	≤ 1.0 ppm
Total phosphorus	≤ 0.1 ppm	≤ 0.1 ppm	≤ 0.1 ppm

[1]From Chinese national standards GB 3833-88.

Table 6. Recommended standards for water quality for aquaculture in China.[1]

Item	Standard
Color, smell and taste	No peculiar smell, color and taste
Surface	No obvious film and foam
Suspended particles	$\leq$ 10 mg/L
pH value	6.5 - 8.5 in fresh water, 7.0 - 8.5 in sea water
BOD_5	< 5 mg/L
DO	> 3 mg/L at night; 5 mg/L at daytime
Hg	$\leq$ 0.0005 mg/L
Cd	$\leq$ 0.005 mg/L
Pb	$\leq$ 0.05 mg/L
Cr	$\leq$ 0.1 mg/L
Cu	$\leq$ 0.01 mg/L
Zn	$\leq$ 0.05 mg/L
Ni	$\leq$ 0.05 mg/L
As	$\leq$ 0.1 mg/L
Cyanide	$\leq$ 0.005 mg/L
Sulfide	$\leq$ 0.2 mg/L
Fluoride	$\leq$ 1.0 mg/L
Volatile phenol	$\leq$ 0.005 mg/L
Yellow phosphorus	$\leq$ 0.001 mg/L
Petroleum	$\leq$ 0.05 mg/L
Acrylic aldehyde	$\leq$ 0.02 mg/L
BHC	$\leq$ 0.02 mg/L
DDT	$\leq$ 0.001 mg/L

[1]From Chinese national standards GB 3833-88 and GB 11607-89.

The impact of the chemicals used by aquaculture farms on the environment remains unmonitored, largely because of the perception that aquaculture is not one of the main factors causing environmental deterioration. The results of a country-wide investigation showed that the fishery sector is not only a victim of environmental pollution, but also a source of pollution. The main adverse impacts of aquaculture on the environment are believed to be eutrophication of receiving waters and the transmission of pathogens, and not pollution due to the chemicals used in the farms.

RESEARCH ON USE OF CHEMICALS IN AQUACULTURE

In the last 50 years, scientific research and education have developed rapidly in China, thus meeting the requirements of the different aspects of aquaculture. There are 52,000 technical personnel involved in fisheries in the whole country, including 2800 senior staff and 12,000 intermediate workers. There are 203 research units engaged in fishery research. The national research units, besides conducting research on pure and applied sciences, also take part in technological development and in providing technical service. The research units at the provincial level focus on applied research and on technical development, consultation and extension services. The research units at the county level deal mainly with extension. There are at present five fishery colleges and 28 universities with fisheries departments. In addition, there are 16 other fisheries schools and nine schools with attached freshwater aquaculture curricula. These entities provide basic training to prepare the staff needed to support the aquaculture industry.

Through their long-term accumulation of research results and experience, quite a number of research units are able to design medication regimes with good curative effects against fish diseases. Once a new aquatic drug is successfully formulated and tested, the technical data necessary for license application can be transferred to factories, so that batch production can commence. Most aquatic chemicals in use in Chinese aquaculture were developed in this manner.

At present, many laboratories are studying drugs, mainly on the following aspects:

- To determine if any new drugs used for humans or veterinary animals can be introduced into aquaculture systems.
- To enhance drug efficacy by establishing correct dosage, or by changing the proportions of active ingredients and additives.
- To find new methods to prevent and control diseases.

Still, the problem is that no new drugs are being synthesized solely for use on fish. Due to lack of financial support, very little basic research on residue formation or pharmacokinetics has been conducted.

CONCLUSIONS AND RECOMMENDATIONS

The production and use of chemicals for aquaculture in China has developed very rapidly in recent years. Chemicals are important tools to control disease, reduce losses, and increase fish production. The benefits derived from aquaculture are numerous; thus chemical usage will probably continue to increase.

The chemicals used in aquaculture were introduced from human and veterinary medicine. From a long-term point of view, certain types of antibiotics should be limited strictly for use in aquaculture.

The problems surrounding the use of chemicals in aquaculture (e.g., product quality, pattern of usage etc.) could be corrected or avoided by enhanced management, formulation and implementation of legislation, and training of farmers. The development of drug-resistant strains of pathogens will affects the efficacy of drugs and may have adverse impacts on human health.

As the production of chemicals for aquaculture is a recent development, not enough rules and guidelines for their management have been established. Regulations should not only control drug production and sales, but also the management of products and their handling and usage. This problem is now being recognized by the administrative agencies concerned and it is being addressed. It can be predicted that the situation will improve greatly in 5-10 years. The key point is to set up strict management of chemicals, establish standards, and license production so that unsuitable drugs can be banned from the market.

Research should focus on developing new drugs for use in aquaculture, not just introducing those already in use in human medicine. Important areas for research are the following:

- Developing antibiotics and chemicals specifically for fish and other aquaculture commodities.
- Developing drugs that will not induce resistance among microorganisms.
- Investigating the use of traditional medicinal herbs to cure fish diseases.
- Conducting studies on the pharmacology and toxicology of available chemicals to provide scientific basis for standardizing their usage.
- Finding alternative and non-medicinal control measures against fish diseases.

SUPPLEMENTARY BIBLIOGRAPHY

Although no references are cited in the text, the following books and articles are important sources of the information presented in this paper. As most are written in Chinese, we advise interested individuals to request the author's assistance in obtaining copies.

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