# The Use of Chemicals in Aquaculture in Taiwan, Province of China

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## ABSTRACT

Aquaculture in Taiwan has a history of more than three centuries. To satisfy consumer preferences, a wide variety of aquatic species, 71 in 1993, are being cultured in Taiwan. It is difficult to control diseases when many species are cultured and stocking densities are high. At present, it is important to manage the use and application of chemotherapeutants effectively. Many aquatic animal diseases fall under the category of potentially curable illnesses. These include diseases of bacterial, protozoan, fungal, and environmental etiologies. This paper summarizes the chemicals used in aquaculture, farm management practices, alternative disease prevention methods, national regulations, and the current research on chemical use for aquaculture in Taiwan.

## INTRODUCTION

Aquaculture in Taiwan has a history of more than three centuries and has passed through both spectacular and difficult times (Liao 1991). Liao (1993) noted that there were 71 major and 37 candidate species for commercial culture in 1993. These include finfishes, crustaceans, molluscs, reptiles, amphibians, and seaweeds.

The practice of traditional polyculture and extensive culture did not pose any major problems except when natural disasters struck. As culture shifted to semi-intensive and intensive systems, stocking densities were raised and formulated feeds were used. Management of water quality and maintenance of the culture environment became difficult, and thus the cultured species became more susceptible to diseases. Normally, pathogens, by themselves, rarely cause disease in healthy aquatic animals. Three factors must be involved in the disease process: a susceptible host, a facilitative environment, and the presence of a potential pathogen (Snieszko 1974). Liao *et al.* (1977, 1985, 1992) and Lightner *et al.* (1987) reviewed the prevalent diseases that have adversely affected Taiwan's shrimp culture industry. Liao *et al.* (1996) also reviewed the practical approaches to health management in marine fish culture in Taiwan.

Many aquatic animal diseases fall into the category of potentially curable illnesses, which includes those diseases of bacterial, protozoan, fungal and environmental etiologies. This paper summarizes the use of chemicals in aquaculture, farm management practices, alternative disease prevention methods, regulations, and current research on chemical use for aquaculture in Taiwan.

## USE OF CHEMICALS IN AQUACULTURE

To solve the problems associated with heavy nutrient loading, toxic metabolites, and pathogens in intensive aquaculture systems, and to maintain optimal physico-chemical parameters required for aquatic animal growth, various chemical preparations are applied to treat water and pond bottoms, or are incorporated into feeds. Based on their actions, these chemicals can be classified into the following groups:

### Therapeutants

Intensive culture systems increase the risk of transmission of diseases. Chemicals are routinely applied as prophylactics to prevent diseases, or as therapeutants to control diseases once detected. Chemotherapeutic agents can be grouped into three slightly overlapping divisions: (1) antibacterial agents, including antibiotics (e.g., erythromycin, chloramphenicol, florfenicol, oxytetracycline, streptomycin), quinolones (e.g., oxolinic acid), fluoroquinolones (e.g., flumequine), nitrofurans (e.g., furazolidone, nitrofurazone, nifurpirinol), sulfonamides (e.g., sulfamonomethoxine, sulfadimethoxine), quarternary ammonium compounds (e.g., benzalkonium chloride, benzethonium chloride), malachite green, and methylene blue; (2) anti-protozoal agents, such as copper compounds (e.g., copper sulfate, chelated copper), formalin, and salt; and (3) metazoan parasiticides composed mainly of organophosphate compounds (e.g., trichlorofon) (Table 1).

### Disinfectants

Disinfectants are used to prevent or minimize the spread of pathogens and diseases within a system. The effectiveness of most disinfectants is usually hindered by the presence of organic matter. Iodine (e.g., povidone-iodine, iodophor) and chlorine compounds (e.g., sodium hypochlorite, chlorinated lime) are frequently applied as disinfectants to wash fertilized eggs or to dip aquatic animals when they are transferred from one aquarium or pond to another. These compounds can also be used to disinfect tanks and other holding equipment (Table 2).

### Soil and Water Treatment Compounds

The environmental factors influencing aquatic animal cultivation are fluctuation of temperature and pH, types of algae and their concentration, and deterioration of water and pond bottom quality. Chemicals used for water and soil treatment in aquaculture in Taiwan are listed in Table 3. Lime ($CaCO_3$, $Ca(OH)_2$, $CaO$) is generally applied on dried and cracked pond bottoms to eradicate most infectious agents. Lime is also used to increase the pH level of acidic soil and water, the dosage used depending on the condition of the pond (Chien 1993). Ozone can be added into water to eliminate pathogens (Kou *et al.* 1988, Chen *et al.* 1993). Teaseed cake, whose active ingredient is saponin, is applied as an organic fertilizer to enrich algal growth, as a piscicide to eradicate fish, and as a stimulant for molting of shrimp (Liao *et al.* 1985). Zeolite is a hydrated alkali-aluminum silicate that absorbs ammonia, hydrogen sulphide, and other toxic gases. The recommended application of zeolite is 100-120 kg/1000 $m^2$ (Liao *et al.* 1992). Potassium permanganate can increase the dissolved oxygen (DO) levels of the pond (Chien 1993). To chelate and reduce the heavy metals in rearing water, EDTA (ethylenediamine tetraacetic acid) at a dose of 3-10 ppm is applied (Licop 1988, Boonyaratpalin 1990, Carpenter 1992). Enzymes (e.g., proteases, cellulases, amylases, lipases) are also used to hasten the rate of decomposition of organic matter and reduce the amount of pond sludge (Chien 1993).

**Table 1.** Chemotherapeutants used in aquaculture in Taiwan.

| Chemotherapeutant | Use | Dose | References |
|---|---|---|---|
| Antibiotics | Bactericide | | |
| Erythromycin | | 40-75 mg/kg B.W. daily, oral for 5-10 d; 80 ppm, bath 1 d; 2-5 ppm, long bath | Boonyaratpalin 1990, Liao *et al.* 1996 |
| Chloramphenicol | | 100 mg/kg B.W. daily, oral for 21 d; 1-10 ppm, bath | Liao *et al.* 1992 |
| Florfenicol | | 10 mg/kg B.W. daily, oral for 3-5 d | Fukui *et al.* 1987 |
| Oxytetracycline | | 50-75 mg/kg B.W. daily, oral for 10 d; 10-20 ppm on eel, or 40-60 ppm on shrimp, long bath | Kou *et al.* 1988, Liao *et al.* 1996 |
| Streptomycin | | 100 ppm, bath | Kou *et al.* 1988 |
| Quinolone | Bactericide | | |
| Oxolinic acid | | 20-40 mg/kg B.W. daily, oral for 5 d | Liao *et al.* 1992, Guo and Liao 1994a |
| Fluoroquinolone | Bactericide | | |
| Flumequine | | 10-20 mg/kg B.W. daily, oral for 5 d | Barnes *et al.* 1991 |
| Nitrofurans | Bactericide | | |
| Furazolidone | | 10 mg/kg B.W. daily, oral for 3-6 d; 10 ppm, bath 1 d | Kou *et al.* 1988, Liao *et al.* 1992 |
| Nitrofurazone (Furacin®) | | 10 mg/kg B.W. daily, oral for 3-6 d; 10 ppm, bath 1 d | Kou *et al.* 1988, Liao *et al.* 1992 |
| Nifurpirinol (Furanace®) | | 2-4 mg/kg B.W. daily, oral for 3-5 d; 0.01-0.1 ppm, long bath | Kou *et al.* 1988 Liao *et al.* 1992 |
| Sulfonamides | Bactericide | | |
| Sulfamonomethoxine | | 100-240 mg/kg B.W. daily, oral for 10-20 d | Kou *et al.* 1988 |
| Sulfadimethoxine | | 100-240 mg/kg B.W. daily, oral for 10-20 d | Kou *et al.* 1988 |
| Quarternal ammonium compounds | Bactericide | | |
| BKC® (50% Benzalkonium chloride) | | 1-2 ppm, bath 1 d; 0.3-0.6 ppm on shrimp larvae | Liao *et al.* 1985, 1992; Kou *et al.* 1988 |
| Hyamine® (50% Benzethonium chloride) | | 1-2 ppm, bath 1 d | Liao *et al.* 1985, Kou *et al.* 1988, Chen *et al.* 1993 |
| Dyes | Bactericide; fungicide | | |

**Table 1.** Continued. . .

| Chemotherapeutant | Use | Dose | References |
|---|---|---|---|
| Malachite green | | 0.5-0.8 ppm, bath 1 d; 0.015 ppm, long bath | Kou *et al.* 1988, Chang 1994 |
| Methylene blue | | 8-10 ppm, bath 1d; 2 ppm, bath 3-5 d | Kou *et al.* 1988, Chang 1994 |
| Copper compounds | Ectoparasites | | |
| Copper sulfate | | 0.3-0.5 ppm, bath 1 d | Kou *et al.* 1988, Liao *et al.* 1992, Chang 1994 |
| Chelated copper | | 1 ppm, bath 1 d; 0.2-0.5 mg Cu/L, dip 4-6 h; 0.1 mg Cu/L, bath 1 d | Lightner 1983 |
| Formalin | Ectoparasites | 25-30 ppm (adult), or 15 ppm (larvae), bath 1 d; 15-20 ppm (juvenile), bath 10-12 h; 200-300 ppm, dip 30-60 sec | Liao *et al.* 1985, 1992; Kou *et al.* 1988; Chen *et al.* 1993 |
| Salt | Ectoparasites | 10-15 gm/L, dip 20 min | Kou *et al.* 1988 |
| Trichlorofon | Ectoparasites | 0.3-0.5 ppm, bath 1 d | Kou *et al.* 1988, Chang 1994 |

**Table 2.** Disinfectants used in aquaculture in Taiwan.

| Disinfectant | Dose | References |
|---|---|---|
| Iodine compounds | | |
| Povidone-iodine | 50-300 mg I/L, bath 10-60 min | Kou *et al.* 1988, Chen *et al.* 1993 |
| Iodophor | 0.02-0.06 ppm (larvae) or 0.1-0.45 ppm (juvenile) or 0.3-0.6 ppm (adult), long bath; 200 ppm (fertilized egg) or 20 ppm (larvae), 30 sec | Kou *et al.* 1988, Chen *et al.* 1993 |
| Chlorine compounds | | |
| Sodium hypochlorite (10-15% active ingredient) | 150 ppm, 2-3 d (disinfect water, tanks, etc.) | Boonyaratpalin 1990, Carpenter 1992, Guo and Liao unpubl. data |
| Chlorinated lime (60% active ingredient) | 20-30 ppm, 2-3 d (disinfect water, tanks, etc.) | Boonyaratpalin 1990, Carpenter 1992, Guo and Liao unpubl. data |

## Anesthetics

Aquatic animals are usually handled at various phases of culture for marking, tagging, artificial spawning, and packaging processes. To reduce mortality and stress, anesthetics are routinely used in handling and shipping processes. For such purposes, anesthetics such as benzocaine (ethyl aminobenzoate), MS-222 (3-aminobenzoic acid ethyl ester methanesulfonate), and phenoxyethanol (2-phenoxyethanol) are usually used (Table 4) (Mattson and Riple 1989, Lee 1995).

## Feed Additives

A variety of chemicals are added to the feeds when stunted growth, deformities or diseases are observed in cultured fish. These include vitamins (e.g., vitamins A, B complex, C, D, E and K, folic acid, inositol, choline, PABA); enzymes (e.g., proteases, cellulases, amylases, lipases); minerals (e.g., calcium lactate, magnesium sulfate, potassium chloride, ferric citrate, copper sulfate, zinc carbonate, manganese sulfate, cobalt carbonate, calcium iodate, dipotassium phosphate, sodium dihydrogen phosphate, calcium chloride); binders (e.g., carboxymethyl cellulose sodium, alginic acid); pigments (e.g., zeaxanthin, β-carotene, astaxanthin); attractants (e.g., tyrosine, phenylalanine, histidine, lysine, glycine, proline); preservatives, including antioxidants (e.g., butylated hydroxyanisole, ethoxyquin, butylated hydroxytoluene) and fungicides (e.g., benzethonium chloride, benzoic acid, calcium propionate, p-hydroxybenzoate, propionic acid, sodium propionate, sorbic acid, formic acid, acetic acid, ammonium propionate, sodium citrate, citric acid); and other specific additives (e.g., cholesterol, lecithin) (Taipei Commercial Association of Feeds and Feed Additives 1994).

## Chemical Application in Biotechnology

The recent development of biotechnology in aquaculture is a new frontier, and it may have a significant impact on both basic and applied research in Taiwan. Preliminary studies in biotechnology related to chemical use are in the cryopreservation of gametes, induction of triploidy and diploid monosex species, and sex reversal. In the cryopreservation of gametes, cryopreservative agents provide cryoprotection to labile enzymes and stabilize proteins during the freezing process. Ethylene glycerol, methanol, dimethylsulfoxide (DMSO), acetamide, ethylene glycol, propylene glycol, glycerol, glucose, trehalose, and polyethylene glycol have been used in studies of sperm, embryo, and larval cryopreservation by stepwise or vitrification freezing method (Chao 1991). For studies of induction of triploidy and diploid monosex species, cytochalasine B, 6-dimethylaminopurine, and caffine have been used to retain the 1st or 2nd polar body during the early stage of zygote development (Chao *et al.* 1993). The common androgens and estrogens used for sex reversal are methyl testosterone, ethyl testosterone, estradiol, and ethinyl estradiol. These chemicals are generally recognized as effective androgens and estrogens in the sex reversal of fishes (Hung 1994, Chang *et al.* 1995).

# MANAGEMENT PRACTICES ON USE OF CHEMICALS

## Antibiotics

Antibiotics are antibacterial agents which are derived originally from other microbes, chiefly bacteria, molds, and Actinomyces. They selectively inhibit or destroy pathogenic organisms without showing any appreciable harm to the host. Five antibiotics namely, erythromycin, chloramphenicol, florfenicol, oxytetracycline, and streptomycin are commonly used in aquaculture in Taiwan.

Erythromycin is a macrolide antibiotic that is particularly effective against Gram-positive bacteria. It is usually applied to control diseases such as streptococcicosis in marine fish (e.g., grey mullet,

**Table 3.** Chemicals used for water and soil treatment in aquaculture in Taiwan.

| Chemical | Use | References |
|---|---|---|
| Lime | | |
| ($CaCO_3$, $Ca(OH)_2$, CaO) | To disinfect bottom soil and to increase pH | Chien 1993 |
| Ozone | | |
| ($O_3$) | To apply as water treatment | Kou *et al.* 1988, Chen *et al.* 1993 |
| Teaseed cake | | |
| (10% saponin) | To stimulate shrimp molting and to eliminate unwanted fish | Liao *et al.* 1985 |
| Zeolite | | |
| (hydrated alkalialuminum silicate) | To absorb ammonia, hydrogen sulphide, and other toxic gases in ponds | Liao *et al.* 1992 |
| Potassium permanganate | | |
| ($KMnO_4$) | To increase DO levels and to reduce organic matter | Chien 1993 |
| EDTA | | |
| (ethylenediamine tetraacetic acid) | To reduce heavy metals in water | Boonyaratpalin 1990, Carpenter 1992 |
| Enzymes | To decompose organic matter | Chien 1993 |

**Table 4.** Anesthetics used in aquaculture in Taiwan.

| Anesthetic | Dose | Anesthetic effect | References |
|---|---|---|---|
| Benzocaine (ethyl aminobenzoate) | 40 mg/L | Rapid | Mattson and Riple 1989 |
| MS-222 (3-aminobenzoic acid ethyl ester methanesulfonate) | 75 mg/L | Rapid | Mattson and Riple 1989 |
| Phenoxyethanol | | | |
| (2-phenoxyethanol) | 0.3 mL/L | Loss of equilibrium and swimming ability only (no anesthetic effect) | Mattson and Riple 1989, Lee 1995 |

seabream), edwardsiellosis in eel, and vibriosis in shrimp larvae. The recommended dosage for treatment is 40 mg/kg body weight daily for 7 d (Liao *et al.* 1996) or 50-75 mg/kg body weight daily for 5-10 d by oral administration, or 80 ppm bath for 1 d, or 2-5 ppm bath for a long period (Boonyaratpalin 1990).

Chloramphenicol is a broad-spectrum antibacterial agent and is used to control edwardsiellosis (*Edwardsiella tarda*) and vibriosis (*Vibrio anguillarum*) in eel. The recommended application is 100 mg/kg body weight daily for 21 d by oral administration (Kou *et al.* 1988). Bacterial shell disease, appendage rot, bacterial fouling disease on gills, and septicemias of larval shrimp can be treated with chloramphenicol at 1-10 ppm for bath (Liao *et al.* 1992).

Florfenicol, a broad spectrum antibacterial agent, is a fluorinated derivative of thiamphenicol which is a chloramphenicol analogue. *In vitro* testing using this agent shows its equal or superior effect against pathogenic bacteria compared with thiamphenicol and chloramphenicol. Florfenicol has shown therapeutic efficacy against experimentally induced pseudotuberculosis (*Pasteurella piscicida*) in yellowtail, edwardsiellosis in eel, and vibriosis in goldfish (Fukui *et al.* 1987). A dose of 10 mg/kg body weight is orally administered daily for 3-5 d to control bacterial diseases.

Oxytetracycline is a broad-spectrum antibacterial agent. A dose of 50-75 mg/kg body weight is applied daily for 10 d or 10-20 ppm bath for a long period to control eel diseases caused by *Aeromonas hydrophila*, *Pseudomonas anguilliseptica*, *E. tarda*, *V. anguillarum*, and *Flexibacter columnaris* (columnaris and tail rot) (Kou *et al.* 1988). Bacterial shell disease, appendage rot, septicemias, bacterial fouling gill diseases, and necrotic hepatopancreas of shrimp larvae caused by *Vibrio*, *Aeromonas*, *Pseudomonas*, *Spirillum*, or *Flavobacterium* can also be treated with oxytetracycline at 40-60 ppm for bath (Liao *et al.* 1992). It is also used to control gaffkemia in lobster.

Streptomycin is an aminoglycoside which is a mid-broad spectrum antibacterial compound. The drug is used to control diseases caused by Gram-negative bacteria such as *Vibrio*, *Aeromonas*, and *Edwardsiella*. Streptomycin at 100 ppm is used as a prophylactic or as a therapeutant to prevent or control eel diseases (Kou *et al.* 1988).

## Oxolinic Acid

Oxolinic acid is a quinolone that has a broad-spectrum antibacterial activity, especially against Gram-negative bacteria causing a variety of serious diseases in cultured fish, such as vibriosis and furunculosis. Isolates of *Vibrio* and *Aeromonas* obtained from farmed fish in Taiwan (seabream, grey mullet, grouper, eel, etc.) are sensitive to oxolinic acid. To control such diseases, oxolinic acid is applied at a dose of 20-40 mg/kg body weight mixed with feed and administered to fish daily for 5 d (Liao *et al.* 1992, Guo and Liao 1994a).

## Flumequine

Fluoroquinolones are second generation 4-quinolones. Flumequine is one of the fluoroquinolone derivatives and has been shown in recent years to be a useful antibacterial drug in the treatment of fish disease. Barnes *et al.* (1991) stated that flumequine is more effective than oxolinic acid due to its microbiological activity. Flumequine at 10-20 mg/kg body weight is applied daily by oral administration for 5 d to treat fish infected by *Vibrio* and *Aeromonas.*

## Nitrofurans

Nitrofuran compounds, which have the 5-nitrofuran-ring structure, are applied as prophylactic or therapeutic agents to prevent or control bacterial diseases such as edwardsiellosis, vibriosis, branchiomycosis, columnaris and tail rot disease of fish; and bacterial shell disease, appendage rot, septicemias, bacterial fouling gill diseases and necrotic hepatopancreas of shrimp. Furazolidone, nitrofurazone, and nifurpirinol are the commonly used nitrofurans in treating diseases of cultured aquatic animals. Furazolidone and nitrofurazone (Furacin®) at 10 ppm bath for 1 d, or 10 mg/kg body weight daily by oral administration for 3-6 d are applied for fish and shrimp diseases. Nifurpirinol (Furanace®) is used to control disease by oral administration with a dose of 2-4 mg/kg body weight daily for 3-5 d, or 0.01-0.1 ppm bath for a long period (Kou *et al.* 1988, Liao *et al.* 1992).

## Sulfonamides

Sulfonamides are synthetic compounds that are usually given orally because they reach therapeutic levels in the blood and body tissues rapidly through that route. Oral administration is the best choice because fish can hardly absorb the drug from the surrounding waters. To produce a synergistic effect, sulfonamides are often combined with trimethoprim or ormetoprim. Sulfonamides, such as sulfamonomethoxine and sulfadimethoxine, are applied at a dose of 100-200 mg/kg body weight daily for 10-20 d or 220-240 mg/kg body weight daily for 14 d to prevent or control fish diseases caused by *Aeromonas*, *Pseudomonas*, *Edwardsiella*, *Vibrio*, and *Cytophaga* (Kou *et al.* 1988).

## Quarternary Ammonium Compounds

Among the quarternary ammonium compounds, benzalkonium chloride (BKC®) and benzethonium chloride (Hyamine®) are very popular with aquafarmers. These compounds are used for controlling bacterial diseases such as those caused by *Cytophaga* and *Vibrio*. BKC® or Hyamine® at 1-2 ppm bath used for 1 d is effective (Liao *et al.* 1985, 1992; Kou *et al.* 1988). BKC® at concentrations of 0.3-0.6 ppm is used on larval and juvenile shrimp to prevent bacterial diseases, especially *Vibrio* infection (Chen *et al.* 1993).

## Dyes

Malachite green and methylene blue are dyes that possess antimicrobial properties, particularly against *Saprolegnia* infection. They are also applied to disinfect larval fish and fertilized eggs and to control fungal infections (Chang 1994). Malachite green, given as bath at 0.5-0.8 ppm, or methylene blue at 8-10 ppm for 1-d bath are used to treat diseased shrimp (Liao *et al.* 1985). To disinfect fish larvae or broodstock, malachite green is applied at 0.15 ppm bath for a long period or methylene blue at 2 ppm is administered as a daily bath for 3-5 d (Kou *et al.* 1988, Chang 1994). Malachite green and methylene blue may remain in aquatic animal tissue for up to one month. Therefore, fish and prawns treated with these chemicals should not be harvested until at least one month post-treatment. This is because the chemicals are carcinogenic (Liao *et al.* 1992).

## Copper Compounds

Among copper compounds, copper sulfate and chelated copper (e.g., Cutrine-plus®) are frequently used. Their effects are largely attributed to cupric ions, with their toxicities increasing with decreasing salinity and hardness of water (Liu 1980, Guo and Liao 1992). They are used as algicides (against blue-green algae, *Oscillatoria*), bactericides (to treat columnaris disease, bacterial fin rot), fungicides (against *Saprolegnia*), external protozoacides (against *Trichodina*, *Amyloodinium*), and for control of monogeans (*Dactylogyrus*, *Gyrodactylus*). Copper sulfate at 0.3-0.5 ppm used as a 1-d bath is sufficient to kill algae and to control fish diseases (Kou *et al.* 1988, Liao *et al.* 1992, Chang 1994). Chelated copper, a form of copper bound by such chelating agents as ethanolamine, at a level of 1 ppm, is applied daily to kill protozoans. *Leucothrix* infestations on the gills of shrimp larvae may be eliminated by dipping them in 0.2-0.5 mg Cu/L for 4-6 h, or in 0.1 mg Cu/L for 1 d (Lightner 1983).

## Formalin

Formalin is used to treat infestations of peritrichous protozoans and monogenetic trematodes, such as *Zoothamnium*, *Epistylis*, *Vorticella*, *Ambiphrya*, *Apiosoma*, *Trichodina*, *Ichthyophthirius*, *Dactylogyrus*, and *Gyrodactylus*; filamentous bacteria such as *Leucothrix*; and fungi such as *Saprolegnia* in cultured shrimp and fish (Lightner 1983, Kou *et al.* 1988, Liao *et al.* 1992). Formalin, with formaldehyde as its active ingredient, is an agent that reacts with a variety of organic compounds. The presence of organic material in aquaculture ponds may result in formalin becoming less effective. The dosage of formalin depends on the duration of treatment, the condition of the pond, and the size of the aquatic animals to be treated. Adult fish and prawn are treated with 25-30 ppm bath for 1 d, larvae with 15 ppm for 1 d, and juveniles with 15-20 ppm baths for 10-12 h. Aquatic animals are not fed during formalin treatment and water has to be drained after 24 h to remove traces of the chemical (Liao *et al.* 1985, 1992; Kou *et al.* 1988). Formalin is also used to wash fertilized eggs of *Penaeus monodon* (100 ppm for 1 min) or nauplii (200-300 ppm for 30 sec to 1 min) to prevent *P. monodon*-type baculovirus (MBV) (Chen *et al.* 1993).

## Salt

Salt (NaCl) is commonly used to control fungus (*Saprolegnia*), external freshwater protozoans (e.g., *Trichodina*), and monogeneans (e.g., *Dactylogyrus*, *Gyrodactylus*) by dipping fish at concentrations of 10-15 gm/L for 20 min (Kou *et al.* 1988).

## Trichlorofon

Trichlorofon is an organophosphate compound that can penetrate the chitinous exoskeleton of arthropods to paralyze or poison the nervous system. Trichlorofon is the most frequently recommended chemical for *Lernaea* or *Caligus* infections. To control such parasites entirely, applications of 0.3-0.5 ppm for 1 d need to be repeated 2-3 times every 7-10 d (Kou *et al.* 1988, Chang 1994).

## Iodine Compounds

Among the organic iodine compounds, povidone-iodine and iodophor are commonly used on cultured aquatic animals. They can prevent and control diseases caused by *Aeromonas*, *Pseudomonas*, *Vibrio*, *Flexibacter*, and fungi. These compounds are particularly used to treat eggs and larvae, and to disinfect equipment (Guo and Liao 1994b). A concentration of 100 mg iodine/L with dipping for 10 min is usually applied to fish eggs to prevent the spread of disease. Iodophor, at 0.02-0.06 ppm, 0.1-0.45 ppm, and 0.3-0.6 ppm is applied on larval, juvenile and adult eel, respectively, as a long-period bath (Kou *et al.* 1988). Chen *et al.* (1993) reported that shrimp eggs and nauplii were dipped into iodophor solution for 30 sec at concentrations of 200 ppm and 20 ppm, respectively, to avoid the introduction of MBV from broodstock sources.

## Chlorine Compounds

Chlorine compounds, such as sodium hypochlorite (NaOCl) and chlorinated lime (calcium hypochlorite; $Ca(OCl)_2$, are widely used as disinfectants because they are inexpensive, easily available and effective. Sodium hypochlorite and chlorinated lime, which are strong oxidizing agents, are frequently used to disinfect water, ponds, tanks, and equipment. To kill nematode eggs in ponds, the bottom silt is purged and 50-100 ppm sodium hypochlorite or chlorinated lime is applied (Kou *et al.* 1988, Liao *et al.* 1992). Either 20-30 ppm chlorinated lime (60% active ingredient) or 150 ppm sodium hypochlorite (10-15% active ingredient) can be applied to water in the reservoir for 2-3 d. Strong aeration (15-20 L/min) should be provided to mix chlorine throughout the tank. Before use, the water in the tank should be tested for the presence of chlorine. Chlorine residues can be removed by adding sodium thiosulphate (Boonyaratpalin 1990, Carpenter 1992).

## Potassium Permanganate

Potassium permanganate ($KMnO_4$) is a strong oxidizing agent and is widely used to treat external protozoan infestations and bacterial diseases. Its efficacy is affected by the presence of dissolved and particulate organic matter; thus the amount of agent needed for an effective treatment has to be increased if the organic content of the water is high. Potassium permanganate is also applied as a detoxifier. A 1-2 ppm application is commonly used to increase DO levels and to reduce excessive organic material in the pond (Chien 1993). Liao *et al.* (1985) reported that potassium permanganate dip for 30-60 min at 25-30 ppm can control epicommensal protozoan disease of *P. monodon*. Immersing grouper infected with monogeneans in a 2 ppm potassium permanganate solution for 24-48 h has been found effective (Chang 1994). Potassium permanganate at 3-5 ppm bath for a long period, or 20 ppm for 1 h is also applied to cure columnaris disease (*Flexibacter columnaris*), to control protozoans (e.g., *Trichodina*, *Ichthyophthirius*), and to remove monogeneans (e.g., *Gyrodactylus*, *Dactylogyrus*) from eels (Kou *et al.* 1988).

### Teaseed Cake

The effect of teaseed cake is largely attributed to the 10% saponin present in it. Saponin is an irritant to both fish and external parasites. Teaseed cake at 10-25 ppm is used to remove unwanted fishes in shrimp-culture ponds and to stimulate shrimp molting (Liao *et al.* 1985, 1992).

## ALTERNATIVE DISEASE PREVENTION METHODS

Although chemicals can be used to prevent and cure diseases, a good health management system is the best tool for disease prevention. Several measures concerning disease control should be considered in advance. The use of vaccines (Song *et al.* 1980, Lin *et al.* 1982, Chen and Kou 1985), immunostimulants, biological control (Wu and Chao 1984), or probiotics containing beneficial microorganisms has the potential to replace chemotherapy. To date, however, the efficacy of these measures is not yet encouraging.

## NATIONAL REGULATIONS ON THE USE OF CHEMICALS IN AQUACULTURE

To manage the use of chemicals in aquaculture, the Council of Agriculture (COA) plans to set up a "Guidelines on Chemicals Use in Aquatic Animals." The COA has extended financial support for a series of studies on such topics as larval toxicity (Table 5) (Liao and Guo 1985, 1986a, b, 1990a, b; Liao *et al.* 1989; Guo and Liao 1992, 1993), pharmacokinetics and residues in juvenile fish (Guo and Liao 1994a). The guidelines focus on collecting information on dosage, treatment, and withdrawal period in target species. Chemicals to be regulated include amoxicillin, ampicillin, erythromycin, florfenicol, flumequine, furazolidone, oxolinic acid, oxytetracycline hydrochloride, sulfadimethoxine (or sodium sulfadimethoxine), sulfamonomethoxine (or sodium sulfamonomethoxine), and trichlorofon. Based on the guidelines, the COA will establish appropriate regulations to monitor and manage the use of chemicals in aquaculture.

## CURRENT RESEARCH ON CHEMICAL USE FOR AQUACULTURE

To collect data and to understand the importance of chemical use in aquaculture management, studies are being conducted. These include investigations on the prevention and control of diseases; the toxicity of chemicals to aquatic animals; residues in fish, soil and water; the development of resistance in bacteria; pharmacokinetics; and environmental impact. Studies on feed additives (e.g., pigments, glucan, vitamin C) are also being done.

## CONCLUSIONS

To meet consumer preferences, 71 aquatic species are cultivated on a commercial scale in Taiwan. Disease control has become difficult due to this increase in the number of species available and to the high stocking densities being employed. At present, it is important to apply and manage the use of chemotherapeutants effectively. Although chemicals can be used against diseases, sound pond management (e.g., well-designed ponds, adequate pond preparation, optimal stocking density, excellent water source and proper feed quality) and the enhancement of the immune capability of

**Table 5.** The median tolerance limit (TLm) of the postlarvae of the six species of cultured prawn bathed in chemicals for 24 h.

| Chemical | *Penaeus monodon* | *P. japonicus* | *P. semisulcatus* | *P. penicillatus* | *Metapenaeus ensis* | *Macrobrachium rosenbergii* | References |
|---|---|---|---|---|---|---|---|
| Chloramphenicol | 247[1] | 334 | 362 | 404 | 437 | 2,717 | Liao and Guo 1985 |
| Oxytetacycline | 954 | 936 | 908 | 916 | 1,397 | 1,250 | Liao and Guo 1986b |
| Streptomycin | 4,884 | 6,616 | 9,813 | 6,635 | 17,173 | 6,325 | Liao and Guo 1986b |
| Furazolidone | 50 | >200 | 67 | 36 | 109 | >300 | Liao and Guo 1986a |
| Nitrofurazone | 55 | 73 | 78 | 40 | 139 | >362 | Liao and Guo 1986a |
| Formalin | 168 | 136 | 184 | 275 | 633 | 423 | Liao and Guo 1989 |
| Copper sulfate | 436 | 427 | 231 | 319 | 465 | 0.39 | Liao and Guo 1990a |
| Malachite green | 0.73 | 1.18 | 3.2 | 0.3 | 3.73 | 1.14 | Liao and Guo 1990a |
| Potassium permanganate | 4.8 | 9.6 | 5.2 | 3.9 | 17.0 | 6.0 | Liao and Guo 1990a |
| Saponin | 135 | 41 | 146 | 135 | 162 | 168 | Liao and Guo 1989 |
| Benzalkonium chloride | 3.1 | 3.3 | 1.5 | 1.6 | 3.0 | 2.0 | Liao and Guo 1990b |
| Benzethonium chloride | 10 | 5.3 | 3.2 | 4.4 | 9.0 | 6.0 | Liao and Guo 1990b |

[1]Units = parts per million (ppm).

aquatic animals (e.g., application of vitamin C and the immunostimulant, glucan) are still the best and preferred tools for disease prevention. To assure man's health and to reduce damage to the environment, the use of chemicals in aquaculture should only be employed as a last resort.

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