The Use of Chemicals in Aquaculture in Thailand

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ABSTRACT

In Thailand, many chemicals are used to treat diseases of cultured aquatic animals and to improve water quality in culture facilities. Along with the intensification of aquaculture practices that has occurred in recent years in Thailand, chemical use has also increased, particularly in marine shrimp culture. This paper summarizes information on the types of chemotherapeutants commonly used in Thailand, their sources and costs, the treatment regimes used, the adverse impacts that have resulted and the hazards posed. Also included is information on national regulations, a summary of on-going research, and recommendations to aquaculturists, producers and suppliers of chemicals, government agencies and scientists. It is concluded that although chemicals and drugs will continue to play an important role in the development of Thai aquaculture, they must be used with caution to avoid adverse effects such as environmental damage and the development of resistant strains of pathogens. To minimize chemical usage, additional emphasis needs to be placed on developing good management practices for aquaculture systems.

INTRODUCTION

A number of chemicals have been used for aquaculture in Thailand for quite some time. The chemicals are used mainly to treat diseased animals and, to a lesser degree, to improve water quality in culture facilities. In recent years, as aquaculture in Thailand has become more intensive the use of chemicals has intensified, particularly in marine shrimp culture.

Farmers want to get maximum yield, but few would like to increase their cost of buying chemicals. The aggressive promotion of chemical products by salesmen has partly led to an increased use of drugs and chemicals. Furthermore, the situation is aggravated by the lack of specific legislation on the use of therapeutic drugs and chemicals.

With present culture practice, the use of some chemicals is widespread; but farmers must be cautious since they produce food for human consumption. The use of chemicals must be adopted only as a last resort. For the success of aquaculture, chemicals must be judiciously and responsibly used.

USE OF CHEMICALS IN AQUACULTURE

Environmental degradation in some areas has increasingly made the water quality unsuitable for aquaculture. Drugs and chemicals are often applied to improve water quality and to reduce risk from disease. Chemical use in aquaculture has specific effects. Chemicals can be applied either singularly or in combination. The advantage of using a specific chemical cannot be seen if chemicals are used indiscriminately. Wellborn (1985) stated that prior to chemical treatment, the following four “Ks” must be considered:

- know the water
- know the fish
- know the chemical
- know the disease

Failure to consider any of the four "Ks" and indiscriminate use of the chemicals may be detrimental.

An advantage of chemical application is that it achieves quick results. For example, for acid sulphate soil, liming can quickly adjust soil pH. Similarly, it can control diseases of fish, especially external parasites.

This section presents the drugs and chemicals presently used in aquaculture in Thailand. It is not possible to list all the chemicals used in Thai aquaculture practice because some of them are being used discreetly in isolated cases. In many instances, products are known by their trade names with no further information on ingredients. The information in this report was obtained from the existing literature, and from interviews with farmers and various suppliers.

Soil and Water Treatment

Lime

Lime is a major chemical used for soil and water treatment in Thai aquaculture. It is used to correct pond bottom and stabilize water pH. It is also reported to ensure a healthy plankton bloom (Chanrachakool *et al.* 1995).

There are at least four types of lime used in Thailand:

- Agricultural lime/lime stone or crushed shell ($CaCO_3$)
- Hydrate lime or slake lime ($Ca(OH)_2$)
- Quicklime/burnt lime or burnt shell lime (CaO)
- Dolomite or dolomite lime ($CaMg(CO_3)_2$)

Each type of lime has a specific effect. The farmer must understand the reactions of the various types of lime to be able to use them for the right purpose and at the proper dose. For example, $Ca(OH)_2$ should be used on soil with a low pH (< 4). If it is used in soil with high pH, excessively high water pH will result. Water with high pH makes ammonia more toxic and can result in mortality of aquatic animals. Agricultural lime ($CaCO_3$) is used to increase the buffering capacity of the water. It does not result in drastic pH changes and can, therefore, be used in relatively large quantity. The quality of $CaCO_3$ in the market may vary due to contamination with soil. The amounts of $CaCO_3$ and $Ca(OH)_2$ required to adjust different pH are presented in Table 1.

Table 1. Lime application recommended during pond preparation.

Soil pH	Quantity of $CaCO_3$ (t/ha)	Quantity of $Ca(OH)_2$ (t/ha)
> 6	1 - 2	0.5 - 1
5 - 6	2 - 3	1 - 1.5
< 5	3 - 4	1.5 - 2.5

Lime is also used in ponds with normal pH. It conditions the soil when applied at 0.5-1 t/ha spread evenly over the bottom.

Dolomite ($CaMg(CO_3)_2$)

Dolomite is another form of limestone which contains magnesium. It is primarily used to improve the buffering capacity and to supply Mg^{++}. The rate of application in low pH (< 5) ponds is 100 to 300 kg/ha per application.

Teaseed Meal

Teaseed meal is made up of ground teaseed containing saponin, and applied to ponds to kill predators or unwanted species before stocking. It is also used to induce molting of shrimp. Dosage used to eliminate predators depends on the species and their sizes. If used as a disinfectant, dosage is about 1-25 gm/m^3 of 7% saponin teaseed meal. Saponin is not only a fish toxicant but also a molluscicide.

Chlorine

Chlorine has been used routinely to disinfect water supplies in fish and shrimp hatcheries in Thailand and elsewhere in the world. Recently, chlorination has become a standard procedure adopted by most Thai shrimp farmers for pond preparation. The purpose is to eliminate harmful organisms entering the pond with water. The most commonly used form of chlorine is powdered calcium hypochlorite (65% active chlorine content) at the rate of 180 kg/ha. However, the rate is by no means standard because of the variability in chlorine demand of the water.

Organic and Inorganic Fertilizers

Fertilization is a basic part of pond preparation. Plankton as food for herbivorous fish such as tilapia and milkfish must be in adequate quantities before stocking fish. Fertilization is also included in a standard procedure for shrimp pond preparation after chlorination and before stocking. Chicken manure can be used at a rate of 300 kg/ha by suspending manure bags in the water away from pond dikes. Inorganic fertilizers such as urea and N-P-K mixture are widely used. Urea is applied at 15-30 kg/ha after fertilization. Water is added gradually at 10-20 cm daily until the desired depth is achieved. If the desired phytoplankton bloom is not achieved, more fertilizer is added.

Disodium Ethylene Diamine Tetraacetate (EDTA)

EDTA is a chemical used to improve water quality by reducing heavy metal concentrations. In shrimp larval rearing, it is applied at 10 mg/L prior to stocking of nauplii. Many hatcheries use EDTA as a treatment for ectocommensal fouling to stimulate juvenile molting. EDTA is normally applied at 1-5 ppm to remove organic substances in the water.

Zeolite

Zeolite is applied to shrimp ponds to remove hydrogen sulphide, carbon dioxide and ammonia, as it has a strong capacity to absorb molecules. Shrimp farmers use zeolite to clean pond bottoms. Zeolite is available in the market under various brand names, and it is supplied as fine grains in bags of 20 kg. The recommended dose is 180-350 kg/ha. The effectiveness of zeolite is still questionable.

Chemotherapeutants

Disinfectants

There are a number of chemicals recommended for pond and hatchery disinfection. Although suppliers claim that they are laboratory tested and effectively kill bacteria and other pathogenic organisms, many appear to be ineffective in pond or hatchery environments. The high level of organic material in the ponds may inactivate the disinfectant before it creates a significant effect on the pathogens.

The substances widely used as disinfectants in aquaculture in Thailand include chlorine, iodine, formalin and benzalkonium chloride (BKC). There are numerous commercial disinfectants available on the Thai market, but almost all of them contain any one of the above as basic ingredient. The following information, therefore, is based on these active ingredients.

Chlorine

Among various forms of chlorine used to disinfect water, chlorine gas (Cl_2), sodium hypochlorite (NaOCl) and calcium hypochlorite ($Ca(OCl)_2$) are most common. In brackish or sea water with pH normally above 7, the chlorine exists exclusively in free residue form as HOCl and OCl^-. Chlorine in the form of hypochlorous acid is a hundred times more toxic to microorganisms than as the hypochlorite ion. Thus, lowering pH increases the percentage composition of hypochlorous acid, resulting in greater chlorine toxicity to microorganisms. The effectiveness of chlorine is also affected by the amount of organic matter, reduced compounds and turbidity present in the water to be treated. If chlorine is used in water with high organic matter, the rate of application should be higher. The dosage depends on the active ingredient of residual chlorine. Sodium hypochlorite (5.25% chlorine) is not as effective as calcium hypochlorite due to its low chlorine content. Although farmers use it, as it is much cheaper than calcium hypochlorite, it must be applied at a higher rate. While $Ca(OCl)_2$ is used at 10-30 gm/m^3, NaOCl must be used at 100-300 gm/m^3.

Iodine

Iodine is widely used as a disinfectant in hatcheries and ponds at 1-5 gm/m^3. Granular iodine should be thoroughly dissolved in water before spraying over the pond bottom to eliminate aquatic bacteria and other pathogens.

Formalin (37-40% Solution)

Formalin can be used as a disinfectant and has been used to treat against external parasites in fish, especially freshwater fish, at a rate of 25-50 ppm. As a disinfectant, it is applied at about 10-15 ppm. It can be used at concentrations up to 200 ppm to treat hatchery facilities. To be precise in dosage, it is necessary to measure the formaldehyde content before use.

Benzalkonium Chloride (BKC)

BKC is one of the broad spectrum disinfectants used in aquaculture. Thai shrimp farmers use it to reduce the concentration of plankton and dinoflagellates in closed pond systems. If it is used in a very small amount (0.1-0.5 ppm) and applied only in one corner, it will not kill plankton. However, if applied in large amounts, the resulting decomposition of organic matter will have an effect on animal health.

The dosages of chemical compounds commonly used to disinfect shrimp ponds in Thailand are shown in Table 2.

Table 2. Disinfectants and dosages used in shrimp culture in Thailand.

Disinfectant	Dosage used (gm/m³)
Benzalkonium chloride (BKC)	1-5
Formalin	5-10
Iodine	1-5
Sodium hypochlorite (5.25%)	100-300
Calcium hypochlorite (HTH 65%)	10-30
Teaseed (7% saponin)	1-25
Calcium oxide	1000-1500 kg/ha

Therapeutants

Tonguthai and Chanrachakool (1992) reviewed the current usage of chemotherapeutic agents in Thailand and found that 23 basic chemicals and antibiotics were used. Plumb (1995) concluded, from a questionnaire survey of fisheries scientists in Asia, that no less than 38 antimicrobials and 28 parasiticides were used in Asian aquaculture during 1990-93.

An attempt to list the drugs and chemicals presently used in aquaculture in Thailand follows. Chemicals that have been reported, but which are not widely used at the present time are excluded. Again, the following chemicals are referred to by active ingredients only. The commercial names of chemical products available in Thailand are mentioned in a separate section.

Acriflavin

This chemical is used to treat fish eggs and aquarium fish for infections by bacteria and external protozoans. It is recommended as a treatment for *Flexibacter columnaris* in seabass (Ruangpan 1986) and against bacteria in walking catfish (Primpol 1990). The dose is 100 ppm for dipping eggs for 3-5 sec and 25 ppm for prolonged treatment of *F. columnaris* in seabass. For walking catfish, only 5 ppm is recommended. For aquarium fish, 5-10 ppm bath for 24 h is recommended.

Copper Compound (Cutrine Plus)

Copper compound is the only chemical so far approved by the US FDA for shrimp culture (Williams and Lightner 1988). It is also one of the oldest and most widely used chemicals in fish culture. It is used as a parasiticide against external protozoan infestation. Limsuwan (1985) recommended 40-50 ppm of $CuSO_4$ as a 20-30 min bath to treat protozoans in fish. Ruangpan (1987) recommended Cutrine Plus at the rate of 0.5 ppm to treat against filamentous bacteria in shrimp. If copper compounds are used continuously in shrimp ponds, copper may accumulate in the pond bottom, which is dangerous to shrimp.

Dipterex (Chlorofos, Dylox, Foschlor, Masoten, Neguvon, Trichlorofon)

Dipterex is widely used to treat for crustacean, monogenean, and protozoan parasites in pond-cultured fish. A rate of 0.25-0.3 ppm is used for prolonged treatment; however, it is necessary to repeat treatment 2-3 times at 3-d intervals (Kanchanakarn 1986).

Recently, Dipterex has been applied to water storage canals and reservoirs to eliminate wild crustacean vectors of shrimp viruses that enter ponds through the water supply. These vectors were found to carry systemic ectodermal and mesodermal baculovirus (SEMBV) and yellowhead disease (YHD).

To completely eliminate these crustaceans, farmers use Dipterex at 0.3-0.5 ppm or higher concentrations than those used for fish.

Formalin

Formalin is approved by the US FDA for use in aquaculture of food fish. When formalin is applied to ponds, it can kill phytoplankton and cause oxygen depletion. Formalin apparently reacts with ammonia to form hexamethylenetriamine and possibly formamide (Brewsters and McEven 1961).

In freshwater fish culture, formalin is widely used to treat external parasites such as ciliated protozoans, monogeneans, etc. In shrimp culture, it is not only used as a disinfectant in ponds and hatcheries, but also to remove ammonia and kill plankton. Shrimp farmers use formalin at 25-40 ppm to control phytoplankton bloom. In fish culture, it can be used at 25-30 ppm, depending on the size of fish and the parasites to be treated.

Malachite Green

A mixture of formalin and malachite green at a ratio of 25:0.1 ppm appears to be very effective to treat "Ich" in both aquarium and food fish. It has been used to control *Lagenidium* in shrimp hatcheries at 0.01 ppm for 24 h (Ruangpan 1987).

Potassium Permanganate ($KMnO_4$)

$KMnO_4$ is one of the first chemicals to be used as a chemotherapeutant in aquaculture, and has been applied since the early part of the century. In Thailand, it is used to treat against external parasites such as monogeneans, particularly in the aquarium fish industry. When applied at the rate of about 5 ppm, it is also a good treatment for external bacterial infections such as *Columnaris* disease. To treat against *Aeromonas hydrophila*, it can be used at 4 ppm in excess of potassium permanganate demand. For aquarium fish, it can be used at up to 500 ppm as a dip treatment for 5 min.

Benzalkonium Chloride (BKC)

BKC is used as a bactericide and fungicide in shrimp hatcheries at 1.0-1.25 ppm or as a 200 ppm bath for 30 min.

Trifuralin (Treflan)

Trifuralin is commonly used as a prophylactic chemical against fungal infection in shrimp hatcheries at 0.01-0.05 ppm daily. Ruangpanich (1988) recommended Treflan at 0.01 ppm to treat against *Lagenidium*.

Antibiotics

Infections due to bacteria are major disease problems in both freshwater and brackishwater aquaculture. In Thailand, *Aeromonas hydrophila* causes major problems in the culture of freshwater fish and other aquatic animals such as frogs and softshell turtles. Various species of *Vibrio* are involved in diseases of brackishwater species including shrimp.

To treat diseased fish, antibiotics are generally applied orally by mixing with feed. Injection can be applied to large fish. Antibiotics are most likely to be effective when administered at the early stage of a disease. At later stages, they may not be of much use, as sick fish normally refuse to eat.

Almost all of the antibiotics used in aquaculture are also medicines for human use. The use of antibiotics for aquatic animals may not only initiate environmental pollution problems but also can affect human health due to drug residues (Aoki *et al.* 1990).

The following are some of the antibiotics widely used in Thailand:

Erythromycin

Erythormycin has been used to treat bacterial infection in walking catfish and also against vibriosis in shrimp larvae.

Nitrofurans (Furacin, Furanace)

Nitrofurans are a group of antibiotics that are generally not considered safe for humans because of their potential carcinogenic effects. However, there are a few antibiotics in this group being widely used in aquaculture.

Furacin is used to treat *Vibrio* spp. infection in shrimp larvae (Limsuwan 1987) at a dose of 10 ppm. The withdrawal period is about 10 d at temperatures greater than 22 °C. Furanace is used as an antimicrobial agent for walking catfish and is commonly applied to fish during transportation at the rate of 0.1-0.2 ppm. It is not effective in salt water.

Oxytetracycline

Oxytetracycline is one of the antibiotics approved by the US FDA and has been widely used in the treatment of freshwater fish, frogs and softshell turtles. It is also effective in the control of vibriosis and columnaris disease in both fresh- and brackishwater fish. The rate used in fish is about 10 ppm, while in shrimp it is given at about 1-5 gm/kg feed/d for 4-5 d. The withdrawal period in shrimp is 15 d at temperatures greater than 22 °C. As oxytetracycline has been used in aquaculture for a long time, its use may have resulted in severe environmental contamination and has aroused concerns about its impact on public health.

Sulphamonomethoxine (Dimeton)

Sulphamonomethoxine has been recommended for treatment of bacteria in fish (Saitanu and Chularak 1983) at 100-200 mg/kg of feed for 10-14 d and a withdrawal period of about 15 d at temperatures greater than 22 °C.

Oxolinic Acid

Oxolinic acid is also approved by the US FDA for use in aquaculture and is now widely used in shrimp for treatment of vibriosis. In freshwater fish, it is used effectively against *Aeromonas hydrophila*. For shrimp, the rate of use is 2 gm/kg feed/d for 5 d, and the withdrawal period is about 15 d at temperatures greater than 22 °C.

Feed Additives

Artificial feeds are often advertised to contain not only protein, carbohydrate and fat, but also additives such as vitamins, minerals, carotenoid pigments, phospholipids and many others, to enhance growth and survival of cultured animals.

Antibiotics

Investigations using chromatographic methods (HPLC and TLC) have determined that many artificial larval feeds, including shrimp flakes and micro-encapsulated diets, are adulterated with various antibiotics such as oxytetracycline, oxolinic acid and even chloramphenicol. Antibiotics are added to feed as growth promotors.

Hormones

Hormones such as corticosteroids, anabolic steroids and other steroids have been incorporated in feed in shrimp hatcheries to make the larvae look healthy and uniform in size.

Vitamins

In extensive culture systems, natural food may be abundant enough to provide essential vitamins, as aquatic organisms require only minute amounts of these substances for normal growth, metabolism and reproduction. However, in intensive aquaculture systems in Thailand, natural food is limited, so that the addition of vitamins to the diet is recommended. Among the vitamins, vitamin C is widely used in shrimp diets.

Immunostimulants

The most obvious disadvantage of chemical use in aquaculture is that some strains of pathogen become resistant to certain antibiotics due to their overuse or misuse. The antibiotics do not completely eliminate these pathogens, resulting in the recurrence of disease. In addition, their residues may accumulate in fish flesh and the environment.

Some scientists believe that using immunostimulators against infectious diseases is more advantageous than using antibiotics because there is no residue in tissues and strain resistance of bacteria to antibiotics is avoided. Glucan has been shown to stimulate the non-specific defense mechanism of aquatic animals and to enhance protection against bacterial challenge (Raa *et al.* 1992). Peptidoglycan has also been experimentally shown to cause significant increases in growth rate, survival and feed conversion of treated animals. It also causes a dramatic increase in the phagocytic activity of hemocytes. Several products of peptidoglycan have been widely distributed in the Thai market.

Vaccines

Vibrio anguillarum vaccine for fish is available in Thailand. Vibrogen-S is a vaccine developed by Aqua Health (Asia) Ltd. against vibriosis in marine shrimp. It is claimed to be effective against *Vibrio parahaemolyticus* under both laboratory and field conditions. It is administered by immersion, injection and with food. Immersion is recommended for larvae, while injection and oral feeding are recommended for broodstock and pond grow-out.

SUPPLY OF CHEMICALS

As a consequence of the expansion of aquaculture, especially for marine shrimp culture in Thailand, chemical usage has become increasingly a part of management. When the demand for chemicals increases, various types of commercial products are produced to meet the demand. In Thailand, the number of suppliers of aquaculture chemicals has greatly increased. They distribute products all over the country, especially in the east and south where shrimp farms are concentrated.

The following are some of the commercial chemical products presently available in the Thai market. The list is by no means exhaustive; the listed of brand names have been gathered from suppliers mainly in the east of Thailand.

Commercial Products for Pond Soil and Water Treatment

These include Freshwater Brite, N'clear, Freshwater Marplex Surewater, Plankz, Saltwater ACT, Saltwater Ultrashield, Anticlean, Chloro-60, Isorep, Algicide-27, Hydrolite, Star-Chlon, Zeolite, USA Dolomite, Cleara, Zooline, Neolife, Colorant Bactapur, etc.

Disinfectants

Disinfectants in use in Thailand include Thyrodine, Povidone, Saver BKC 80, Saver BKC 50, Chloryle, Septer 50, Septer G Glutatreat, Cleara, Biosafe, Aquasafe, Intersafe, Copper A, Povidine, Aquadine 10, etc.

Therapeutants

Among the therapeutants are Dermashell, Wound Rx, Saltwater Coppersafe, Control, Protokill plus, ZooCutx, Zotaril, etc.

Antibiotics

These include Floxpro, Farmsafe, Antidis, Imequyl-s, Oxycure, Oxxo, Terramycin, Anti Bac, Pi-Coli, Tribrissen, Chloro A, Oxy A, Fura A, Bacta A, etc.

Vitamins

Vitamin preparations in use in Thailand include Agino mixer, Farm mix, PV marine oil, Aqua green, Pure Vit, Selenium Yeast, Vitapure Aqua Stable, Vitamin C, V-100, Premium VC-A, Ginovit Aquatic C, C-sulphate, Super Omega, etc.

Immunostimulants

These include products such as β-glucan, LPS, Penstrim, Immuno Guard, Vetregard, Aquagen, Berlaa, etc.

Bioremediation Products

Bioremediation products available in Thailand include DMS-100, AB-1, Biomaster industrial, Subdu, Bacillus subtilis, Aquazyme, etc.

Cost of Chemical Use in 1995

A cost/benefit analysis of various farms in the east showed that the farmers spent about 10 Baht for chemical per 1 kg of shrimp produced. In 1995, when the shrimp production reached 250,000 t, it was estimated that at least 2,500 million Baht (US$ 100 million) was spent on chemicals alone. These products are mostly imported from the USA, Canada, the UK, Australia and Japan.

HAZARDS AND ADVERSE IMPACTS

In response to the extensive use of antibiotics, resistant strains of pathogenic bacteria may have increased considerably; and this increase could create a great deal of difficulty in the treatment of bacterial infections in aquatic animals.

Numerous studies have been carried out on the effects of drugs on larval quality. The use of synthetic drugs in hatcheries, especially chloramphenicol and oxolinic acid, may adversely affect larval growth and inhibit defense mechanisms. They may reduce the activity of acid or alkaline phosphate acid, which are considered to play a major role in the protein metabolism of shrimp.

Larval shrimp that consume drug-laced feed and antibiotics incorporated with steroids usually have good appearance and uniform size. Once they leave the hatcheries and reach the grow-out ponds, however, they become sensitive to external stresses and pathogens, resulting in growth retardation and/or mass mortality. Shrimp broodstock fed diets containing nitrofurans for a long period may produce eggs of lower quality.

Some chemicals, such as a mixture of formalin and malachite green, give a very effective treatment against "Ich," but malachite green has teratogenic and toxic potential.

Insecticides such as Dipterex have been widely used as effective treatments for crustacean parasites in fish ponds. Since their introduction into shrimp culture systems to treat small shrimp and other viral disease vectors such as crabs, the amount of these chemicals applied by aquaculturists has increased considerably, causing a great concern for the environment, as very little is known about their residues in aquatic animals and in the environment.

The currently quoted prices for the commercial chemical products available in Thailand are presented in Table 3.

Table 3. Current prices for commercially available chemical products used in aquaculture in Thailand.

Chemical Product	Price (US$)	Size of Package
Pond and Water Treatments		
Zeolite	5-8	20 kg
Artificial dyes	120-140	1.5 kg
Bacterial product	20-60	5 L
Disinfectants		
B.K.C. 50%	80-120	20 L
B.K.C. 80%	200-250	20 L
Copper chelate	300-350	20 L
Povidone-iodine 10%	150-200	20 L
Vitamin and Feed Supplements		
Aquatic - C Coated-vite	10-15	1 lb
C - sulphate	10-15	1 lb
Fish oil	12-18	4 L
Squid oil	70-90	20 L
Antibiotics		
Oxytetracycline	20-30	1 lb
Oxolinic acid 50%	60-70	1 lb
Furazolidone	20	1 lb

NATIONAL REGULATIONS ON THE USE OF CHEMICALS IN AQUACULTURE

In Thailand, there is no specific legislation regarding the use of therapeutic drugs and chemicals in aquaculture. Their uses are unregulated.

Most veterinary drugs are similar to those used in human medicine, while chemicals used in aquaculture are the same as those used for agricultural purposes. The Ministry of Public Health is responsible for human drugs. The Ministry of Agriculture and Cooperatives is responsible for the chemicals used in agriculture. Recently, the Department of Fisheries, under the permission of the Ministry of Industry, took full responsibility for the regulation of 12 hazardous compounds commonly used in aquaculture. These are:

1. Acetic acid < 80% w/w
2. Benzalkonium chloride
3. Calcium hypochlorite
4. Chlorine
5. Fentin acetate
6. Trichlorfon
7. Formaldehyde
8. Hydrochloric acid < 15 % w/w
9. Rotenone
10. Sodium hydroxide < 20 % w/w
11. Sodium hypochlorite
12. Trifluralin

Importation of these compounds for use in aquaculture must be registered at the Department of Fisheries.

ON-GOING RESEARCH ON CHEMICAL USE FOR AQUACULTURE

Several research institutes in Thailand are involved in aquatic animal health research. These include:

- Aquatic Animal Health Research Institute (AAHRI), Bangkok
- National Institute of Coastal Aquaculture (NICA), Songkhla
- Faculty of Fisheries, Kasetsart University, Bangkok
- Faculty of Veterinary Medicine, Kasetsart University, Bangkok
- Faculty of Veterinary Medicine, Chulalongkorn University, Bangkok
- Faculty of Marine Science, Chulalongkorn University, Bangkok
- Mahidol Medical University, Bangkok

All of these institutes are actively involved in aquatic animal health research and research on proper chemical usage. AAHRI and NICA actively provide health management services and advice on chemical uses to farmers.

Some studies are being conducted by AAHRI on shrimp defense mechanisms and immunomodulation to enhance sustainability and reduce antibiotic usage in shrimp culture. AAHRI also does research on bacterial diseases of frogs and softshell turtles and methods for their control.

At NICA, the effect of guava (*Psidium guajava*) extract against some fish and shrimp pathogens is being studied. Studies of the immune system of black tiger prawn (*Penaeus monodon*) and on the production of bacterial and viral vaccines are also being done.

Information on chemical effects and their uses is limited in Thailand. Available information is generally obtained from text books and the scientific literature; however, information on the results of some experiments on the concentrations and efficacies of chemicals used against parasites and diseases found in Thailand and their withdrawal periods is available at the above-mentioned institutes. At present, fish and shrimp farmers obtain information on chemical usage through seminars organized by government agencies, chemical suppliers and their consultants.

RECOMMENDATIONS

To Farmers:

- Do not use chemicals to attempt to overcome poor management.
- Do not let aggressive promotion by suppliers of chemical products lead to the overuse of these drugs.
- Do not use chemotherapeutants due to their availability; use them only as a last resort.
- Treat diseases based on accurate diagnoses, and treat them as early as possible.
- Remember that high stocking density leads to a greater risk of disease and an increase in the need for chemical use.

To Producers and Suppliers of Chemicals:

The industry must be responsible for giving accurate information on the specificity of chemicals and must clearly exhibit the ingredients of each product.

To Government Agencies:

- It is the government's responsibility to establish rules and regulations on uses of drugs and chemicals.
- The government should try to find effective means to raise awareness among farmers, not only to maximize their production, but also to make them aware of the impact of chemical use on the environment and public health.
- National drug and chemical regulating boards must be established to work closely with the aquatic disease research institutes.
- Enough disease diagnostic laboratories must be established to give adequate service to farmers.
- There is an urgent need to establish an information center within the country and internationally to update, distribute and exchange information.
- An effective quarantine system should be established to prevent disease transmission.

To Regional and International Organizations:

- There is an urgent need to promote regional and international cooperation on disease prevention and to support research on chemical uses in aquaculture.
- An information center on aquatic animal health is urgently needed, especially to maintain epizootilogical records and to exchange this information.

To Scientists:

- Scientists need to conduct more research on chemical use in aquaculture to ensure their effectiveness and safe uses.
- Scientists should consider and prioritize research to meet the urgent needs of farmers.
- The information obtained from research results must be immediately disseminated to farmers.

However, on-farm trials should be conducted, as many of the chemicals appear not to be effective when applied in ponds or hatcheries.

- It is the responsibility of the scientists to inform the government if any drug or chemical must be prohibited.

CONCLUSIONS

Clearly, chemicals and drugs play an important role in present aquaculture systems, whether they are intensive, semi-intensive, semi-closed or closed systems. However, it is also obvious that good management can considerably reduce the chemical use in aquaculture. Certain types of chemicals, if used inappropriately, can cause damage to animals and the environment. Overuse of chemicals, especially antibiotics, not only increases production costs but also intensifies adverse consequences.

The adverse impacts of chemical use in aquaculture may be outweighed by their advantages; however, there has been increasing concern about their uses, and they must be used with great caution. Chemical residues in food products originating from aquaculture and the effects of chemicals on the aquatic environment should be monitored.

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