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The Use of Chemicals in Aquaculture in Malaysia and Singapore

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ABSTRACT

Aquaculture is an increasingly important force in both the Malaysian as well as the Singaporean economies. In recent years, Singapore has focused on the aquarium fish trade, making it one of the largest ornamental fish production and transhipment centers in the world. Similarly, the Malaysian aquaculture industry has made rapid strides in the last few years and is poised to become a major contributor to the national fish supply by the early part of the next century. A significant trend in both countries has been the growing intensification of culture systems to achieve higher production per unit area. This has led to a greater occurrence of disease, particularly among aquarium fish, shrimp and marine fish farms. To obviate and control these diseases, there has been a concurrent increase in the use of chemotherapeutants. The three major groups of commonly used chemotherapeutants are: topical disinfectants, antimicrobials and probiotics. There is a wide range of topical disinfectants used by aquafarmers. The most common of these include lime, teaseed cake, formalin, benzalkonium chloride, acriflavine, malachite green, hypochlorite and poly-vinyl pyrrolidine. Of these, lime and teaseed cake are used exclusively in ponds, and acriflavine and malachite green only in hatcheries, while the others are used in both systems. Antimicrobials being

used include sulfonamides, tetracyclines, nitrofurans, chloramphenicol, oxolinic acid and virginiamycin. A number of other chemotherapeutants are also used, albeit on a limited basis. The current concerns surrounding the use of chemotherapeutants and the legislative framework surrounding their sale and distribution are also discussed.

INTRODUCTION

The Malaysian and Singaporean aquaculture industries are of relatively recent antecedents, the first recorded attempt being the culture of Chinese carps in mining pools at the early part of the century (Tan 1998). However, by the mid-1990s, the industry in both countries had begun to acquire a strong economic profile, producing both food and ornamental fish. In 1994, total aquaculture production in Malaysia amounted to 114,114 mt of food fish valued at US$145.8 million and 227.8 million aquarium fish valued at $17.5 million (Department of Fisheries 1994). In the same year, the Singaporean aquaculture industry produced 2,821 mt of food fish and aquarium fish valued at $10.7 million and $54.5 million, respectively.

The growth of the aquaculture industry in both countries has been spurred by government support in the form of research and development, and extension and support services, as well as financial incentives. Under these circumstances, it is likely that production will continue to increase in the future. While this increase will no doubt come from an expansion of the area under culture, most of it will probably be from intensification of existing culture sites. Given the increasing cost of land and labor in both countries, it is likely that future development in the industry will gravitate toward a more comprehensive use of land and water resources, and the employment of sophisticated production technology to maximize unit output and reduce labor requirements. The implemented intensification has some consequences. In particular, the employment of high-density culture increases the chances of epizootic infections. Fish diseases, once considered only of academic importance, have acquired significant recognition in recent years, and widespread epizootic infections have been a serious obstacle in the development of aquaculture, particularly shrimp and marine fish farming. Diseases in Malaysian aquaculture have been reported as far back as the mid-1980s (Anderson 1988). Shariff and Subasinghe (1993) identified a number of parasitic, bacterial, viral and fungal pathogens common in the Malaysian aquaculture industry. Losses through disease are considered significant, although hard data are lacking. Recent disease outbreaks in Kedah are thought to have cost the industry up to $10 million (Shariff 1995). In Singapore, diseases such as sleepy grouper disease and viral nervous necrosis in groupers have affected valuable stocks, causing significant losses in recent years (Chua *et al.* 1993).

Fish disease is usually mediated by the presence of the pathogen and unfavorable environmental conditions that predispose the animal to infection. In aquaculture, most disease problems arise out of poor sanitation and water quality. While the more obvious strategy would be to improve sanitation as a first step, the acute mortalities that characterize many epizootics do not allow a window where such sanitation measures can take effect immediately. In addition, many farmers tend to look for a "quick fix solution" for the disease problems that face them. Both these factors have encouraged the use of chemotherapeutants in disease management.

The term chemotherapeutant covers any medication, drug or chemical that is used in preventing or combating disease and which can be used either for prophylaxis or for treatment. This definition also includes those chemicals used to improve the rearing environment. However, it does not include nutritional supplements such as vitamins and immune enhancers, although these have, no doubt, an important role to play in disease management.

A wide range of chemicals and drugs is used in the aquaculture industry worldwide. Few, if any, have been specifically developed for the aquaculture industry *per se*. Most are holdovers from human and veterinary medicine or wastewater treatment. There has been little work on the toxicity, pharmacology and pharmacokinetics of drugs and chemicals applied in fish and invertebrate culture systems. Most studies that have been undertaken were based upon temperate conditions and species. Thus, much of chemotherapeutant use is based on ease of availability and on guess-work, rather than on a systematic protocol involving identifying pathogens and prescribing the appropriate treatment.

Chemotherapeutants can be divided into four major groups, i.e., topical disinfectants, antimicrobials, probiotics and anesthetics. Topical disinfectants cover a wide range and are used mainly to eliminate external opportunistic bacteria, fungi and protozoans. Antimicrobials are basically antibacterial drugs. Although there is a great variety of such drugs, the focus has been generally on antibiotics and sulphonamides. The third group is composed of probiotics or bacterial concentrates that are used to enhance microbial degradation of organic accretions in the pond, thus reducing the biochemical oxygen demand and the possibility of anaerobiosis. The fourth group, anesthetics, includes substances that are used to sedate fish during transport and handling. The widespread use of these chemotherapeutants without control can lead to serious problems.

This paper outlines the status of use of the major chemotherapeutants used in the Malaysian and Singaporean aquaculture industries and suggests means to enhance their effectiveness.

TYPES OF CHEMOTHERAPEUTANTS USED

The main chemotherapeutants used in the local aquaculture industry are as follows:

Topical Disinfectants

Lime

Liming is considered an integral part of pond management and is undertaken for a number of reasons. These include improvement of soil chemistry like reducing soil acidity, increasing total alkalinity, neutralizing sulfides and acids, precipitating suspended or soluble organic material, decreasing biochemical oxygen demand, improving fine textured bottom soils in the presence of organic material, and improving nitrification (Kungvankij and Chua 1986). Lime is also used as a piscicide and for disinfection (Apud 1984).

There are several types of lime that are used in grow-out ponds. The most common is ground magnesium limestone (GML), which is a mix of calcium and magnesium carbonate. The extensive use of GML is related to its availability. It is used widely in the agriculture sector for soil improvement and can be found in any agriculture supply shop. However, its calcium carbonate fraction is not soluble in sea water, and is not an effective buffer (King 1973). Calcium oxide is also used, although not as frequently as GML. This is because it is caustic and must be handled with some care. Limestone products and derivatives are widely manufactured and sold within the country, although some are imported from Thailand. To increase the pH of water, 100-300 kg/ha is applied in shrimp ponds during the culture period, whereas 2-5 mt/ha is used for pond preparation. The price of lime ranges from $40-65/mt.

Saponin

Saponin has been traditionally used by aquafarmers as a piscicide to kill predator fishes prior to stocking. It is particularly favored by shrimp farmers because it is toxic to fish but not to crustaceans. It is also used to facilitate molting in shrimp. The main source of saponin is teaseed cake, the residue from oil processing of the seeds of *Camellia* sp. that contain 10-15% saponin. As there is no teaseed cake production locally, all teaseed products are imported from China or Myanmar. However, saponin concentrates containing 100% active ingredient imported from China are now available and are increasingly replacing teaseed cake.

Saponin is also effective against a number of pathogens. Saponin (20-30 ppm) has been recommended for the treatment of blackspot disease in shrimp. Saponin can also be used to control algal fouling. Teaseed cake at 3.5-5 kg/1000 m^2 is also promoted as a treatment for tail rot and is used at 5-25 ppm to treat protozoan infections (Baticados and Paclibare 1992). Locally, it is applied at 2-3 ppm for 24 h to stimulate molting in shrimp. The same application also helps prevent and get rid of protozoan and other fouling organisms on the shrimp body. The concentrated form is sold at $6/kg, whereas teaseed cake is available at $0.40/kg.

Formalin

Formalin has a very old history as an aquatic chemotherapeutant. The first recorded use of formalin in the treatment of fish disease was in 1909 (Alderman and Michel 1992). Formalin kills microorganisms by condensing with amino acids to form azomethines. It is active against a wide range of organisms, including fungi, bacteria and ectoparasites (Herwig 1979). However, its action is slow. At a concentration of 5,000 ppm, 6-12 h is required to kill bacteria and 2-4 d to kill spores. At 80,000 ppm (8% solution), it requires 18 h to kill spores (Harvey 1975). It is also ineffective against internal infections. Formalin has been approved by the US FDA for use in treatment of food fish.

Locally, formalin is used both in hatcheries and in ponds. In the hatchery, formalin is used for prophylaxis as well as treatment. Gravid broodstock are disinfected with formalin to prevent vertical transmission of disease. The rate used varies from 100-200 ppm for 1-2 min, although the recommended rate for this purpose is 25 ppm for 10-15 min (Platon 1978). With respect to treatment, formalin is used mainly for ciliate protozoan infestations. In addition, it is also being used to control necrotic shell and gill diseases of shrimp. The recommended dosage rates are 150 ppm for a 1 h bath and 25ppm for long-term treatment.

Formalin is also applied directly in ponds at rates varing from 10-25 ppm, especially during disease outbreaks, as a cure-all remedy. However, the effectiveness of formalin is uncertain. Formalin binds with organic matter and a large excess must be applied to overcome depletion (Harvey 1975). However, formalin also causes oxygen depletion (Plumb 1992) and this excess can be deleterious in the long run. Even if effective, the action of formalin would be too slow to be of any significant use.

On the other hand, the farmer runs the risk of destroying beneficial bacteria such as the nitrifying bacteria during formalin treatment. At the concentrations at which formalin is an effective and a rapidly acting germicide, it causes alteration of tissue proteins, causing local toxicities and promoting reactions such as eczematoid dermatitis. The chemical is also noxious to humans and can induce nausea if used for prolonged periods. Additionally, there appears some contemporary information that formalin may have some carcinogenic properties. Handling of formalin by the farmer, therefore, must be undertaken with care.

As a chemotherapeutant, formalin is inexpensive. The current cost of laboratory-grade formalin is about $3/L. However, industrial grade formalin is available at $16.00/25 kg/drum. Both grades are manufactured locally.

Benzaklonium Chloride

Benzaklonium chloride (BKC) is a cationic compound that, like formalin, is toxic to a wide range of bacteria, fungi, and viruses. Unlike formalin, however, it is non-irritating to tissue and has a rapid onset of action. It does not, however, kill spores. Herwig (1979) recommends its use at 2 ppm for treating bacterial, protozoan and monogenean infections. BKC has also been recommended as a bactericide and fungicide in shrimp hatcheries. Suggested dosages are 1-1.25 ppm to treat vibriosis, 0.1 ppm for 16 h for protozoea and mysis, 0.2 ppm for 24 h for early stages of postlarvae (PL), and 0.94 ppm for 24 h for PL18. (Tonguthai and Chanratchakool 1992).

Despite, its superiority over formalin, BKC is not commonly used in local hatcheries. However, an application rate of 0.8 ppm of commercial BKC (50% active ingredient) for 1-2 d is used to treat infections in shrimp ponds. The cost of the product, which is imported from Britain, is about $4/kg. Like the use of formalin, the impact of BKC on pond conditions is uncertain. The reduction of pathogenic organisms has to be balanced by the concurrent loss of beneficial microflora that play a vital part in maintaining the integrity of the pond ecosystem. Most of the BKC available locally comes from Thailand, Taiwan or Korea.

Acriflavine

Acriflavine is a mixture of 3,6-diamino-10-methylacridinium chloride and 3,6-diaminoacridine. Known also as Trypaflavine, it has been used extensively in egg disinfection; as an antiseptic for treating wounds, ulcers, and bacterial lesions; and in protozoan and monogenean infections. Acriflavine is normally used as a long-term bath and is known to kill plants. It may also create vulnerability to bacterial disease in marine fish.

In the local context, acriflavine is used to a limited extent in shrimp and aquarium fish hatcheries as a broad-based prophylactic agent and therapeutant. The main impediment to its widespread use is cost. Although widely available, good quality acriflavine imported from Thailand costs about $240/kg. At an application rate of about 10 ppm, this would amount to a cost of about 26 cents/100 L of water. There appears to be little information to indicate the efficacy of acriflavine on shrimp, although its use on fish has been well established (Herwig 1979). Further research into the pharmacology and pharmacokinetics of the chemical is required.

Malachite Green

Malachite green is the common name for p,p-benzylidenebis-N,N-dimethyl aniline. It was originally developed in the 1920s as a textile dye. In its original form, it contained zinc, which is toxic to fish. However, later variants came in a zinc-free form, making it more applicable as a therapeutant. Malachite green has been extensively used in controlling infections due to bacteria, fungi, protozoans and monogenetic trematodes on eggs, fry and adult fish (Herwig 1979). It is used by itself, or in combination with salt or dimethyl sulphoxide (DMSO). Next to formalin, it is, perhaps, one of the most important therapeutants in the aquaculture industry.

In recent years, however, there have been strong moves against malachite green application, especially with respect to its use in food fish. This is because the chemical has a moiety that is known to be carcinogenic. While there has been no evidence actually linking malachite green with any carcinoma, the US FDA has banned its use in food fish. Studies have also indicated that malachite green may have very long withdrawal times. Meinertz *et al.* (1995) established that residues of malachite green could be found in fry some 30 d after eggs were disinfected.

Locally, malachite green is commonly used in fish and shrimp hatcheries for the treatment of fungal and ciliated protozoan diseases. It is also extensively employed in the aquarium trade for the same purpose. It is either dissolved directly in the rearing water or combined with formalin. The cost is about $48/kg for the dry powder, although liquid concentrates are commonly sold. Most of the malachite green used in Malaysia and Singapore is imported from Taiwan; a significant amount also comes from Germany. It is usually applied at 1-2 ppm for short exposure, and for long baths at 0.01 ppm for shrimp postlarvae and 0.1 ppm for juveniles.

Hypochlorite

Both sodium and calcium hypochlorites have a long tradition of use in the local aquaculture industry. Both have been used in hatchery as well as pond situations. Hypochlorites act by releasing hypochlorous acid, which is the primary active ingredient. Hypochlorites are potent germicidal agents. They are particularly effective in acidic conditions. For example, the bactericidal effect of hypochlorite is 10 times greater at pH 6 than at pH 9. At pH 7.0, a 0.1-0.25 ppm hypochlorite solution will kill most organisms within 15 to 20 sec. However, some acid-fast pathogens, particularly *Mycobacterium*, require concentrations 500 times higher.

Hypochlorites are too toxic to be used directly on tissues and therefore cannot be used for treatment or prophylaxis. Both products, however, are used extensively as disinfectants. In hatcheries, hypochlorites are used to disinfect tanks and equipment. They are commonly employed during the break cycle, when the entire hatchery system, including water and aeration pipes, is subject to thorough disinfection.

In ponds, hypochlorites have been traditionally used as piscicides (Apud 1984). However, a more recent use has been their application to disinfect incoming water. Water is pumped into reservoir ponds and then treated with hypochlorite (mainly calcium hypochlorite) to reduce bacterial load. This approach was particularly prevalent among farmers in the Sungai Merbok area in Kedah over the last two years to prevent their ponds from being affected by high levels of *Vibrio* in the river. Limsuwan (1993) also reported that calcium hypochlorite was being used directly on the pond bottom by Thai farmers during fallow periods to prevent yellowhead disease. Locally, farmers use 20-30 ppm of hypochlorite for pond disinfection. A dosage 0.08 ppm is used for prophylaxis in ponds with shrimp. There is no equivalent application where freshwater ponds are concerned. Hypochlorites are easily available and inexpensive. The cost of sodium hypochlorite (10%) is $20 for a 25 kg drum. Calcium hypochlorite, which is sold in a powder form containing 65% free chlorine, costs $120 for a 50 kg drum. Hypochlorites are manufactured locally or imported from China.

Polyvinyl Pyrrolidone Iodide

Polyvinyl pyrrolidone iodide (PVPI) is an iodophor compound sold under the name Betadine or Ovadine. An iodophor compound is basically a complex of iodine with a solubilizing agent or carrier that liberates free iodine in solution. Iodine, like chlorine, is a halogen and has a strong oxidizing capability. It is lethal to microflora and to viruses, which are killed within 15 min in a 50 ppm solution (Harvey 1975).

Like chlorine, PVPI can be used only for disinfection and is too toxic for treatment or prophylactic purposes. However, it has a much lower toxicity as compared to chlorophors (such as hypochlorite) and thus can be used to treat eggs of shrimp and fish. In addition, PVPI is not inactivated by organic matter to the extent that chlorine is. Even a solution as dilute as 10% PVPI will exert adequate bactericidal action in the presence of organic matter.

PVPI has been found to be effective against viruses on salmonid eggs (Amend and Pietsch 1972), against bacteria on trout eggs (McFadden 1969) and against fungi (Ross and Smith 1972). Shrimp eggs and nauplii can also be disinfected by immersing them in 100 ppm PVPI for 1 min or at 400 ppm for 30 sec. The eggs or nauplii are then immersed in a 1 ppm PVPI solution for 1 min before being rinsed and returned to the incubation jar.

PVPI use in local circumstances appears to be limited due to its high cost and limited availability. PVPI use in egg disinfection was only introduced in 1995, while its use as a hatchery disinfectant is still not widespread. On the other hand, PVPI is being used in ponds, especially in combatting viral infections. Although hard data are lacking, anecdotal feedback on its use indicates that it is efficacious. PVPI is sold in 10% solution at a cost of $7.2/L. PVPI is generally imported from Korea and the United States.

Zeolite

Zeolite is often used by fish and shrimp farmers to improve pond bottom condition. This is related to its capacity to absorb ammonia and metabolites from water. However, the efficacy of zeolite in this respect diminishes with increasing hardness. Zeolite has been found to be almost totally ineffective in absorbing ammonia when immersed in sea water. Under these circumstances, the value of using zeolite in shrimp ponds is highly questionable. Further research is needed to establish if zeolite is cost effective in shrimp ponds. Zeolite is produced locally and is also imported from Indonesia, Japan and Thailand. It is sold at $160-400/mt. It is usually applied in shrimp ponds at 300-500 kg/ha.

Copper Sulphate

Copper sulphate is a broad-based disinfecting agent used in some shrimp and aquarium fish farms. It is effective against a wide range of organisms including blue-green algae, bacteria, fungi, protozoans, digeneans, leeches and monogeneans (Herwig 1979). Overdosing can easily kill the animals being treated, and thus caution is called for in its use. In the context of the local industry, copper sulphate is used at a rate of 0.5 ppm in freshwater aquaria and at 0.5-1 ppm in marine shrimp ponds. It is imported from China and sold at $2.5/kg.

Organophosphates

Organophosphate pesticides are used in both freshwater fish ponds and marine shrimp hatcheries to control infections by crustaceans, and monogeneans and ciliates, respectively. The main organophosphates used are Malathion (O,O-dimethyl s-(1,2 biscarbethoxyl ethyl) phosphorothioate), Dipterex (also sold as Masoten) (O,O-dimethyl-2,2,2, trichloro-1-hydroxyethyl phosphate), Dichlorvos (O,O-dimethyl O-(2,2-dichlorovinyl) phosphate), and Dursban (O,O-diethyl-O-3,5,6-trichloro-2-pyridyl phosphorothioate). All three are effective against crustacean parasites (especially *Lernaea* and *Argulus*), and protozoans (*Ichthyophthirius, Trichodina*), and are used as broad-spectrum anthelminthics to control monogeneans. In Singapore, Demerin (chlorophenyl difluorobenzoyl) has been recently introduced as a treatment for *Lernaea*.

In many freshwater fish farms, these organophosphates are also used to control aquatic insects that prey upon fish fry, such as dragonfly larvae. Dosage is usually about 0.5-1 ppm administered daily for 3 to 7 d. In shrimp farms, organophosphates are used mainly to eliminate crustaceans that are vectors of whitespot virus in the rearing water. The water is treated in reservoirs at the rate of 0.5 ppm for 2 d before being channeled for use. Organophosphates are imported from Europe and sold at $18/kg.

Antimicrobials

There is a wide variety of antimicrobials used for treating fish and shrimp diseases. In practice, however, legal restrictions prevent the use of many of them on a large-scale basis. Almost all the antimicrobials in use are generic imports from China and Thailand. Commercial preparations (non-generics) from Japan, Europe, and North America generally come with adequate labelling containing information on composition and some precaution about their application. The main antimicrobials being used are:

Sulfonamides

Sulfonamids are a group of antimicrobial agents that act by blocking the folic acid pathways of susceptible microorganisms. Sulfonamides today are popularly promoted by regulatory authorities world wide, mainly because of their rapidly declining use in human medicine (Brander and Pugh 1977). There are many sulfonamides, such as sulfamethazine, sulphamerazine and sulphathiazole. There are also potentiated sulfonamides such as Romet-30 and Tribessen, both of which are approved for use in food fish by the US FDA. Locally, the main sulphonamides used are Daimethoprim or Tribressen (which is a sulphonamide-potentiated trimethoprim) and sulphamonomethoxine and sulfadimethoxine, both of which are sold under the trade name Dimeton and cost about $18 for a 45 gm pack.

Dimeton is used in hatcheries to control bacterial infections including *Vibrio* sp. It is, however, not a preferred antimicrobial because of its limited efficacy and high cost. Dimeton is also used in some parts of the country to treat fin rot in seabass and grouper reared in floating cages. One half gm is added to each kg of trash fish. Shrimp hatcheries use it at 20 ppm. Sulfonamides tend to induce resistance in target pathogens and thus cannot be used for any length of time. Potentiated sulfonamides are generally more effective and less amenable to inducing resistance. There are two commercially available potentiated sulfonamides on the market: Romet-30, which is sulphadimethoxine potentiated with ormetoprim, and Tribressen, a sulphadiazine potentiated with trimethroprim. The original drugs are too expensive for general use. Generic sulphadimethoxine and trimethoprim can be acquired separately at reasonable prices but must be blended by the farmers themselves. Other sulfonamides have not been extensively used in the local aquaculture industry.

Tetracyclines

Tetracyclines belong to a group of broad-spectrum antibiotics whose action is mainly bacteriostatic by causing interference with bacterial protein synthesis (Alderman and Michel 1992). They are effective against a wide range of Gram-negative and Gram-positive bacteria. The most widely used tetracycline is oxytetracycline. Developed by Pfizer at the end of World War II, it is the only antibiotic allowed for food fish use in Canada and the United States, although all use of the antibiotic must cease 21 d before fish are to be harvested for human consumption.

Locally, the use of oxytetracycline in the livestock industry, particularly swine and poultry farming, is very common. It is quite natural that aquaculture would take its cue from this situation. The drug may be administered through feeds or simply dissolved in water and absorbed through the gills. Oral administration calls for the drug to be combined with feed at a rate of 3-5 gm/kg. Dosage in a dip or bath situation is about 20 ppm. The drug is available through selected stores licensed under the Poisons Act, 1984 to retail veterinary pharmaceuticals. The cost is about $32/kg.

The efficacy of oxytetracycline in brackishwater ponds is very limited. Oxytetracycline binds with the calcium and magnesium in sea water to form a complex that is unable to penetrate the gill lining. As much as 95% of the efficacy of the drug is inactivated this way in sea water. Oxytetracycline administered through the feed also meets a similar fate in the lumen of the shrimp's gut.

Nitrofurans

Nitrofurans, such as furoxone, nitrofurazone (Furazolidone) and nifurpirinol (Furanace) were thought to hold promise for aquaculture at one time. Furanace has since been totally banned for its carcinogenic potential, while the use of the other two has been severely limited. In Malaysia, all three are still available for use by the aquaculture industry, although they are not extensively used.

Administration is through the feed at a rate of 3-5 gm/kg. The drug is sold at licensed shops at about $36-40/kg.

Chloramphenicol

This is another widely used antibiotic that has a broad-spectrum action against a wide range of Gram-positive and Gram-negative bacteria. Although in common use in the aquaculture industry world wide, its use has been banned in almost all developed countries because of its continued use and efficacy in human medicine. In addition, chloramphenicol can, even at very low dosages, cause irreversible aplastic anemia in humans, thus posing a risk for workers handling the products. Nonetheless, it is still available in both Singapore and Malaysia, and can be purchased from licensed dealers at about $60/kg. It is usually administered through feed at 3-5 gm/kg.

Oxolinic Acid

This is a first generation quinoline antibiotic that is used only under exceptional circumstances. The main reason surrounding its lack of use is availability and cost. The cost of the product is $200/kg, making it substantially more expensive than other antibiotics currently available on the market. The antibiotic is administered through feed at 3-5 gm/kg.

Virginiamycin

Virginiamycin is a peptolide antibiotic that is widely used in animal feeds as a growth promoter. It has no application in human health. The use of Virginiamycin has been shown to enhance fish growth (Padmasothy 1987), and it has been incorporated in some fish feeds.

Dimetridazole/Metronidazole

Dimetridazole and Metronidazole are potent protozoacides that are used for the treatment of internal protozoan infections in fish. Their use is largely restricted to the aquarium trade, where they are primarily employed for treatment of *Hexamita* infections, particularly in commercially valuable species such as discus. The drugs are administered through feed at a dosage of 0.15% for 3 d.

Probiotics

Probiotics are basically bacterial concentrates employed for the bioremediation of fish and shrimp ponds. They were originally developed for waste water treatment, and have since been promoted as a effective method of reducing organic accretions in aquaculture ponds. There are over 10 brands of probiotic available locally. All are imported from Australia, Europe, Japan, Thailand, and the United States. The prices range from $20-100/kg. However, there has been little work to establish if these products really work as claimed. In addition, it is important to establish whether or not the introduction of the exotic bacteria that these products contain is deleterious to the new environment. Clearly, further research is required.

Anesthetics

Anesthetics are mainly used during handling and transport of fish to market. A significant proportion of aquaculture output in Malaysia and Singapore is sold live. Food fish and shrimp are consigned mainly to the restaurant trade, where they command prime prices (Gopinath 1990). The aquarium industry is totally reliant on live transport to move product to market. The main anesthetic used in live transport is methyl quinoline, which is sold commercially in 30 mL squeeze bottles for about $2.50 each. Recommended dosage is at the rate of 1.0 mL of the anesthetic to 13.5 L of water, although in practice the farmers administer it until the fish are sedated. A less commonly used anesthetic is tricaine methonosulfonate (TMS), also known as Finquel or MS-222. Considerably more expensive at $480/kg, TMS is used only to a limited extent. Application rates are in the range of 40-60 ppm.

Other Chemotherapeutants

A large number of other chemotherapeutants are also employed, albeit on a limited basis. These include antimicrobials such as erythromycin phosphate, Neomycin and Terramycin. Neomycin is increasingly being used in the aquarium trade as a prophylaxic (10 ppm) in packing water. This is because it is colorless and thus avoids problems with regulatory authorities in importing countries, most of which actively discourage the use of antibiotics. Since analyses of packing water for antibiotics can be complicated, most of these authorities look for the tell tale yellow coloration that normally accompanies the use of antibiotics such as chloramphenicol and oxytetracycline. Other chemotherapeutants used include sodium nifurstyrenate and disinfecting chemicals, such as potassium permanganate, chloramines, chlorine dioxide and quaternary ammonium compounds. Their use, however, is limited compared with the others listed above.

FARM MANAGEMENT AND USE OF CHEMOTHERAPEUTANTS

Prophylaxis

The most common measures taken by Malaysian and Singaporean aquaculturists to obviate diseases relate to good management practices and effective environmental management. These include keeping stocking densities within prudent limits and ensuring optimal water exchange.

The most common means of chemical prophylaxis is liming. Pond liming is carried out during the pond preparation phase that precedes the beginning of a culture cycle, immediately after drying. Lime is broadcast by hand, and more often than not, it is not evenly distributed on the pond bottom. Lime is allowed to sit for varying periods of time ranging from to 1 d to 3 wk before the ponds are filled for stocking. Liming may also be carried out during the production phase, although this practice is infrequent.

Another prophylactic measure that is gaining popularity, particularly in shrimp farming, is the application of hypochlorites (chlorination) during pond preparation or immediately after harvest. This practice, however, is not common in freshwater pond culture. Many aquarium fish farms routinely disinfect their tanks with hypochlorite, formalin or PVPI prior to their use. Prophylactic treatment of aquarium fish with antiseptics and antibiotics prior to introduction into farms or during the packing process for export is also common.

Some farmers, especially those engaged in shrimp farming, administer antibiotics added to feed as a prophylactic measure. However, the relatively high cost of the drugs limits this practice to only a few farms. The use of immune enhancers such as glucans and Encap is more common. These are administered by top dressing them on the feed.

Therapeutic Measures

Therapeutic measures include administration of therapeutants in feed as well as in dips or baths. In Malaysia, both methods are common: the former is regularly used in the farming of food fish, while the latter is confined to the aquarium trade. In Singapore, administration of drugs through feed is less common. The exception to this is the use of Metronidazole-treated feed for aquarium fish.

Measures to Improve Productivity

Most farms use organic or inorganic fertilizers to produce and sustain natural productivity. There is a decided shift in the freshwater sector away from relying entirely on fertilizers to engender production, due to the potential for producing off flavors in the cultured animals. There is now a greater reliance on formulated feeds. Aquarium fish also do not rely extensively on fertilizer-generated food. For the most part, aquarium fish are reared in small ponds or tanks. Formulated feeds are the norm, with some measure of supplementation of natural food through fertilization. The same holds true for marine shrimp farming. Marine cage culture is almost totally reliant on supplied feeds.

Hazards, Impacts and National Regulations

In general, the use of chemotherapeutants has not had a negative impact on farm productivity. Occasional accidental overdose has been reported, but losses in such cases are usually limited and confined to individual farms. In 1992, a batch of Nitrofurazone from China was found to be toxic after several marine farms reported acute losses after treatment. Bioassay showed irreversible gill damage from short 10 ppm bath treatments. No further incidents were reported.

Adverse impacts of aquaculture chemicals on farm workers and consumers are also seldom encountered in Singapore. Most food-fish farmers exercise some degree of self-regulation with regard to antibiotic administration. This is because using antibiotics, particularly during the grow-out stage, is expensive in terms of both drug cost and labor. Officers from the Primary Production Department (PPD), Singapore, provide advice on withdrawal periods for food fish. Antibiotic residue surveillance is also conducted by the PPD.

In Singapore, chemicals used in aquaculture have not been implicated as causing negative enivronmental effects. Farms, especially those in the agrotechnology parks, have to abide by strict regulations on effluent quality set out by the Ministry of the Environment or risk being penalized. Effluents from land-based farms go through sewage treatment facilities before discharge.

In Singapore, aquaculture chemicals are regulated under the Poisons Act, which is administered by the Ministry of Health. All importers of chemicals are required to be licensed under this Act. The PPD is consulted before any new products are allowed into the local market. Only practicing veterinarians and licensed farmers may obtain drugs and chemicals from suppliers. Records of sales are monitored by the Ministry of Health.

The impact of chemotherapeutant use in Malaysia is unclear. There are, at present, no regulations or government agencies concerned with the use of chemotherapeutants in aquaculture. The Poisons Act, 1984 requires all drugs to be registered with the Drug Control Authority. Trade and distribution are also controlled by the Pharmaceutical Division of the Ministry of Health. As these regulations cover only the use of human pharmaceuticals, veterinary drugs do not require registration by the DCA and their movement and trade are thus not controlled.

The Poisons Act comes into the picture only when the drug in question has a human pharmaceutical use, i.e., in the case of antibiotics. Even then, the emphasis is more on its storage and sale rather than its use. The Animal Act, 1952 does have provisions to control the use of antibiotics in animal farming, but its provisions are rarely applied. In addition, those provisions do not apply for fish. The Fisheries Act (Amended 1993) does not have any regulations for controlling the use of drugs in the aquaculture sector. Most prescribing is done by untrained salespersons whose main concern is to move product. Farm workers have little knowledge on the specifics of the products or the manner in which they are to be handled. Often the products prescribed have little to do with the disease. For instance, the use of PVPI for systemic shrimp diseases like MBV is likely to be of limited efficacy. As some of these chemicals and products may enter the natural environment through the discharge water, it is likely that disruptions to the natural aquatic ecosystem may occur.

ON-GOING RESEARCH ON CHEMICALS

In Malaysia, the Fisheries Research Institute in Penang has completed some work on antibiotic residues in fish and water and plans to do more work in the future. The Freshwater Fisheries Research Institute in Batu Berandam, Melaka also conducted various treatment regimes on the common freshwater diseases. At the Universiti Putra Malaysia, routine trials on treatment regimes for specific diseases are being regularly conducted, while at the Universiti Sains Malaysia, treatment trials are usually conducted on marine cage-cultured fishes. USM has also undertaken a project on the survival of grouper fry treated with chemotherapeutic agents after shipment.

In Singapore, research on chemicals is primarily undertaken by the PPD, where studies to develop treatment regimes to control specific disease agents and to enhance the post-shipment survival of fish are carried out. Such studies are sometimes conducted with academic institutions. Monitoring of chemical residues in fish destined for human consumption is undertaken by the Veterinary Public Health Laboratories of the PPD.

CONCLUSIONS AND RECOMMENDATIONS

In Singapore and Malaysia, the use of chemotherapeutants in the aquaculture industry is not as yet worrying. However, Malaysia needs more comprehensive mechanisms to monitor the types of chemotherapeutants used and the manner in which they are administered. This would be, in fact, a precursor to a legislative framework that would ultimately guide the industry. In Malaysia, this mechanism does not exist. Singapore has a much more developed administrative and legislative mechanism to manage the use of chemotherapeutants by the industry.

Several other sound recommendations were made by Shariff (1995), including the need for more studies on the efficacy of antibiotics and chemotherapeutants to specific diseases under tropical conditions. Currently, such information is limited to temperate situations. Investigations should be made on the commonly used chemotherapeutants in relation to the duration of treatment, optimal dosages, efficacy in different systems and for different fish species, and residual patterns in the host and the environment. The latter is very important in the perspective of consumer health and the impact on the environment.

Research should also be conducted to understand the pond dynamics in relation to the use of bioremediation in shrimp farming, since it is claimed that keeping the water clean reduces mortalities. However, many of the products used for bioremediation were developed in temperate countries. Investigations should be made on the possible impacts exotic microorganisms may have on the natural aquatic ecosystems. Meanwhile, researchers should also focus on the use of local microorganisms, as these might be more effective.

Overall, research should be orientated towards developing more environmentally friendly chemotherapeutants, and on the use of immunostimulants and non-specific enhancers incorporated in diets. Emphasis should also be given to the development of vaccines, which have been used successfully in the west.

A more holistic approach and a proper understanding of the environmental factors should be made, with less reliance on chemotherapeutants. Prevention will be easier by providing a better environment for the host, so that it will be able to combat a wide range of pathogens without the use of chemotherapeutants. It must be cautioned that chemotherapeutants, vaccines and immune enhancers can only be used with success if the host is not already under stress from poor environmental conditions.

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