The Use of Chemicals in Aquaculture in the Philippines

Erlinda R. Cruz-Lacierda
Leobert D. de la Peña

Aquaculture Department
Southeast Asian Fisheries Development Center,
5021 Tigbauan, Iloilo, Philippines

and

Susan C. Lumanlan-Mayo

Bureau of Fisheries and Aquatic Resources
Quezon Avenue, 3008 Quezon City, Philippines

ABSTRACT

The intensification of aquaculture in the Philippines has made the use of chemicals and biological products inevitable. A recent survey conducted nation wide among shrimp and milkfish culture facilities revealed the use of more than 100 products for rearing, prophylaxis, and treatment purposes. The most commonly applied chemicals are disinfectants, soil and water conditioners, plankton growth promoters, organic matter decomposers, pesticides, feed supplements, and antimicrobials. All of these are readily available in the market. The dosages, purposes, patterns of use, origins, and manufacturers of these chemicals and biological products are discussed in this paper.

The indiscriminate use of chemicals has caused mortalities and morphological deformities in the host and development of antibiotic-resistant bacterial strains. The use of chemicals in aquaculture also poses dangers to public health. Government policies regulating or prohibiting the use of certain chemicals for aquaculture have helped curtail the destructive consequences of chemotherapy. Moreover, research institutions have geared their studies towards discovering environmentally safe drugs and other alternatives to disease control. However, these efforts will be futile unless a strong and aggressive campaign on the cautious and restricted use of drugs in aquaculture is conducted among shrimp and fish farmers, drug manufacturers and suppliers.

INTRODUCTION

In the Philippines, aquacultural activity is largely directed toward the production of milkfish (*Chanos chanos*) and tiger shrimp (*Penaeus monodon*). Of the 220,000 ha of brackishwater ponds, 176,000 ha are devoted to milkfish and 47,776 ha to tiger shrimp culture (ICAAE 1993, BFAR 1994). In 1994, aquaculture produced a total of 226,108 mt (Table 1) of which 135,682 mt were milkfish and 90,426 mt were shrimp (BFAR 1994). Milkfish and shrimp are mostly produced in Region VI in Western Visayas. Of the 298 commercial shrimp hatcheries operating in 1992, 59.4% are also found in this region (ICAAE 1993).

The use of chemicals has become integral to traditional and intensive aquaculture and more often than not, operations are dependent on it. Chemotherapy is widely practised in the Philippines, especially to treat disease problems in shrimp-culture facilities. Chemicals are effective against multiple diseases or multiple pathogens and their application is versatile. Chemicals can be used as prophylactic agents and can be applied quickly when a disease condition occurs. They can be applied in various ways, such as in bath, by injection, or as feed additives.

Table 1. Milkfish and tiger shrimp production (mt) in the Philippines by region.[1]

Region	Milkfish	Tiger Shrimp	Total
NCR	4,216	67	4,283
I	11,875	413	12,288
II	70	30	100
III	29,247	27,749	56,996
IV	13,162	4,161	17,323
V	1,752	925	2,677
VI	39,648	38,375	78,023
VII	10,774	2,520	13,294
VIII	1,883	204	2,087
IX	10,304	6,053	16,357
X	215	1,511	1,726
XI	7,866	5,568	13,434
XII	2,091	1,507	3,598
XIII	2,007	1,276	3,283
ARMM	572	67	639
Total	135,682	90,426	226,108

[1]Source: BFAR (1994).

This paper attempts to document the general use of chemicals in aquaculture in the Philippines. It covers the chemicals and biological products used during preparation of rearing facilities, during the culture period, and during disease control, and includes notes on their patterns of use and suppliers or sources. The problems in chemical use, alternative approaches to disease prevention, the current laws and regulations on chemical use, and some recommendations are also discussed. This paper is largely based on a survey carried out throughout the Philippines with interviews conducted among fish and shrimp farmers/operators. The available published literature was also gleaned.

TYPES OF AQUACULTURE CHEMICALS USED IN THE PHILIPPINES

A survey of 18 shrimp hatcheries, 58 shrimp grow-out farms, and 26 milkfish brackishwater ponds in the Luzon, Visayas, and Mindanao areas was undertaken from July 1995 to April 1996. A questionnaire was used to obtain a comprehensive database on the types of chemicals used and their efficacies. Farm technicians, managers, and technical consultants were interviewed during these visits.

Tables 2-9 summarize the chemicals and biological products used in shrimp hatcheries and grow-out ponds, and in milkfish grow-out farms at various phases of culture. The chemical name, brand name, amount used, pattern of use, and cost and source of these chemicals are provided. More than 100 chemicals and biological products are currently being used by fish and shrimp farmers. The amounts applied vary from farm to farm and are usually based on experience, available published literature, or the supplier's recommendation. Table 10 provides a supplementary list of chemicals and biological products available in the market at the time of the study.

Table 2. Chemical and biological products used in *Penaeus monodon* hatcheries in the Philippines.

Chemical Group	Commercial Product/ % Activity	Pattern of Use	Amount Used	Price/Country of Origin/ Manufacturer/ Distributor
DISINFECTANTS:				
Calcium hypochlorite	Calcium hypochlorite, 70% chlorine	Disinfection of rearing tanks, few seconds to 24 h, splash or bath	200-1000 ppm	P 4,000/50 kg
		Disinfection of rearing water, 12-24 h	5-70 ppm	
		Disinfection of hatchery paraphernalia, few seconds to 12 h, dip or bath	10-200 ppm	
		Artemia cyst disinfectant, 5 min, short bath	20 ppm	
		Disinfection of diseased stock	50-1000 ppm	
Formalin	Formalin	Spawner disinfectant, 1 min-1 h	100-500 ppm	P 690/2.5 L
Iodine	Biodin/Argentyne	Footwear disinfectant	200 ppm	
ANTIBIOTICS:				
Tetracycline	Oxytetracycline	Every other day from stocking to harvest, long bath	1-2 ppm	P 1,300/kg, Germany
		Disease control, daily until disease disappears	2-4 ppm	
Rifampicin	Rifampicin/Rimactane	Every other day from stocking to harvest, long bath	0.1 ppm	P 28.00/600 mg, CIBA
		Disease control, daily until disease disappears	0.2 ppm	
	Bactrin Forte	Every other day from nauplii to harvest, as substitute for Rifampicin	0.1 ppm	P 20.00/600 mg
Chloramphenicol	Chloramphenicol	Every other day from Z_1 to harvest, long bath	1 ppm	P 3,000/kg, Germany
		Disease control, 3 d, long bath	2-4 ppm	
Nitrofuran	Furazolidone, 98%	Every other day from Z_1 to harvest, long bath	0.5-1 ppm	P 1,600/kg, Taiwan
		Disease control, 3 d, long bath	2-3 ppm	
	Prefuran	Disease control, 3 d, long bath	1 ppm	
Erythromycin	Erythromycin	Disease control, 3 d, long bath	2-3 ppm	P 2,000/100 gm
FUNGICIDES:				
Malachite green	Malachite green	Every other day from M_1 to harvest, long bath	0.003-0.015 ppm	P 910/100 gm
Trifluralin	Treflan-R	Every 3-5 d from stocking to harvest, long bath	0.1 ppm	
		For spawners, 1 h	5 ppm	
		Disease control	1 ppm	
FEED ADDITIVES:				
Vitamin C	Enervon C	M_1 to harvest, mix with artificial feed	1 ppm	P 6.00/500 mg
	Oderon C	M_1 to harvest, mix with artificial feed	1 ppm	
Unknown	immune enhancer	Every 3-4 d from Z_1 to harvest, long bath	0.5-1 ppm	

Table 3. Disinfectants used in *Penaeus monodon* grow-out ponds in the Philippines.

Chemical Group	Commercial Product/ % Activity	Pattern of Use	Amount Used	Price/Country of Origin/ Manufacturer/ Distributor
Benzalkonium chloride	Benzalkonium chloride	Pond prep., 10-30 cm water, broadcast	3-5 ppm	P 5,000/25 L, Clean Water
		Pond prep., 1 m water, broadcast	0.3-1 ppm	
		Disease control	0.5-6 ppm	
	Cococide chloride	Pond prep.	0.5 ppm	P 4,400/20 L, Argent
		Rearing phase	0.5-1 ppm	
Didecyl dimethyl ammonium bromide ($C_{22}H_{48}NBr$)	Bromosept-50, 50%	Pond prep., 30-50 cm water, broadcast	0.5-10 ppm	P 583.45/L, Israel, Inphilco
		Rearing phase, 1x/mo up to 1 mo before harvest	0.5-5 ppm	P 4,400/20 L
		Disease control, 1x/wk for 2 wk	0.5-3 ppm	
Iodine	Biodin	Pond prep.	5 L/ha	
Alkyl dimethyl benzyl ammonium chloride	Fabcide B-50	Rearing phase	0.5-1 ppm	P 1,200/gal, Taiwan
	Aquasept	Pond prep.	5-10 ppm	P 272.90/L, Denmark, Inphilco
		Rearing phase	0.25-1 ppm	
		Disease control	0.5-1.5 ppm	
Formalin	Formalin	Rearing phase, overnight, barnacle control	25 ppm	P 690/2.5 L
Potassium permanganate	Potassium permanganate	Pond prep., spray	2 kg/ha	P 1,250/100 gm
Malachite green	Malachite green	Disease control, daily for 2 d, 1 m water	1 kg/ha	P 300/25 gm
Unknown	CDS 100	Pond prep.	0.6-1.2 ppm	P 106.60/kg, Phils., Ino-Aqua
	PDS 100	Pond prep.	0.6-1.2 ppm	P 149.50/kg, Phils., Ino-Aqua
	SHD 1000	Pond prep., 1 m water	15 kg/ha	P 173.33/kg, Phils., Ino-Aqua
	SHD 2000	Pond prep., spray	13 kg/ha	P 190/kg, Phils., Ino-Aqua

Table 4. Soil and water treatment chemicals used in *Penaeus monodon* grow-out ponds in the Philippines.

Chemical Group	Commercial Product/ % Activity	Pattern of Use	Amount Used	Price
Lime	Hydrated lime [$Ca(OH)_2$]	Pond prep., broadcast Rearing phase, periodic Disease control	500-2,000 kg/ha 20-300 kg/ha 50-300 kg/ha	P 1,800/t
	Agricultural lime ($CaCO_3$)	Pond prep., broadcast Rearing phase, 1x/wk-daily Disease control	200-8,000 kg/ha 10-500 kg/ha 100-300 kg/ha	P 300/t
Calcium hypochlorite	Calcium hypoclorite, 70% chlorine	Pond prep., 3-7 d, 20 cm-1.3 m	50-150 kg/ha	P 4,000/50 kg
Dolomite	Dolomite	Pond prep. Rearing phase, periodic	100 kg/ha 50-250 kg/ha	P 1,200/t
Biolite	Biolite	Pond prep. Rearing phase	100 kg/ha 100 kg/ha	
Zeolite	Zeolite	Rearing phase Disease control, daily until disease disappears	80-300 kg/ha 50 kg/ha	P 350/25 kg
	Daimetin Health lime Health stone/Wonder stone	Rearing phase Rearing phase, 1x/wk until harvest Disease control, plankton die-off	100-150 kg/ha 150 kg/ha 200-400 kg/ha	

Table 5. Plankton growth promoters used in *Penaeus monodon* grow-out ponds in the Philippines.

Chemical Group	Commercial Product	Pattern of Use	Amount Used	Price/Country of Origin/ Manufacturer
Inorganic fertilizer	16-20-0 (mono-ammonium phosphate)	Pond prep., broadcast	4-100 kg/ha	P 305/50 kg
		Rearing phase, periodic, broadcast	150-300 kg/ha	
	18-46-0 (diammonium phosphate)	Pond prep.	3.2-50 kg/ha	P 405/50 kg
		Rearing phase	0.6-20 kg/ha	
	14-14-14 (NPK, complete fertilizer)	Pond prep. Rearing phase	7.5-15 kg/ha 3 kg/ha	P 310/50 kg
	46-0-0 (urea)	Pond prep. Rearing phase	5-120 kg/ha 3.2-5 kg/ha	P 380/50 kg
	0-20-0 (solophos)	Pond prep. Rearing phase	3-20 kg/ha 5-10 kg/ha	P 220/50 kg
	21-0-0 (ammonium sulfate)	Pond prep.	100-500 kg/ha	P 195/50 kg
	Calcium nitrate	Pond prep., broadcast Rearing phase, broadcast	3-50 kg/ha 5-10 kg/ha	P 450/50 kg
Organic fertilizer	Chicken manure	Pond prep., tea bags Rearing phase, tea bags	100-3,000 kg/ha 100-1,000 kg/ha	P 1,000/t
	Cow manure	Pond prep., tea bags Rearing phase, tea bags	100-500 kg/ha 100-200 kg/ha	
	Carabao manure	Pond prep., tea bags Rearing phase, tea bags	240-300 kg/ha 100-200 kg/ha	
	VIMACA (chicken/ pig manure)	Pond prep., tea bags	1,000 kg/ha	P 75/50 kg
	B-4	Pond prep., substitute for manure	50 kg/ha	
Nutrients, others	Lab-me	Pond prep., 2 applications	200 mL/ha/wk	P 120/L, U.S.A., Nutri-Systems
	Algae grow	Pond prep.	0.5 ppm	P 127/kg
	Unknown growth factor	Pond prep., broadcast	30 kg/ha	Taiwan
	PA-100	Rearing phase, every 15 d up to DOC 90	15 kg/ha	
		Pond prep.	0.1-0.2 ppm	P 130/L, Philippines, Ino-Aqua

Table 6. Organic matter decomposers used in *Penaeus monodon* grow-out ponds in the Philippines.

Chemical Group	Commercial Product	Pattern of Use	Amount Used	Price/Country of Origin/ Manufacturer
Bacteria + enzyme Preparation	ER 49	Pond prep., broadcast	4-5 kg/ha	P 1,350/kg, U.S.A Nutri-Systems
	NS-SPO series	Pond prep.	160-320 gm/ha	
		Rearing phase, every 7 d until harvest	2-3 kg/ha/culture	
		Disease control	1 L/ha	P 1,100/kg, U.S.A., Nutri-Systems
	Biozyme	Pond prep.	5 kg/ha	
		Rearing phase, every 7 d until harvest	5 kg/ha	
	Micro aid activator	Pond prep.	5-20 kg/ha	P 250/kg, Japan
		Rearing phase, 1x/wk up to harvest	10-20 kg/ha	
	Aquazyme	Rearing phase, 2x/wk, every water change	0.5 kg/ha	P 370/500 gm
		Disease control, daily for 3 d	2 kg/ha	
	Twinner 19	Rearing phase, every 7 d	5 kg/ha	

Table 7. Pesticides and algicides used in *Penaeus monodon* grow-out ponds in the Philippines.

Chemical Group	Commercial Product	Pattern of Use	Amount Used	Price
Saponin	Teaseed powder	Pond prep., broadcast, 20 cm-1 m water	8-30 ppm	P 1,200/50 kg
		Rearing phase, periodic	5-25 ppm	
		Disease control, first 30-60 d	15-35 ppm	
Copper compounds	Copper control	Pond prep., spray	2 ppm	P 50/100 gm
		Rearing phase, until phytoplankton bloom	2 kg/ha/d	
Potassium permanganate	Potassium permanganate	Pond prep., spray	2 ppm	P 1,250/100 gm

Table 8. Feed additives used in *Penaeus monodon* grow-out ponds in the Philippines.

Chemical Group	Commercial Product/ % Activity	Pattern of Use	Amount Used	Price/Country of Origin/ Manufacturer
ANTIMICROBIALS:				
Chloramphenicol	Chloramphenicol	DOC 1-30	3 gm/kg feed	P 3,800/kg, Germany
		Disease control	2-2.5 gm/kg feed	
Tetracycline	Oxytetracycline	DOC 1-30	3 gm/kg feed	P 1,300/kg, Germany
		Disease control, 3x/d for 3-7 d	1-5 gm/kg	
Oxolinic acid	Oxolinic acid	DOC 12-60, 1-3x/d	1 gm/kg feed	P 18,000/kg
		Disease control, 1-3x/d for 7 d	0.2-4 gm/kg feed	
Furazolidone	Furazolidone, 98%	DOC 1-100, 5x/d	1 gm/kg feed	P 1,600/kg, Taiwan
		Disease control	1-2.5 gm/kg feed	
	PE-30	DOC 1-35, alternate with vitamin/ wk, all feedings for 5-7 d	20 gm/kg feed	P 400/kg, Philippines
	PE-40	Disease control, 2-3x/d for 5-7 d	20 gm/kg feed	P 800/kg, Philippines
	PE-60	DOC 1-30, alternate with PE-30, 4-5x/d	20 gm/kg feed	P 550/kg, Philippines
VITAMINS/LIPIDS/ MINERALS/ PROTEIN:				
Vitamin C	Ascorbic acid	Rearing phase, DOC 60-120, 1x/d	1-5 gm/kg feed	
	Aquamix	DOC 37 to harvest, 3x/wk	20 gm/kg feed	
		Disease control, daily for 3-5 d	20 gm/kg feed	
	Rovimix Stay C	Rearing phase, DOC 1 to harvest, 1x/d	1-20 gm/kg feed	P 700/kg, Roche
	Enervon C (capsule)	Rearing phase	0.5-5 gm/kg feed	P 6.00/500 mg
	(syrup)	Rearing phase	10 mL/kg feed	
	SVT	Rearing phase	25 mL/kg feed	P 1,000/L
	Stroner	Rearing phase, DOC 13 to harvest, 5x/d	2-3 gm/kg feed	P 370/500 gm, Taiwan
	Hypo 66	Rearing phase, DOC 1 to harvest, 2x/d	25 gm/kg feed	
	Bactozyme	Rearing phase, DOC 13 to harvest, 5x/d	5 gm/kg feed	
Astaxanthin + Vitamin C	Nutri Asta-C	DOC 1 to harvest, 1x/d	4-5 gm/kg feed	P 1,100/kg, U.S.A., Nutri-Systems
		Disease control, 3-4x/d	5-10 gm/kg feed	
Vitamin A, C, E	Aquace	DOC 1 to harvest, 1x/d	1-2 gm/kg feed	P357.35/100 gm, England P 4,860.30/2 kg, PH Pharma- ceuticals

Table 8. Continued . . .

Chemical Group	Commercial Product/ % Activity	Pattern of Use	Amount Used	Price/Country of Origin/ Manufacturer
Vitamin A, D + fatty acid + protein	Nutri-Pro	Rearing phase, 5x/d	5-10 gm/kg feed	P 250/kg, U.S.A., Nutri-Systems
Enzyme/vitamin /mineral	Nutria	Rearing phase	1 gm/kg feed	P 850/kg, U.S.A., Nutri-Systems
Fatty acid	Aquatak	Coating medium	20 mL/kg feed	P 567.70/L, England, PH Pharmaceuticals
	Grow-Well	Coating medium	30 mL/kg feed	P 56/kg, Taiwan
	Nutri-Oil	Coating medium	20 mL/kg feed	P 480/gal, U.S.A., Nutri-Systems
	Fin-oil	Coating medium	2 gm/kg feed	P 157.25/L
	Cooking/squid/ cod liver oil	Coating medium	10-20 mL/kg feed	P 60/L, P 120/L
	Chicken egg	Coating medium	1-2 pc/kg feed	P 2.50/pc
Calcium compound	Calcium lactate	Rearing phase, 1 wk prior to harvest, 1x/d	10 tablet/kg feed	P 30/100 tablets
	HUFA (B-meg)	Rearing phase, 5 d, 5x/d	10 mL/kg feed	
ANTIMICROBIAL/ VITAMIN/ MINERAL MIX:				
Unknown	Inoxyline	DOC 1-30, 2x/d	2 gm/kg feed	P 1,625/500 gm, Philippines, Ino-Aqua Systems
		DOC 31-1 mo before harvest, 2x/d	0.5 gm/kg feed	
	Ino-Forte	Disease control, 10 d, 5x/d, 30 d withdrawal	2 gm/kg feed	P 2,340/500 gm, Philippines, Ino-Aqua Systems
	Ino-moto	Rearing phase, 5x/d	2-3 gm/kg feed	Philippines, Ino-Aqua Systems
	Ino stress	Disease control, 5x/d	2-3 gm/kg feed	Philippines, Ino-Aqua Systems
	Terravite	Rearing phase, DOC 1-30, 5x/d, alternate with Inoxyline or PE-30	5 gm/kg feed	Pfizer
	Chronic Prevention Herbal	Disease control, 7 d, 1x/d	20 gm/kg feed	

Table 9. Chemical and biological products used in milkfish ponds in the Philippines.

Chemical Group	Commercial Product / % Activity	Pattern of Use	Amount Used	Price/Country of Origin/ Manufacturer
SOIL AND WATER TREATMENT:				
Lime	Agricultural lime	Pond prep., broadcast	300-5,000 kg/ha	P 300/t
	Hydrated lime	Pond prep., broadcast	150-1,000 kg/ha	P 1,800/t
PLANKTON GROWTH PROMOTERS:				
Inorganic fertilizer	18-46-0 (diammonium phosphate)	Pond prep., broadcast	50-150 kg/ha	P 405/50 kg
	16-20-0 (mono-ammonium phosphate)	Pond prep., broadcast	100-300 kg/ha	P 305/50 kg
		Rearing phase, every 15 d up to harvest, broadcast	3.2 kg/ha	
	46-0-0 (urea)	Pond prep., broadcast	25-200 kg/ha	P 380/50 kg
		Rearing phase, every 15 d up to harvest, broadcast	12 kg/ha	
Organic fertilizer	Chicken manure	Pond prep., broadcast	500-3,000 kg/ha	P 1,000/t
		Rearing phase, tea bags	200 kg/ha	
	Goat/pig manure	Pond prep., broadcast	500-1,000 kg/ha	
	Bioearth	Pond prep., broadcast	500 kg/ha	P 180/50 kg
PESTICIDES:				
Saponin	Teaseed powder/ cake, 10%	Pond prep., broadcast	5-400 kg/ha	P 1,200/50 kg
Nicotine	Tobacco dust	Pond prep., broadcast, substitute for teaseed	400 kg/ha	
Rotenone	Derris root, 10%	Pond prep., broadcast, 25 cm water	300-800 kg/ha	P 12/kg
		rearing phase	300-800 kg/ha	
Organotin	Brestan, 60%	Pond prep., 1/yr-1/3 yr, broadcast or spray	250-600 gm/ha	P 2,500/kg, Indonesia/ Malaysia, Hoescht
	Gusathion	Pond prep.	0.1 ppm	Philippines, Planters Products
Azimphos ethyl	Hostathion	Pond prep.	1 L/3 ha	
Saponin, flavonoid, and tannin	Protek FP (24.5%)	Pond prep., broadcast	45-75 kg/ha	P 630/15 kg, Philippines, Cyanamid
Benzene hexachloride	Diazinon/Zumithion	Pond prep.		
Endosulfan	Thiodan	Pond prep.	0.1 ppm	P 600/L, Hoescht

Table 10. Supplementary list of products available in the market for use in intensive prawn farms in the Philippines. [1]

Use	Chemical Group	Commercial Product
Therapeutants and disinfectants	Erythromycin, Doxycycline	Y Mycin
	Nitrofurans	Furazan
	Oxolinic acid	Oxalic acid
	Sulfa drugs	Bacta-S 051
		Sulfa Drug
	Assorted antibiotics	Antibiocide 106
	Iodine	Chiefiodo
		Poly-iodon
	Alkyl dimethyl benzyl ammonium chloride	Aquazal
		Progen
	Calcium sulfide	Propond
	Laundry detergent	Tide
	Sodium hypochlorite	Sodium hypochlorite
Neutralizer, chelator	Sodium thiosulfate	Sodium thiosulfate
Organic matter decomposer	Bacteria+enzyme preparations	Fritz-Zyme
		Photo Synthemin
		Soil reformer
Pesticides, algicides, fungicides, parasiticides, herbicides	Copper compounds	Prolongcop
		Cutrine Plus
	Dichloro-phenoxy-acetic acid	2-4-D
Plankton growth promoters	Inorganic fertilizers and/or minerals	Biophos
		Greenpond
		Tan-Pax-So
	Phosphorus	Super P
Feed additives	Vitamins, minerals, enzymes and/or hormones	Ebi-C
		Ebizyme
		Prawnon
		Prawn strong
		Progromone
		Vitpac
		Vitamin B complex
	Proteins and protein extracts	Prohepa
		Powder Feed 2000
	Microorganisms (bacteria, yeast and/or enzymes)	Toaraze
		Protase

[1]Modified from Primavera *et al.* (1993).

FARM MANAGEMENT AND THE USE OF CHEMICALS

Preventive Methods

Maintenance of good water quality and sanitation is important in the hatchery and grow-out ponds. Rearing tanks in shrimp hatcheries are cleaned and disinfected between culture periods with detergent solution and 200 ppm chlorine for at least 1 h or 100 ppm for several hours and dried under the sun for 1-2 d (Lio-Po *et al.* 1989). In the present survey, some hatcheries used as high as 1000 ppm chlorine solution for a few seconds to disinfect rearing tanks. Treated water is discharged directly into the sea. Hydrochloric acid solution at 10% is also splashed onto tanks, which are rinsed thoroughly with fresh water to remove the chemical, and sun dried for 1 d (Parado-Estepa *et al.* 1991). Grow-out ponds are disinfected either by complete sun-drying or by applying 1-2 t/ha hydrated lime, 2-4 t/ha agricultural lime, or 5 ppm chlorine (using 5% sodium hypochlorite or 1.5 kg/ha calcium hypochlorite) at 2 cm water depth (Apud *et al.* 1985, Apud 1988). Ammonium sulphate (21-0-0) at 100-200 kg/ha is also added immediately after liming to eradicate pests and predators (Norfolk *et al.* 1981, Apud *et al.* 1985). Rotenone powder (5-8%) at 5 ppm, derris root at 20-40 kg/ha, tobacco dust or shavings at 200-400 kg/ha, or teaseed cake at up to 10 ppm at 10 cm water depth is effective against pests, predators, and snails (Apud *et al.* 1985).

Water used for rearing in shrimp hatcheries is disinfected by chlorination or ozonation. Chlorination is done by applying calcium hypochlorite ($Ca(OCl)_2$, 70%) to sand-filtered water. Lio-Po *et al.* (1989) recommended 5-20 ppm available chlorine for at least 12 h to disinfect rearing water in shrimp hatcheries. Baticados and Pitogo (1990) reported that chlorination with 5-30 ppm for 24 h significantly reduced the initial bacterial load from 10^5 to 10^0-10^1 cfu/mL. Our survey showed that a level as high as 70 ppm chlorine is being used to disinfect rearing water. Chlorinated water is neutralized with sodium thiosulfate ($Na_2S_2O_3$) until residual chlorine is zero. Chlorinated water should be used within 6 h after neutralization as bacterial load increases within 24 h (Baticados and Pitogo 1990). The addition of 5 or 10 ppm disodium salt of ethylene diamine tetraacetic acid (Na-EDTA) in rearing water improves survival of *Penaeus monodon* larvae by chelating heavy metals in the medium (Licop 1988). Ozone (O_3) is used to disinfect rearing water in some small-scale shrimp hatcheries.

Hatchery paraphernalia such as brushes, scoop nets, pails, water hoses, glassware, etc. are disinfected between use by dipping in 400 ppm chlorine for a few minutes and then rinsed thoroughly with clean fresh water. Disinfection rugs/trays for footwear are placed at the entrance of hatchery facilities using 200 ppm chlorine solution or 3% Lysol solution (Lio-Po *et al.* 1989) or 200 ppm Argentyne (10% iodine) solution. Sand filters are disinfected with 200 ppm chlorine for 24 h at least once a month (Kungvankij *et al.* 1986).

Artemia cysts are disinfected with 30 ppm chlorine or 10 ppm formalin at least 1 h before hatching (Lio-Po *et al.* 1989). Parado-Estepa *et al.* (1991) recommended 200 ppm chlorine fo 30 min to disinfect *Artemia* cysts.

Shrimp spawners are usually disinfected with 5 ppm Treflan-R (23.1% trifluralin) for 1 h (Gacutan 1979) or 3 ppm Furanace (Platon 1979). Formalin at 25-200 ppm for 10-30 min has been recommended to disinfect shrimp spawners (Platon 1979, Kunvangkij *et al.* 1986, Parado-Estepa *et al.* 1991). In our survey, 100 ppm for 1 h to 500 ppm formalin for 1 min were used to disinfect spawners.

Several prophylactic agents have been used on the eggs of *P. monodon*. These include 1 ppm methylene blue for 10 min, 0.5 ppm malachite green for 10 min, and 3 ppm $KMnO_4$ for 30 min (Kungvankij *et al.* 1986). Following treatment, eggs are rinsed with clean water. Laundry detergent (e.g. Tide) at 20 ppm for 2-4 h can also be used to disinfect shrimp eggs; again, following treatment the eggs are rinsed thoroughly, with complete water change before hatching (Lio-Po and Sanvictores 1986). The strategic egg prophylaxis (SEP) method is used on eggs of black tiger prawn to produce monodon baculovirus (MBV)-free postlarvae (PL) (Natividad and Lightner 1992). The SEP method recommends that eggs be washed and rinsed with benzalkonium chloride, calcium hypochlorite, iodine, or ozone-treated sea water several hours before hatching. This method produces MBV-free PL15. MBV is detected at PL7 in unwashed eggs.

Luminous vibriosis caused by *Vibrio harveyi* and occasionally by *V. splendidus* in larval and postlarval *P. monodon* has been treated with a wide variety of chemicals at prophylactic levels (Baticados *et al.* 1990a, Lavilla-Pitogo *et al.* 1990). These include 2-4 ppm chloramphenicol every other day, 0.5 ppm furazolidone, and 0.07 ppm rifampicin every other day (Baticados and Paclibare 1992). In our survey, the most commonly used chemicals were oxytetracycline (1-2 ppm every other day), chloramphenicol (1 ppm every other day), furazolidone (0.5-1 ppm every other day), and rifampicin (0.1 ppm every other day), given either singly or in combination. In grow-out ponds, 5-15 ppm hydrated lime and 15 ppm teaseed powder are applied as prophylactic agents against luminous vibriosis for 12 h for the first 30-60 d of culture (DOC). Antimicrobials are also incorporated in artificial feeds. These include oxytetracycline or chloramphenicol (3 gm/kg feed for the first 30 d), oxolinic acid (1-1.2 gm/kg feed from DOC 1-60 given for 1-2 feeding rations/d), and furazolidone (20 gm PE-30/kg feed from DOC 1-60).

Fungal infection in larval stages of *P. monodon* is prevented by using 0.1 ppm Treflan-R or 0.1 ppm trifluralin for 24 h every 2-3 d (Gacutan 1979, Baticados *et al.* 1990b). The present survey shows that 0.1 ppm Treflan-R is used as a prolonged bath for 3-5 d. Malachite green is also used as a prophylactic agent against fungi at levels of 0.003-0.015 ppm administered every other day from mysis stage. The reported 96 h LC_{50} of mysis stage to malachite green is 0.006 ppm (Lio-Po *et al.* 1978).

THERAPEUTIC MEASURES

Shrimp diseases

Luminous Vibriosis

In shrimp hatcheries, luminous vibriosis is treated with antimicrobials such as baths of 0.05-1 ppm Prefuran for 24 h, 10-20 ppm furazolidone for 24 h, 4 ppm erythromycin, and 1-5 ppm oxytetracycline (Baticados and Paclibare 1992). In our survey, luminous vibriosis in shrimp hatcheries was treated using long baths of either 2-4 ppm oxytetracycline, 2-4 ppm chloramphenicol, 2-3 ppm furazolidone, 1 ppm Prefuran, or 2-3 ppm erythromycin for 3 consecutive days with minimal success. In grow-out ponds, various chemicals are used. These include 25 ppm hydrated lime for 4 consecutive days, 0.5-3 ppm benzalkonium chloride, and 1 ppm Bromosept-50. Antimicrobials are also added to artificial feeds such as oxytetracycline (2-5 gm/kg feed for 3 d given at all feeding rations), chloramphenicol (2-2.5 gm/kg feed for 3 d given 5 times per d), oxolinic acid (1.2-4 gm/kg feed given 5 times per d), or furazolidone (1gm/kg feed given 5 times per d). However, it has been shown that chemotherapy is of limited use in luminous vibriosis (Baticados *et al.* 1990a).

Shell Disease

Exoskeletal lesions in tank- and pond-reared shrimp have been associated with *Vibrio* spp. (Lio-Po and Lavilla-Pitogo 1990). *In-vitro* tests showed that the isolates were sensitive to chloramphenicol, furazolidone, nitrofurantoin, oxytetracycline, and sulfamethoxazole trimethoprim. However, the use of antimicrobials is recommended only for tank-reared broodstock.

Filamentous Bacterial Disease

Filamentous bacterial disease caused by *Leucothrix mucor* in postlarval stages of *P. monodon* is treated using Cutrine-Plus at 0.15 ppm copper in 24 h flow-through treatments or with 0.5 ppm copper for 4-6 h short bath (Baticados *et al.* 1990b). The 48 h LC_{50} of copper sulphate to larval *P. monodon* is 0.2 ppm (Canto 1977).

Larval Mycosis

Larval mycosis in shrimp caused by *Lagenidium callinectes*, *Lagenidium* sp., and *Haliphthoros philippinensis* (Baticados *et al.* 1977, Hatai *et al.* 1980) is treated with 0.2 ppm Treflan-R or 0.2 ppm trifluralin for 24 h using the static or drip method (Lio-Po and Sanvictores 1986, Baticados *et al.* 1990b). Gacutan (1979) reported that 2-4-D (2-4-dichloro-phenoxy-acetic acid), a herbicide, has a 96 h LD_{50} of 0.6 ppm for mysis stage and is effective in controlling *Lagenidium* infections. Furanace (6-hydroxymethyl-2-2-5-2-furyl vinyl pyridine), reported to be effective against bacterial and fungal pathogens, has a 24 h LC_{50} of 1.6, 2.0, and 5.0 ppm for zoea, mysis, and postlarvae, respectively (Gacutan *et al.* 1979). The *in vitro* effect of fungicides to *Lagenidium* and *H. philippinensis* has been reported by Lio-Po *et al.* (1982, 1985).

Protozoan Infections

Ciliated protozoans such as *Acineta*, *Ephelota*, *Epistylis*, *Vorticella*, and *Zoothamnium* in juvenile and adult shrimp are treated with 30-100 ppm formalin for 30 min (Baticados *et al.* 1990b). However, these levels are lethal to larvae and postlarvae (Vicente and Valdez 1979, Lio-Po and Sanvictores 1986).

Fish Diseases

Bacterial Infections

Bacterial infections associated with post-transport mortalities in milkfish juveniles can be controlled using oxytetracycline (OTC) baths for 5 d (Lio-Po 1984). Transport-stressed milkfish fingerlings are also treated with 1 ppm Furanace bath for 5 d (Lio-Po 1984). The reported 96 h LC_{50} of Furanace (nifurpirinol) to milkfish fingerlings is 1.7 ppm (Tamse and Gacutan 1994). Localized *Vibrio parahaemolyticus*-like infection (Lio-Po *et al.* 1986) due to repeated hormone implantations in milkfish broodstock is routinely treated with topical application of Terramycin after each implantation (Lacanilao *et al.* 1985). The vibrios isolated are sensitive to polymyxin B and sulfamerazine. *Vibrio parahaemolyticus*-like bacteria are also associated with opaque-eyed milkfish juveniles (Muroga *et al.* 1984, Lavilla-Pitogo 1991).

Vibrio sp. isolated from juvenile and adult grouper are sensitive to chloramphenicol, nalidixic acid, and oxytetracycline (Lavilla-Pitogo *et al.* 1992a). Vibriosis in broodstock and adult grouper (3-7 kg) is controlled by intramuscular injection of 25 or 50 mg OTC/kg body weight of fish for 5 d (C. Lavilla-Pitogo and M.C.L. Baticados, pers. comm.). Grouper broodstock with opaque eyes, petechiae, or suspected to have bacterial infection are treated with 100 ppm Ektecin (30% sulfamonomethoxine and 10% ormetoprim, Daiichi, Japan) bath for 1 h for 5-7 d (N. Yasunaga, pers. comm.), 100 ppm OTC bath for 1 h for 5-7 d (L. de la Peña, unpubl. data), or 200 ppm formalin bath for 1 h for 5-7 d (G.F. Quinitio, pers. comm.).

In spotted scat (*Scatophagus argus*), bacterial infections are controlled by 50 ppm chloramphenicol bath for 10 h, oral administration of chloramphenicol at 500-750 mg/kg feed given at 3-10% body weight for 5-7 d, or by intramuscular injection of either chloramphenicol at 15 mg/kg fish or OTC at 20-50 mg/kg fish (Cruz and Barry 1988).

Infections by *Flexibacter columnaris* and *Aeromonas* sp. in catfish (*Clarias macrocephalus*) can be controlled after oral administration of Dimeton (sulfamonomethoxine) given at 50-200 mg/kg fish or tetracycline at 20-100 mg/kg fish for 3-7 d (S. Hara, unpubl. data). Tank-reared fry of bighead carp (*Aristichthys nobilis*) infected by *Pseudomonas* sp. and silver carp (*Hypopthalmichthys molitrix*) broodstock with *Aeromonas hydrophila* and *Citrobacter* sp. infections are treated by injection with 7.5 gm OTC/100 kg fish/d for 7-12 d (F. Palisoc, pers. comm.). Fry of Nile tilapia (*Oreochromis niloticus*) reared in nursery tanks with *Pseudomonas* infection are fed oxytetracycline-treated artificial feeds at 7.5 gm/100 kg fish/d for 7-12 d (F. Palisoc, pers.comm.). Kanamycin and oxytetracycline show some promise in controlling *Pseudomonas* sp. in tilapia fry (Lio-Po and Sanvictores 1987).

Fungal Infections

Fungal infections in milkfish are controlled using baths of 10 ppm potassium permanganate ($KMnO_4$), 2 ppm pyridyl mercuric acetate, or 10 ppm malachite green for an undisclosed period (Timbol 1974). The reported 24 and 96 h LC_{50} of $KMnO_4$ to milkfish fingerlings are 1.5 and 1.2 ppm, respectively (Cruz and Tamse 1989); however, significant histopathological changes are observed in gills, liver, and kidney even at sub-lethal concentrations (Cruz and Tamse 1986). In spotted scat, fungal infection is treated with a combination of 0.10 ppm methylene blue and 24 ppm formalin for 1 wk (Lio-Po and Barry 1988). Malachite green at 1% is swabbed directly onto dermal lesions and fins of spotted scat to control secondary fungal infections (Cruz and Barry 1988). Juvenile seabass (*Lates calcarifer*) with suspected fungal infections are dipped in 100 ppm malachite green for a few seconds (R. Duremdez-Fernandez, pers. comm.). Fungal infections of adult carp cultured in cages are treated with 10,000 ppm salt indefinitely after fish have finished spawning and before being returned to their cages (F. Palisoc, pers. comm.).

Parasitic Infections

In milkfish broodstock, infestations of *Caligus* can be treated with 0.25 ppm Neguvon (2,2,2-trichloro-1-hydroxyethyl-phosphoric acid-dimethylethol) bath for 12-24 h (Laviña 1978) or 90 ppm formalin bath for 2 h (Lio-Po 1984). Milkfish fingerlings can tolerate formalin at 200 ppm for 48 h or 100 ppm for 96 h without any adverse effect (Cruz and Pitogo 1989). Mass infection of milkfish by larval stages of *Lernaea* sp. is treated with 3-5% salt solution, while adult stages of the parasite can be controlled by drying and liming the pond bottom (Velasquez 1979). In spotted scat, *Trichodina* sp. and *Amyloodinium* sp. are treated with an indefinite bath of 0.75 ppm $CuS0_4$ and a combination of 0.1 ppm malachite green/24 ppm formalin for 24 h, while *Caligus* is treated with 0.25 ppm Neguvon for 30 min (Lio-Po and Barry 1988). In grouper, a protozoan (possibly *Cryptocaryon irritans*) is controlled using a combination of 25 ppm formalin and 0.1 ppm malachite green (Baticados and Paclibare 1992). Infections by monogeneans such as *Diplectanum* sp. in grouper juveniles are treated with 50-100 ppm formalin for 1 h (E.R. Cruz-Lacierda, unpubl. data). Recently, infestation of tank-held adult groupers by a marine leech was treated with 50-100 ppm formalin bath for 1 h (E.R. Cruz-Lacierda and J.D.Toledo, unpubl. data). The tolerance levels of milkfish and seabass fingerlings to formalin have been reported by Cruz and Pitogo (1989) and Pascual *et al.* (1994), respectively.

White spot disease caused by *Ichthyophthirius multifiliis* in Nile tilapia is controlled by a combination of 25 ppm formalin and 0.1 ppm malachite green bath (Baticados and Paclibare 1992). Infections by *Trichodina* and monogeneans in tilapia fry are treated with indefinite bath of 10,000 ppm salt solution, while infections by *Lernaea* in tilapia broodstock and silver carp fry are treated with 0.25 ppm Dipterex and indefinite bath of 1000-2000 ppm salt or 15-25 ppm formalin, respectively (F. Palisoc, pers. comm.). *Argulus* on tilapia is controlled using a 5 ppm $KMnO_4$ bath for 5-10 min (Baticados and Paclibare 1992).

HAZARDS OF CHEMICAL USE

The use of chemicals is disadvantageous because: (1) chemicals may be detrimental to treated animals; (2) they may have adverse effects on non-target organisms such as natural food organisims present in the culture system; (3) they may lead to development of drug-resistant bacterial strains through the overuse or misuse of antimicrobials; (4) they are potential threats to human health; (5) their residues may accumulate at harmful levels in fish flesh and in the environment; and (6) the cost of application can be prohibitive.

The use of chemicals to control luminous vibriosis in black tiger prawn larvae results in mortalities or morphological deformities at concentrations that are known to control the disease (Baticados *et al.* 1990a). Cutrine-Plus, a copper-based chemical used against filamentous bacteria, is toxic to prawn larvae at concentrations effective against the pathogen (Baticados *et al.* 1990b). Formalin is effective against protozoan infections in juvenile and adult shrimp; however, it is toxic to larval stages (Lio-Po and Sanvictores 1986). The use of molluscicides such as Aquatin (Baticados *et al.* 1986) and Gusathion (Baticados and Tendencia 1990) in shrimp ponds can result in chronic soft-shelling.

The exposure of non-target species such as *Tetraselmis chuii*, a phytoplanktor used as food for penaeid larvae, to 0.1 ppm trifluralin delays growth and reduces protein content of the alga (Dimanlig 1981). Furazolidone at 0.5 ppm and 2 ppm nitrofurazone significantly reduce the cell size, growth rate, and chlorophyll A content of *Chaetoceros calcitrans* (R. C. Duremdez-Fernandez, pers. comm.). Nauplii of *Artemia* can tolerate oxytetracycline, furazolidone, erythromycin, sodium nifurstyrenate, and Treflan-R, but growth is negatively affected (E.R. Cruz-Lacierda, unpubl. data).

Observations of carcinogenesis and mutagenesis in laboratory animals have led the U.S. Food and Drug Administration (US FDA) to cancel all registered uses of nitrofurans such as furazolidone, nitrofurazone, and nifurpirinol (Meyer and Schnick 1989, Schnick 1991). Malachite green has potential carcinogenic and teratogenic properties (Bailey 1983). Organotin compounds (e.g., Aquatin, Brestan, Gusathion) used as snail killers in milkfish and shrimp ponds have teratogenic properties and suppress immune response in mammals, leading to increased susceptibility to infections (Dean and Murray 1992).

The widespread use of antimicrobials significantly leads to the development of drug-resistant bacterial populations (Aoki 1992). Shotts *et al.* (1976) showed that continued use of oxytetracycline enhances the production of plasmid-mediated resistance in aquatic bacteria. Beladi *et al.* (1978) reported that nitrofurans such as Prefuran can rapidly cause bacterial resistance because of their persistence in water. Baticados *et al.* (1990a) reported that luminous vibrios are resistant to erythromycin, kanamycin, penicillin, and streptomycin, have varied responses to chloramphenicol and Prefuran, and low sensitivity to oxytetracycline. The prevalence of infectious diseases in shrimp hatcheries in the Philippines despite the widespread use of antibiotics suggests that drug resistance has developed among bacterial pathogens (Baticados and Paclibare 1992).

Some chemicals used in aquaculture have potential side effects that may affect users and consumers. Chloramphenicol has been reported to destroy the erythrocytes in humans and can cause aplastic anemia, stomatitis, and other conditions (Farkas *et al.* 1982, Brown 1989, Meyer and Schnick 1989). Chloramphenicol is banned for use in aquaculture by the US FDA (Schnick 1991) and by the Philippine government (Department of Agriculture, A.O. No. 60 and Department of Health, A.O. No. 91, Series of 1990). Oxytetracycline, furazolidone, erythromycin, and kanamycin can cause digestive orders and allergies among humans (Schnick 1991).

Chemicals also accumulate in the flesh of treated animals. In 1991, shipments of locally grown *P. monodon* were rejected in Japan because of antibiotic residues (Lacanilao *et al.* 1992). Studies have also established pesticide accumulation in milkfish tissues (Palma-Gil, pers. comm.).

Chemicals are also potential threats to the environment. They can enter the environment directly, leach from uneaten feeds, or be excreted in the feces (Primavera 1993). Effluents that are dumped directly into the sea can affect neighboring ecosystems (Primavera 1991). As a consequence, water quality problems brought about by farm effluents increase (Phillips 1995).

Chemicals, particularly the antimicrobials, are also very expensive. Large amounts are needed in bath treatments, and they may not be effective at all in systemic infections. The use of medicated feeds may also be ineffective, as diseased animals become anorexic.

MEASURES EMPLOYED TO IMPROVE PRODUCTIVITY

Fertilization is a standard practice during pond preparation to enhance the growth of natural food and fish production. The amount of fertilizer and feed required varies with the intensity of culture. Extensive culture systems rely completely on the natural productivity of the ponds, thus they require heavy inputs of organic fertilizer. Semi-intensive and intensive systems require less fertilizer, but greater inputs of artificial feeds. Fresh supplemental feeds are also used, such as trash fish and mussel meat.

In extensive shrimp ponds, chicken manure at 1-2 t/ha, ammonium phosphate (16-20-0) at 75-150 kg/ha, and urea (46-0-0) at 25-50 kg/ha are usually applied (Apud 1988). Additional fertilizers are applied every two weeks during the culture phase at 100 kg/ha and 10-30 kg/ha for organic and inorganic fertilizer, respectively (Apud *et al.* 1985). In intensive ponds, organic fertilizer is applied at 50-100 kg/ha and inorganic fertilizer at 20-30 kg/ha to induce plankton growth and maintain good water quality (Primavera 1992).

In milkfish ponds, the most commonly used inorganic fertilizers are solophos (0-20-0), monoammonium phosphate (16-20-0), diammonium phosphate (18-46-0), and urea (46-0-0). All these were originally intended for agriculture and not for aquaculture use (Fortes 1984). Animal manure from chicken, pig, cow, and carabao or rice bran are commonly used organic fertilizers. The use and application of organic and inorganic fertilizers have been reviewed by Fortes (1984). A level of 1 ppm nitrogen and 1.5 ppm phosphate should be maintained to sustain the growth of benthic algae (Tan *et al.* 1984). Traditional fertilization practice entails application of 16-20-0 at 50 kg/ha and 45-0-0 at 15 kg/ha (Bombeo-Tuburan *et al.* 1989).

Although fertilization can enhance production, it may also cause soil and water condition to deteriorate if applied indiscriminately. The use of piggery wastes in fish-pig farming has a negative effect on the growth and production of milkfish (Fortes *et al.* 1980). A preliminary study on the use of chicken manure in shrimp culture shows that it can be a source of *Salmonella* contamination in shrimp tissue (Llobrera 1988). Application of chicken manure at 0.5 t/ha and MASA (a fertilizer processed from agricultural and industrial wastes) at 0.5 t/ha results in fish kills due to the build-up of organic matter in the pond bottom, depletion of dissolved oxygen, and presence of hydrogen sulfide (Bombeo-Tuburan *et al.* 1989). A lower input of organic fertilizer is recommended during the rainy season. Subosa and Bautista (1991) showed that biweekly application of 15 kg of nitrogen and 30 kg of phosphorus per ha with or without chicken manure can increase shrimp production; however, further increase in fertilizer application does not improve production. Subosa (1992) tested chicken manure, rice hulls, and sugar mill wastes as potential organic fertilizers in extensive shrimp ponds. Boiler ash (derived from burned bagasse from sugar mills) is a more efficient fertilizer than chicken manure in terms of growth and survival of tiger shrimp.

The role of hormones such as thyroxine in enhancing larval growth, development, and survival has also been studied. Treatment of yolk-sac larvae of Nile tilapia with thyroxine (T4) by immersion in 0.1 ppm significantly increases length and weight of fry after 4 wk (Nacario 1983). Treatment with 0.5 ppm L-thyroxine-sodium (Eltroxin, Glaxo) by immersion for 15 d stimulates growth and development in milkfish fry (Lam *et al.* 1985). Larvae of rabbitfish (*Siganus guttatus*) from spawners injected with 10 and 100 µg T4/gm B.W. are longer and show better survival than control fish (Ayson and Lam 1993). Treatment of larval grouper (*Epinephelus coioides*) with 0.01-1 ppm triidothyronine (T3) or T4 by immersion or by feeding with T3- or T4-enriched *Artemia* resulted in faster metamorphosis than seen in an untreated group (de Jesus *et al.* 1998). Grouper larvae treated with T3 and T4 and stocked in grow-out ponds show faster growth rate than untreated fish (E. Rodriguez, pers. comm.).

OTHER APPROACHES TO DISEASE PREVENTION

Control of diseases through the use of chemicals appears to be limited and ineffective. Other approaches to disease prevention such as environmental and biological methods should be evaluated.

In luminous vibriosis in shrimp, potential sources and routes of entry of bacteria into the larval rearing system have been identified to establish a set of preventive measures (Lavilla-Pitogo *et al.* 1992b). Results showed that *V. harveyi* can enter the hatchery system through the fecal matter from spawners, sea water, or unwashed *Artemia* cysts. The authors suggested that spawners and their fecal matter must be separated from the eggs after spawning and the eggs washed to prevent infection. Natural food such as diatoms may still be used, as these show some antibacterial properties.

The health condition of shrimp and fish larvae or juveniles is assessed prior to stocking in grow-out ponds. It is a common practice among shrimp growers to screen postlarvae for monodon baculovirus (MBV) occlusion bodies, luminous bacteria, and parasites. Of the 144 shrimp samples analyzed by the Fish Health Section of SEAFDEC/AQD in 1995, 23.6% were positive for MBV. Generally, postlarvae infected with MBV have a lower market value. The ratio of the tail muscle to the hindgut diameter is also considered in shrimp fry selection procedures, with a ratio of 4:1 (below PL20) as an indicator of good quality fry. Younger shrimp fry (PL14) can also be subjected to 15 ppt salinity or 100 ppm formalin stress tests for 2 h to assess their health condition (Bauman and Jamandre 1990). Good quality fry must have 100% survival during the exposure period, recover within 24 h, and resume feeding.

Biodegradable or indigenous materials such as derris root can replace non-biodegradable compounds (e.g., Brestan) to eliminate unwanted species in ponds. The roots of *Derris elliptica*, *D. heptaphylla*, and *D. philippinensis*, which are locally available, are placed inside a sack cloth, soaked, and squeezed periodically at a rate of 20-40 kg of root/ha at 10 cm water depth. 5-10 ppm rotenone can eliminate unwanted species in ponds without adverse effect on shrimp (Tumanda 1980). Derris root powder (5-8% rotenone) is commercially available and applied at 10-20 kg/ha at 10-20 cm water depth to attain a 5 ppm concentration (Apud *et al.* 1985). Teaseed cake with saponin as its active ingredient is commonly used at 10 ppm for selective elimination of predators and competitors in shrimp ponds (Apud *et al.* 1985). The tolerances of milkfish, tilapia, and shrimp to rotenone and saponin were reported by Minsalan and Chiu (1986) and Cruz-Lacierda (1992, 1993). Rotenone degrades within 12 h (Cruz-Lacierda 1992) and the levels of rotenone and saponin commonly used in shrimp ponds do not result in chronic soft-shelling (Cruz-Lacierda 1993). Tobacco wastes (dust, shavings, stalks) at 200-400 kg/ha serve not only as predator and snail killers during pond preparation, but also as fertilizer (Apud *et al.* 1985). Toxicity studies of different types of tobacco dust on adult brackishwater pond snails (*Cerithidea cingulata*) under laboratory conditions have been conducted with 700 kg/ha (24 kg nicotine/ha) for 3 d as optimal for 99% eradication of snails (Borlongan *et al.* 1998). Further, this concentration is not lethal to milkfish juveniles. A follow-up of this study under pond conditions is currently in progress in collaboration with the National Tobacco Administration and Iloilo State College of Fisheries. Pond snails can also be eliminated by handpicking (Parado-Estepa 1995) or by burning rice straw piled 15 cm thick at the pond bottom (Triño *et al.* 1993).

The use of bioaugmentation products or probiotics in shrimp culture is a potential biological approach to disease prevention. Probiotics are bacteria and enzyme preparations designed to enhance decomposition or to encourage non-toxic bacteria to overwhelm harmful bacteria (Anon. 1991). At present, a variety of probiotic compounds are available in the market and are used in intensive shrimp farms (Table 6). Most of the available information regarding the use of these products is provided by manufacturers and suppliers. Studies to understand the principles behind bioaugmentation, probiotics, and bioremediation are limited.

The use of lower stocking density can also prevent disease occurrence. A shift to semi-intensive culture has been recommended to avoid the use of large areas in extensive systems and diseases and effluents that result from intensive systems (Primavera 1991).

Sound nutrition and adequate feeding are necessary not only for growth, but also for maintaining the overall health of aquatic animals, allowing them to cope with a variety of pathogens. Chronic soft-shell syndrome in juvenile and adult shrimp, a disease caused by nutritional deficiency, pesticide contamination, and poor water and soil conditions, among other things (Baticados *et al.* 1986), can be reversed by feeding a diet containing 14% mussel meat or a calcium-to-phosphorus ratio of 1:1 (Bautista and Baticados 1990). The feed additives Nutria (enzyme, vitamins, and mineral premix) and Nutri-oil (fish oil), when combined and incorporated into shrimp feed can significantly increase growth rates and improve feed conversion ratio (Baldia 1994). Catacutan and Lavilla-Pitogo (1994) showed that incorporation of 100-200 ppm phosphated ascorbic acid (50-100 ppm ascorbic acid) in test diets fed for 92 d improves the growth of shrimp, as shown by the structure of shrimp's hepatopancreas infected with MBV at the start of the study.

NATIONAL REGULATIONS ON THE USE OF CHEMICALS IN AQUACULTURE

In the Philippines, the Bureau of Animal Industry (BAI) through the Animal Feeds Standard Division (AFSD) formulates regulations on chemicals intended for veterinary animals. The AFSD (1) evaluates, registers, and licenses establishments which engage in the manufacture, distribution, and sale of veterinary products, including those used for aquaculture; (2) inspects and examines veterinary drugs and product premixes and water solubles; and (3) adopts and uses existing standards and requirements of the Department of Health for licensing and registration, including the applicable regulations related to generic labelling for veterinary drugs (Department of Agriculture Administrative Order No. 25, Series of 1991; effective January 1992). In June 1995, the BAI required all veterinary drug and product establishments (manufacturers, traders, and importers) to submit a valid certificate of product registration.

In 1989, the BAI required commercial prawn feed manufacturers to completely label their feed bags and containers. Such labels contain, among other things, the feed ingredients, including drugs or drug ingredients for disease prevention, percentage of drug, directions for use, warning against use under conditions dangerous to the health of livestock and man, and withdrawal period. This is an important development, as recent reports show that a lot of artificial feeds contain antimicrobials such as oxytetracycline, oxolinic acid, and chloramphenicol (Chen 1989). In April 1990, the Department of Agriculture (DA) and the DOH issued Administrative Order No. 60 and Administrative Order No. 91, Series of 1990, respectively, to ban the use and withdraw the registration of chloramphenicol in animals used as food. Violators are fined US$ 40-200 and imprisoned for six months to two years. The Bureau of Fisheries and Aquatic Resources (BFAR) through its Fisheries Administrative Order No. 117-1, Series of 1994, has been authorized to monitor the effect of using antibiotics in shrimp culture by determining the antibiotic (oxolinic acid and oxytetracycline) residues in shrimp tissues.

In 1993, the Subcommittee on Veterinary Drugs of the Department of Health published the Philippine National Veterinary Drug Formulary. The chemicals recommended for use in aquatic

Table 11. Chemicals recommended for use in aquatic animals.[1]

Chemical	Target Species	Mode of Administration Pharmaceutical Form/Strength	Withdrawal Period
ANTI-INFECTIVES:			
Dihydrostreptomycin sulfate	Ornamental freshwater finfish	Injection: 500 mg/mL solution	
Erythromycin phosphate	Ornamental marine/freshwater finfish	Oral: powder	
Furazolidone	Ornamental marine/freshwater finfish	Oral: powder	
Gentamycin sulfate	Ornamental marine/freshwater finfish	Injection: 10 mg/mL; 1 mL ampule, 2 mL vial 40 mg/mL; 1 mL ampule, 2 mL vial	
Isoniazid	Ornamental marine/freshwater finfish	Bath: powder	
Kanamycin	Ornamental marine/freshwater finfish	Injection: 1 gm vial	
Neomycin sulfate	Ornamental marine/freshwater finfish	Bath: powder	
Nifurpyrinol	Ornamental marine/freshwater finfish	Oral/bath: powder	
Nitrofurazone	Ornamental marine/freshwater finfish	Bath: powder	
Oxolinic acid	Edible/ornamental marine/freshwater finfish/crustaceans	Oral: powder 20 mg/kg feed	30 d
Oxytetracycline	Edible/ornamental marine/freshwater finfish/crustaceans	Oral/bath: powder	21 d
Ormetoprim	Edible/ornamental marine/freshwater finfish/crustaceans	Oral: powder	
Sulfadimethoxine	Edible/ornamental marine/freshwater finfish/crustaceans	Oral: powder	
Sulfamerazine	Edible/ornamental marine/freshwater finfish/crustaceans	Oral: powder	25 d
Sulfisoxazole diolamine	Edible/ornamental marine/freshwater finfish/crustaceans	Oral: powder	
Trimethoprim/Sulfadiazine	Edible/ornamental marine/freshwater finfish/crustaceans	Oral: powder 83.3 gm/kg Trimethoprim + 41 gm/kg Sulfadiazine	20 d
ANTIPARASITICS:			
Chloramine T	Ornamental freshwater finfish	Bath: powder	
Copper sulfate	Edible/ornamental marine/freshwater finfish/crustaceans	Bath: powder	
Ivermectin	Ornamental freshwater/marine finfish	Oral: 1% solution	
Malachite green oxalate (zinc free)	Ornamental freshwater finfish		
Methylene blue	Ornamental marine/freshwater finfish Juvenile penaeid shrimp	Bath: powder Bath: powder	
Metromidazole	Ornamental freshwater finfish	Oral: powder	
Potassium permanganate	Edible/ornamental marine/freshwater finfish/crustaceans	Bath: crystal	
Praziquantel	Ornamental freshwater finfish	Bath: tablet	
Quinacrine hydrochloride	Ornamental freshwater finfish/ crustaceans	Bath: powder	
Sodium chloride	Edible/ornamental marine/freshwater finfish/crustaceans	Bath: crystal	
Trichlorfon	Ornamental freshwater finfish	Bath: powder	4 wk
DISINFECTANTS:			
Calcium carbonate	Ornamental marine/freshwater finfish	Bath: powder	
Calcium hypochlorite	Edible/ornamental marine/freshwater finfish/molluscs	Bath: crystal	
Calcium oxide	Disinfection of ponds	Broadcast: powder	

[1]Source: Philippine National Veterinary Drug Formulary, Department of Health, 1993.

Table 11. Continued. . .

Chemical	Target Species	Mode of Administration Pharmaceutical Form/Strength	Withdrawal Period
Didecyl dimethyl ammonium chloride	Disinfection of aquaria, fish holding facilities and equipment	Broadcast: powder	
		Spray: solution	
Formalin	Disinfection of tanks, fish holding facilities	Spray/wash: solution	
Grapefruit extract	Ornamental marine/freshwater finfish		
Polyvinylpyrolidone	Egg disinfectant	Bath: solution	
Potassium permanganate	Edible/ornamental freshwater finfish	Bath: powder	
Quaternary ammonium compound	Finfish	Bath: 50% solution, 0.1-0.5 ppm	
	Crustaceans	Bath: 50% solution, 0.5-1.0 ppm	
Sodium hypochlorite	Disinfection of aquarium fish holding facilities/equipment		
ANTIFUNGALS:			
Chlorhexamine	Edible/ornamental freshwater/marine molluscs	Bath: solution	
Copper sulfate	Edible/ornamental freshwater/marine finfish/crustaceans	Bath: powder	
Formalin (37-40%) (commercial grade)	Edible/ornamental marine/freshwater finfish/molluscs	Bath: solution	4 wk
Griseofulvin	Ornamental freshwater finfish	Bath: powder	25 d
Malachite green oxalate (zinc free)	Ornamental freshwater finfish/juvenile penaeid shrimp	Bath: crystal	
Potassium permanganate	Edible/ornamental freshwater/marine finfish/crustaceans	Bath: crystal	
Trifluralin	Edible/ornamental freshwater/marine finfish/crustaceans	Bath: solution	
PISCICIDES:			
Antimycin A	Edible/ornamental marine/freshwater finfish/crustaceans		
Rotenone	Edible/ornamental marine/freshwater finfish/crustaceans	Bath: 5% solution	4 wk
Teaseed (saponin 10-13%)	Edible/ornamental marine/freshwater finfish/crustaceans	Bath: powder	
ANESTHETICS:			
Tricane methane sulfonate	Edible/ornamental freshwater finfish	Bath: powder	
Quinaldine sulfate	Ornamental freshwater/marine finfish	Bath: solution	
HORMONES:			
HCG	Edible/ornamental freshwater finfish	Oral: powder	
Estradiol	Edible/ornamental freshwater finfish	Oral: powder	
Testosterone	Edible/ornamental freshwater finfish	Oral: powder	
ACARICIDES/ HERBICIDES:			
Copper (chelated elemental copper)	Edible/ornamental marine/freshwater finfish/crustaceans/molluscs	Bath: solution	
Copper sulfate + triethanolamine	Edible/ornamental marine/freshwater finfish/crustaceans/molluscs	Bath: solution	
Dipyridilium	Marine/freshwater crustaceans/molluscs	Bath: solution	

species together with the target species, mode of administration, and withdrawal period are presented in Table 11.

The Fertilizer and Pesticide Authority (FPA), an attached agency of the Department of Agriculture, was created in 1977 to issue guidelines, rules, and regulations about commercial fertilizers, soil conditioners, microbial inocculants, and fertilizer raw materials prior to their distribution and sale. The FPA also registers pesticides and subsequently classifies these for general use, for restricted use, or as banned pesticides (FPA 1989). The registration process involves the review of the product, including specifications, guaranteed analysis of the composition, data on biological efficacy, experimental use permit, data on toxicity studies, residues and fate in the environment, and labelling requirements. Manufacturers, distributors, and importers are also required to secure a license from the FPA. The FPA also monitors all areas of pesticide use, including effects on the environment, pesticide residues in food, pesticide handling and use, poisoning cases, product quality, and sale and distribution. The FPA maintains linkages with the Department of Pharmacology of the College of Medicine, University of the Philippines to conduct toxicology and residue analyses. The FPA coordinates with the Department of Environment and Natural Resources (DENR) on environmental issues regarding the use of pesticides. The Food and Agriculture Organization of the United Nations (FAO) in 1986 initiated the International Code of Conduct in the Distribution and Use of Pesticides, and the Philippines was an active participant in the formulation of the regulations (Neri 1989).

Table 12. Pesticides banned for agriculture and other applications in the Philippines.[1]

Generic name	Brand name	Manufacturer
Organotin	Brestan	Hoechst
	Aquatin 20 EC	Planters Products
	Telustan 60 WP	Shell Chemicals
Fenbutatin oxide	Torque 50% WP	Shell Chemicals
Azinphos ethyl	Gusathion 400 EC	Bayer
	Marsathion	Marsman
	Bionex 40 EC	Planters Products
	Telothion 40 EC	Shell Chemicals
Methyl parathion	Folidol M 50 EC	Bayer
	Methyl Fosferno 50 EC	Jardine Davis
	Methion 50 EC	Marsman
	Meptox 50 EC	Shell Chemicals
	Parapest M 50 EC	Planters Products
	Penncap M (Encap)	Aldiz
	Wofatox 50 EC/80 EC	Chemie International
	Wofatox Konzentrat 50 EC/80 EC	Chemie International
Endosulfan+BPMC	Thiocarb 47 EC	Hoechst
Endosulfan	Thiodan 35 WP	Hoechst
	Thiodan 35 EC	Hoechst
	Endosulfan 35 EC	Marsman
	Endox 35 EC	Planters Products
	Thiodan 2.5 G	Hoechst
Monocrotophos	Nuvacron 30 SCW	Ciba-Geigy
	Azodrin 168	Shell Chemicals
	Azodrin 202 P	Shell Chemicals
Mono+fenvalerate	Azodrin 150	Shell Chemicals
Mono+mevinphos	Azodrin 202	Shell Chemicals
Mono+cypermethrin	Azodrin 137	Shell Chemicals

[1]Source: Fertilizer and Pesticide Authority.

In September 1993, the FPA issued FPA Board Resolution No. 1 banning the use of organotin compounds (Table 12), particularly Brestan, Aquatin, and Gusathion, chemicals used to control snails (*Cerithidea cingulata*) in milkfish ponds. However, despite the ban, fishpond operators defy the national government's stand and continue to use Brestan for lack of an effective and cheaper alternative compound. Although Brestan has been pulled from local stores, smuggled formulations coming from Indonesia and Malaysia are being patronized and applied by milkfish pond owners.

ON-GOING RESEARCH ON CHEMICAL USE FOR AQUACULTURE

A number of institutions in the Philippines have sections working on fish health management research. The Fish Health Section of the Southeast Asian Fisheries Development Center, Aquaculture Department (SEAFDEC/AQD) has capabilities for virology, bacteriology, mycology, parasitology, and histopathology. It has conducted numerous studies on fish and shrimp health management, including the screening of drugs both *in-vivo* and *in-vitro* for chemoprophylaxis and chemotherapy. Several studies on tolerance limits of shrimp and fish to various chemicals have been worked out. All this information has been published in peer-reviewed national and international scientific journals and conference proceedings. Moreover, the SEAFDEC/AQD has published a pamphlet on "Recommended Practices for Disease Prevention in Prawn and Shrimp Hatcheries" (Lio-Po *et al.* 1989) and a manual on "Diseases of Penaeid Shrimps in the Philippines" (Baticados *et al.* 1990b), with industry practitioners as the target audience. Another function of the Section is to provide disease diagnostic services not only to SEAFDEC/AQD researchers, but to the private sector as well. This component provides fish/shrimp farmers with a sound disease control program. An annual "Training Course on Fish Health Management" is conducted with participants from the academe, government agencies, research institutes, and industry practioners. Aside from basic information on fish disease, lectures and hands-on training concerning the use of chemicals in aquaculture are included in the training course.

The following are SEAFDEC/AQD's on-going studies related to the use of chemicals for aquaculture:

- effect of hormones on the metamorphosis and survival of larval fish;
- effect of possible immune modifiers on the non-specific immune response of juvenile fish;
- effect of feed additives on the growth, survival, and disease resistance of fish and shrimp; and
- utilization of indigenous plants and other compounds as molluscicides in brackishwater ponds.

The Fish Health Section of the Bureau of Fisheries and Aquatic Resources (BFAR) has been involved in the formulation of national regulations on the use of chemicals in aquaculture. Its facilities for bacteriology, mycology, parasitology, histopathology, and water quality analyses have given BFAR the capability to diagnose and conduct research on fish diseases and to determine effective health management strategies, including the consequences of using chemicals in aquaculture. As a result of excessive use of drugs, particularly antibiotics in aquaculture, BFAR saw the need to maintain the international standard of shrimp quality and protect consumers from the deleterious effects of antibiotics by providing services to assess chemical and antibiotic residues in fish and shrimp for human consumption. The on-going monitoring and training programs of the government on current fish health management practices in the country guide the agency to strengthen policies on strict implementation of proper management techniques, thereby lessening the aquaculture industry's tendency to use chemicals indiscriminately.

Other institutes with capabilities to conduct fish health management studies and monitor the impacts of chemical use in the environment are the following:

- Brackishwater Aquaculture Center (BAC), College of Fisheries and Department of Biological Science, College of Arts and Sciences, University of the Philippines in the Visayas;

- Marine Science Institute, University of the Philippines;
- Freshwater Aquaculture Center (FAC), Central Luzon State University; and
- Institute of Fisheries Research and Development, Mindanao State University.

Bioassays of organochlorine and organophosphate pesticides commonly used in rice-fish systems have been conducted by the FAC (Cagauan and Arce 1992).

CONCLUSIONS AND RECOMMENDATIONS

A number of adverse impacts of chemical use in aquaculture have been discussed. The use of chemicals in aquaculture should be regarded as a last resort and should not replace sound farm management and husbandry practices. The environmental problems of farming can be tackled by good site selection, proper design and operation, and sound management techniques (Phillips 1995).

The following recommendations are given:

For Users of Chemicals in Aquaculture:

- The use of antibiotics for prophylaxis in hatcheries should be abandoned. In the United Kingdom, antibiotics are used only as therapeutants and not for prophylaxis or growth enhancement (NCC 1989).
- The use of fresh animal manure during pond preparation and rearing phases should be prohibited.
- Banned chemicals should not be used for any purpose.
- In cases where chemotherapy is inevitable, a code of practice on the use of drugs in aquaculture such as the one suggested by Austin (1985) should be strictly followed.
- Strict observance of the required withdrawal period should be implemented.
- Effluents or treated water must not be discharged directly into the sea.
- Medically important drugs should be banned for use in aquaculture because of the possible development of antibiotic-resistant strains.

Recommendations to restrict the use of medicinal drugs for humans in aquaculture has been submitted to government agencies in charge of regulating manufacture, registration, and use of drugs (Baticados and Paclibare 1992). Austin (1985) listed several drugs that are used to treat diseases in humans and should not be used in aquaculture. These include cycloserine, doxycycline, ethionamide, isoniazid, minocycline, and rifampicin for tuberculosis; ampicillin, bacitracin, and kanamycin for staphylococcal infections; chloramphenicol for typhoid fever; streptomycin for bubonic plague and gonorrhoea; furazolidone for intestinal infections; and nitrofurantoin for urinary tract infections.

For Chemical Manufacturers and Suppliers:

- Development of new, effective, efficient, and environmentally friendly chemicals.
- Strict observance of national laws and regulations.
- Registration and licensing of new products.
- Financial support to research institutions for the conduct of research and development in fish health management.

For Government Agencies:

- Intensive dissemination of information on the consequences of using chemicals for prophylaxis should be conducted among fish and shrimp farmers, drug manufacturers and suppliers.

- A strong and intensive campaign on the careful and restricted use of drugs among fish and shrimp farmers is needed.
- Antibiotics, non-biodegradable pesticides, and disease-control chemicals should be banned from use in aquaculture.
- Strict implementation of rules and regulations on the manufacture, distribution, and sale of chemicals is needed.
- Vigilant monitoring on the use of chemicals is required.
- Violators should be apprehended and stiffer penalties imposed.
- Financial support should be provided to research institutions for the implementation of research and development in fish health management.

For Research Institutions:

- Disseminate intensively information on the consequences of using chemicals.
- Conduct a strong and intensive campaign on the careful and restricted use of drugs.
- Develop new, effective, efficient, and environmentally friendly drugs.
- Conduct additional studies to complete information required for chemicals that have pending approval from drug regulatory boards.
- Train qualified staff in new technologies.

Intensive dissemination of information on the consequences of using chemicals for prophylaxis should be done to prevent the development and spread of drug-resistant pathogens. Recently, a statement of 71 Filipino scientists appeared in Aqua Farm News entitled "No to Pesticides and Antibiotics in Aquaculture" (Lacanilao *et al.* 1992). These scientists urged that antibiotics, non-biodegradable pesticides, and disease-control chemicals be banned from use in aquaculture. Further, they encouraged the use of biodegradable plant-based pesticides.

The FAO has published the "Code of Conduct for Responsible Fisheries" (FAO 1995). At the farm level, the following principles for responsible aquaculture should be implemented: (a) improvement in selection and use of appropriate feeds, feed additives, and fertilizers, including manures; (b) minimal use of chemicals including hormones, antibiotics, and other disease control chemicals; (c) regulated use of chemicals which are hazardous to public health and the environment; and (d) disposal of excess veterinary drugs and other hazardous chemicals should not pose hazard to public health and the environment. At the national level, appropriate procedures to assess the environmental impact of use of chemicals should be established.

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