The Use of Chemicals in Aquaculture in India[1]

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ABSTRACT

A review of the use of chemotherapeutants and other chemicals and drugs in Indian aquaculture is presented. A large number of products are used for various purposes such as soil and water treatments, disinfectants, piscicides, herbicides, organic and inorganic fertilizers, feed additives, therapeutants, and anesthetics. Farm management techniques for the use of chemicals are discussed, as are the hazards posed by, and impacts resulting from chemical use. Other approaches to disease prevention (crop holiday, pond preparation, regulating stocking density, effluent treatment systems) are considered, and national regulations on the use of chemicals in aquaculture and current research being conducted in India are summarized. Recommendations for the improved use of chemicals in Indian aquaculture are provided for farmers, government and aquaculture institutions, the chemical industry, regional and international agencies, and research institutions.

INTRODUCTION

Aquaculture has been practiced in India in both freshwater and coastal saline waters from time immemorial. These were characteristically low-input, low-production systems depending on natural seed collection from the wild, with stocking in natural ponds, or impounding in large water bodies without any further management measures. During the last decade, aquaculture has slowly but steadily transformed itself into a profitable business activity. In freshwater carp culture, production rates of up to 15 t/ha/yr have been attained, and in shrimp culture, yields of about 8 t/ha/crop have been achieved. In tilapia culture, production rates of over 400 t/ha/yr in three crops have been reported. With the increase in area devoted to aquaculture and also the intensification of culture practices, environmental issues have come into focus, particularly issues concerning the planning and regulation of aquaculture in coastal areas.

Brackishwater aquaculture in coastal areas primarily involves shrimp culture and is widespread on the east coast in the states of West Bengal (traditional bheries), Andhra Pradesh, Orissa and Tamil Nadu. Along the west coast, Kerala has a predominantly traditional culture system (paddy-cum-shrimp culture). This also exists on a moderate scale in Goa and Karnataka. Huge concentrations of shrimp farms are situated in Nellore, Bhimavaram and Kakinada in Andhra Pradesh, and Tuticorin in Tamil Nadu.

Compared to coastal aquaculture, freshwater carp culture is widespread in the country, particularly in the states of Andhra Pradesh, West Bengal, Madhya Pradesh, Punjab, Uttar Pradesh, Orissa and Bihar. Sea-farming of oysters and pearls is still in the experimental stage in India, but interest is now growing for establishing joint-venture cage-culture projects with sea bass and grouper as

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[1] *The opinions expressed in this paper are those of the authors and not of the organization they represent.*

candidate species.

Aquaculture production in the freshwater sector has steadily increased from a level of 7.9 lakh t in 1987 to 13.25 lakh t during 1994-95. The average has increased from 900 kg/ha in 1984-85 to 2130 kg/ha in 1994-95. Similarly, aquaculture production from coastal waters has increased from 35,500 t in 1990-91 to 74,850 t in 1994-95, with average productivity increasing from 545 kg/ha to 743 kg/ha.

Freshwater fish culture is primarily comprised of Indian major carps (catla, rohu and mrigal), with the secondary species including exotic Chinese carps. In 1993, total inland fish production of India (species-wise) was comprised of 54.7% major carps, 8.1% common carp, 6.1% other carps, 3.6% murrels, 2.2% *Hilsa* sp., and 25.3% other species (GOI 1993).

In traditional coastal shrimp farming systems, production is a mixture of several species of shrimp and fish. In the bheries of West Bengal, *Penaeus monodon* comprises about 18% of the total catch, while in the pokkali fields of Kerala, *Metapenaeus dobsoni* constitutes more than 50% of the total catch. *Penaeus monodon* is the major species cultured in new brackishwater shrimp farming systems all over the country, with *P. indicus* in second place.

Basically, aquaculture in India is largely of the extensive type and primarily related to carp farming. However, there has been an emergence of large-scale commercial, semi-intensive culture of carps in a few states, especially in Andhra Pradesh, where nearly 50,000 ha of carp culture ponds and 35,000 ha of shrimp culture ponds are under commercial operation. With the increase in productivity in semi-intensive carp culture, semi-intensive or intensive shrimp farms, and related hatchery operations, there has been increased usage of artificial inputs in the form of chemicals. Fish farmers faced with serious fish health problems have resorted to management practices involving the use of chemicals and therapeutants. This has resulted in environmental problems that were not previously encountered. Although carp culture is practiced in self-enclosed systems with limited effluent release to the environment, coastal aquaculture farms need large volumes of water daily. Thus, the hazards posed by the release of effluents containing chemicals with residual effect and high nutrient loads into receiving waters are a new dimension that has unfolded in the aquaculture scenario of the country. The sudden change in culture practices that has occurred in India has caught the nation off-guard as regard to effluents affecting the environment.

As these environmental problems are of recent origin, not enough research has been done to assess the gravity of the situation. Since the outbreak of shrimp disease in 1994, the subject has drawn the attention of research and development agencies in aquaculture, and a number of studies have since been conducted on the environmental impacts of such commercial aquaculture activities. However, most studies have concentrated on the nutrient loading of recipient waters, heavy metal pollution, and changes in water and soil characteristics of adjoining areas. Hence, the present review is largely based on findings restricted to the above impacts of aquaculture. The impact of the use of therapeutants on the environment has yet to be studied in detail. However, some isolated studies on the use of chemotherapeutants in controlling fish diseases have been undertaken in various fisheries research agencies in the country.

USE OF CHEMICALS IN AQUACULTURE

The various chemicals used in grow-out farming and hatchery operations in both freshwater and coastal aquaculture in India can be classified into the following broad categories: water/soil treatment products, disinfectants, piscicides, herbicides, organic fertilizers, inorganic fertilizers, feed additives, therapeutants and anesthetics.

Water and Soil Treatment Products

In both freshwater and coastal aquaculture, it is common practice to treat the pond waters for mineralization of organic matter, for adjusting pH, and for disinfection. The chemicals used in this regard are lime in the form of lime stone ($CaCO_3$), slaked lime ($Ca(OH)_2$) or unslaked lime (CaO). Dried ponds are also sterilized using active iodine or potassium permanganate ($KMnO_4$). Soil conditioners that contain high numbers of sulfur-degrading bacteria and organic matter-decomposing bacteria are also used by some intensive shrimp culture farms. Health stone, zeolite, or porous aluminium silicate is applied along with lime to re-activate the soil for stabilizing algal growth and absorbing fouling materials.

Disinfectants

Common disinfectants used are sodium hypochlorite, benzalkonium chloride (BKC), calcium carbide, Na-EDTA, and zeolite. These are used mostly in hatcheries and, to a limited extent, in grow-out ponds.

Piscicides

In both freshwater and coastal aquaculture, eradication of unwanted predatory fishes is a common pre-stocking management practice. The common fish toxicants used are mahua oil cake, teaseed cake, other plant derivatives and anhydrous ammonium substances.

Herbicides

Aquatic weeds are of common occurrence in fishponds in the country and are undesirable, as they pose serious problems by upsetting the oxygen balance and removing nutrients from the aquatic systems. The common herbicides used for controlling aquatic weeds are 2,4-D; Dalapon; Paraquat; Diuron; ammonia; and many others.

Organic Fertilizers

Use of organic manure in fish culture is an age-old practice. The manure used comes mainly from farm animals, the commonly used manures being cow dung, pig dung, poultry droppings, etc. Cattle manure and poultry droppings contain nitrates at the 0.5 % and 1-15% levels and phosphates at the 0.2 and 0.4% levels, respectively. The application of raw cow dung slurry helps to boost diatom bloom (Sarkar 1983). In modified extensive shrimp-culture ponds, 1,000 to 3,000 kg of cow dung/ha is applied initially. It is followed by application of two dosages of 200 to 400 kg of cow dung on the 8th and 14th d, respectively. Poultry droppings contain higher quantities of soluble salts, inorganic substances and organic products than does cow dung, ensuring quick zooplankton production. In semi-intensive carp culture, large amounts of cow dung are applied to increase the fertility and consequent natural productivity of the ponds. Natural food provides 50% of the food requirement in such carp culture ponds.

Inorganic Fertilizers

Considerable quantities of nutrients are removed from the pond ecosystem through the harvested fish crop. Hence, for proper management of pond soil and water, these elements need to be replenished from external sources. The fertilization schedule is prepared on the basis of the fertility status of the soil. Soils with available nitrogen of >50, 25-50, or <25 ppm; and available phosphate content of >6, 3-6, or <3 ppm are classified as "high," "medium" and "low," respectively. The application rate of the different nitrogenous and phosphate fertilizers varies with culture practice and the nature of the fertilizer used. The doses of fertilizers applied for both carp culture and shrimp culture are presented in Table 1.

Feed Additives

With the intensification of aquaculture practices, there is a shift from using supplementary fish feeds comprised of agricultural wastes and by-products to using complete feeds developed to meet the complete nutritional requirements of the species cultured. These feeds usually have other additives in the form of pigments, vitamins, chemo-attractants, and preservatives, like mold inhibitors and antioxidants.

Therapeutants

There is an increasing occurrence of disease caused by parasitic, fungal, bacterial, and viral infections in both hatcheries and grow-out farms. In the recent past, India has witnessed three major outbreaks of disease. The first to strike was the dreaded epizootic ulcerative syndrome (EUS) in freshwater cultured species. This was followed by yellowhead-virus disease and whitespot-virus disease in shrimp farms. The outbreak of these diseases rendered severe blows to the aquaculture industry in the country, creating the need to use therapeutants in both the freshwater carp industry and in shrimp culture.

Anesthetics

The use of anesthetics in aquaculture in India is rather limited. They are sparingly used, particularly in the long distance transport of broodstock and fish seed.

Information on the uses, methods of delivery, doses, frequency of application, and other aspects for chemicals commonly used by the Indian aquaculture industry is presented in Tables 1-4. Information is presented separately for freshwater aquaculture and coastal aquaculture. Information on the use of chemicals other than therapeutants in the freshwater sector is presented in Table 1, whereas that for therapeutants is given in Table 2. The use of chemotherapeutants in freshwater aquaculture is rather limited and has gained significance only since the outbreak of EUS a few years ago. In carp hatcheries, their use is also limited.

Table 1. Use of chemicals (other than therapeutants) in freshwater grow-out culture and hatchery systems in India.

Item	Purpose	Doses	Mode of Application	Remarks
I. Soil and water treatments				
Quick lime	Correcting pH, disinfectant	400 to 2000 kg/ha	Dissolved in water and broadcast over pond surface	Basal dose of 50%. Remaining in equal monthly installments
	Mineralization	400 kg/ha	Dissolved in water and broadcast over pond surface	Applied at the time of pond preparation
II. Disinfectants				
Bleaching powder	Disinfectant	25-30 ppm	Broadcasting/water solution	Toxicity lasts 7-8 d
III. Piscicides				
Mahua oil cake(MOC) *(Basia latifolia)*	Piscicide (4-6% saponin)	200-250 ppm	Soaked in water and spread over water surface	Toxicity lasts 15-20 d, after which it acts as fertilizer
Teaseed cake *(Camellia sinensis)*	Piscicide	75-100 ppm	Same as MOC	Toxicity lasts 10-12 d, after which it acts as fertilizer
IV. Herbicides				
2,4-D	Emergent weeds, grasses	5-10 kg/ha	Foliar spraying/ root zone treatment	Hyacinth, *Ipomea*, sedges, lillies, *Vallisneria*, etc.
Dalapan	Aquatic grasses	5-10 kg/ha	Foliar spraying	
Simazine, Diuron	Submerged weeds	4 kg/ha	Root zone treatment	Horn wort, *Hydrilla*, etc.
Ammonia	Submerged weeds	10-15 ppm	Root zone teatment/ dispersal in water column	Horn wort, *Hydrilla*, etc
	Floating weeds	1-2% aq. soln.	Foliar spraying with 0.25 % wetting agent	*Pistia*, *Salvinia*
Paraquat	Floating weeds	0.2 kg/ha	Foliar spraying	*Pistia, Salvinia*
V. Organic fertilizers				
Cow dung	Fertilization	15 t/ha	1. Pond bottom application, 20 % of total dose 2. Balance in equal mo doses	Initial manuring done 15 d prior to stocking

Table 1. Continued . . .

Item	Purpose	Doses	Mode of Application	Remarks
VI. Inorganic fertilizers (kg/ha)				
A. Nitrogenous fertilizers	Fertilization		Sprayed or distributed over water surface	Applied alternately with organic manure at 15-d interval
Urea		150-300		
Ammonium sulfate		300-600		
Calcium ammonium nitrate		300-600		
B. Phosphate fertilizers			Sprayed or distributed over water surface	Applied alternately with organic manure at 15-d interval
Single super phosphate		150-400		
Triple super phosphate		50-150		

Table 2. Use of chemotherapeutants in freshwater aquaculture and hatchery systems in India (from Rao *et al.* 1990).

Item	Purpose	Doses	Mode of Application	Remarks
A. Parasitic diseases				
Oxytetracycline	*Myxobolus* spp.	5 gm/ 100 kg fish	Supplemented in the feed	Prevents secondary bacterial infection
Sodium chloride	*Epistylis* spp., *Zoothamnium* spp.	20-50 kg/ha	2-3 installments at 4-d interval	
Malathion/ Dichlorvos	*Dactylogyrus* spp. *Gyrodactylus* spp.	0.2 ppm	2-3 times at 4-d interval	Pond water application
	Argulus spp., *Lernaea* spp., *Ergasilus* spp.	0.15-0.25 ppm (Malathion) 0.05-0.1 ppm (Dichlorovos)	2-4 installments at 4-7-d interval	
Gammexane	As above			Immersion treatment
B. Bacterial/fungal diseases				
Sulphadiazine + Trimethoprim	Surface ulcerative and systemic type (*Aeromonas hydrophila*)	5 gm/ 100 kg	Applied for 7 d	Water dispersible powder
Chloro-tetracycline		7 gm/100 kg	---do---	Supplemented in feed

Table 2. Continued. . .

Item	Purpose	Doses	Mode of Application	Remarks
Oxy-tetracycline	Columnaris disease	7-10 gm/100 kg	Applied for 10 d	Supplemented in feed
Nitrofurans	Microbial gill disease	10 gm/100 kg		Immersion treatment
Trimethoprim		5-7 gm/100 kg		
Copper sulfate	*Saprolegnia* spp., *Branchiomyces*	0.2-0.5 ppm	2-3 installments at 3-4 d interval	Immersion treatment

Table 3. Use of chemicals (other than therapeutants) in coastal aquaculture and hatchery systems in India.

Item	Purpose	Doses	Mode of Application	Remarks
I. Soil and water treatment				
Quick lime (CaO)	Correcting pH	270-1130 kg/ha	Dissolved in water and broadcast over pond surface	Basal dose of 50%; remaining dose given in equal monthly installments
Slaked lime ($Ca(OH_2)$)		340-1610 kg/ha		
Lime stone ($CaCO_3$)		380-1690 kg/ha		Dose depends upon pH of soil and water
Gypsum	Reduces turbidity	300 kg/ha	Applied before manuring	
II. Disinfectants				
20% active iodine	Sterilization	1-2 ppm	Applied in dried ponds	
$KMnO_4$	Sterilization	1-2 ppm	Applied in dried ponds	
III. Soil reformers				
Sulfur bacter	Reduces soil pH	75-120 kg/ha	Applied in wet soil and sun dried 2-3 d	
Health stone/zeolite	Reactivates soil/promotes algal growth/ absorbs fouling materials	250-1000 kg/ha		Dose depends on soil pH
IV. Piscicides				
Mahua oil cake (MOC) *(Basia latifolia)*	Piscicide (4-6% saponin)	200-250 ppm	Soaked in water and spread over water surface	Toxicity lasts 15-20 d, after which it acts as fertilizer
Teaseed cake *(Camellia sinensis)*	Piscicide (10-15% saponin)	75-100 ppm	same as MOC	Toxicity lasts 10-12 d, after which it acts as fertilizer
Derris root powder	Piscicide	5-10 ppm	Same as MOC	
Calcium hydroxide + Ammonium sulfate	Piscicide	10 ppm	Applied in 1:4 ratio	

Table 3. Continued. . .

Item	Purpose	Doses	Mode of Application	Remarks
V. a. Organic fertilizers alone				
Cow dung	Fertilization	Primary dose 1-3 t/ha	Applied when water depth is 10 cm	
		Secondary dose 200-400 kg/ha	Two doses, one at 30 cm water depth and another at 100 cm water depth	
Poultry droppings	Fertilization	Primary dose 100-500 kg /ha	Applied when water depth is 10 cm	
		Secondary dose 25-100 kg/ha	Two doses, one at 30 cm water depth and another at 100 cm water depth	
b. Organic fertilizers along with inorganic fertilizers				
(i). Cow dung	Fertilization	200-500 kg/ha	Applied initially by broadcasting	
Urea	Fertilization	150 kg/ha	Applied in 2 doses	Following application of cow dung
Single super phosphate		50-70 kg/ha	Applied in 2 doses	
(ii). Poultry droppings	Manuring	100-250 kg/ha	Applied initially by broadcasting	
Urea	Fertilization	20 kg/ha	Applied in 2 doses	Following application of cow dung
Single super phosphate		6 kg/ha	Applied in 2 doses	
VI. Inorganic fertilizers				
1. Nitrogenous fertilizer	Fertilization	Primary dose dose 0.95 ppm N_2 level.	Applied initially on d 1	Fertilizers are dissolved and dispersed in dilute form
		Secondary dose 0.475 ppm N_2 level	Applied in two subsequent doses on d 8 and 14	
2. Phosphate fertilizer	Fertilization	Primary dose 0.11 ppm P_2O_5 level.	Applied initially on d 1	Fertilizers are dissolved and dispersed in dilute forms
		Secondary dose 0.055 ppm P_2O_5 level	Applied in two subsequent doses on d 8 and 14	

Table 4. Use of feed additives and therapeutants in coastal aquaculture and hatchery systems in India.

Item	Purpose	Doses	Mode of Application	Remarks
A. Feed additives		**/kg feed**		
1. Mineral premix	Mineral requirement		Mixed with feed	
Calcium		10-18 gm		
Phosphorus		18 gm		
Magnesium		0.8-1 gm		
Sodium		6 gm		
Potassium		9 gm		
Zinc		50-100 mg		
Copper		25 mg		
Manganese		20 mg		
Iron		5-20 mg		
Cobalt		10 mg		
Selenium		1 mg		
2. Anti oxidants				
Ethoxyquin	Protects fatty acids	150 mg		
Butylated hydroxy toluene	Protects fatty acids	0.02% of fat content	Added to lipids or vitamin premix	
Butylated hydroxy anisole	Protects fatty acids	0.02% of fat content	Added to lipids or vitamin premix	
3. Antimicrobials	Prevents growth of microbes and fungi	0.1-0.25% of feed	Added to feed	
Sorbic acid derivatives				
Propionic acid derivatives				
Sodium benzoate				
4. Pigments				
Astaxanthin	Coloration	30-35 ppm	Added to feed	
B. Therapeutants				
1. Grow-out ponds				
Teaseed cake	Necrosis of appendages	5-10 ppm		Induces molting
Oxytetracycline	Brown spot disease, bacterial septicemia, black gill disease	1.5 gm/kg feed	Mixed with feed for 10-15 d at the rate of 2-10% of biomass	

Table 4. Continued . . .

Item	Purpose	Doses	Mode of Application	Remarks
Formalin	Protozoan fouling	15-25 ppm	Applied into ponds	
		50-100 ppm	Dip treatment for 30 min	
2. Hatcheries				
EDTA	Vibriosis	10-15 ppm		
Copper sulphate	Filamentous bacterial disease	0.25-1 ppm	Dip treatment for 4-6 h	
Treflan	Larval myosis	0.1-0.2 ppm	Bath for 1 d	
Prefuran	Bacterial necrosis *Vibrio* infection	1 ppm		

Supply of Chemicals

The various chemicals and antibiotics used in aquafarming are mostly available locally, and there is no control on their sale and usage. Most of the farmers use veterinary-grade antibiotics for application in the fishponds. Certain products are imported from companies such as Aurum Aquaculture Ltd (USA), J.V. Marine (Taiwan), Argent Chemical Laboratories (USA), and Pfizer Food Science (USA). Information on the quantitative usage of these chemicals is generally not available and no agencies mandated to regulate usage are in existence at the moment. Information regarding the nature and prices of some of the chemicals available from Indian manufacturers is presented in Table 5.

Table 5. Common pesticides and antibacterials used in aquaculture and their manufacturers.

Pesticide/chemical/ antibiotic	Brand name	Manufacturer	Rate (Indian rupees (rs)/kg, as of Oct. 1990)
Dichlorvos	Nuvan	Hindustan Ciba-Geigy Ltd.	225
Malathion	Cythion	Cyanamid India Ltd.	75
Quinophos	Ecalux	Sandoz India	150
Benzene hexachloride	Gammexene	Local companies	40
Copper sulphate		Local companies	20
Sodium chloride	Common salt	Local companies	0.50
Calcium oxide	Lime	Local companies	1.25
Oxytetracycline	TM-50	Pfizer Ltd.	120
Chlortetracycline	Aurofac-20	Cyanamid India Ltd.	68
Doxycycline	AFS Forte	Vesper	90
Nitrofurazone + Furazolidone	Bifuran	Eskaylab Ltd.	120
Furazolidone	Groviron	Glaxo Laboratories	120
Sulphadiazine + Trimethoprim	Bactrisol	Alved Pharma Pvt. Ltd.	290
Chloramphenicol	Neochlor Forte	Vetcare Division of Tetragen Chemie Ltd.	NA
Neomycin+ Doxycycline	Neodox Forte	Vetcare Division of Tetragen Chemie Ltd.	NA

NA = not ascertained.

FARM MANAGEMENT AND USE OF CHEMICALS

Preventive Methods

Most therapeutic agents have residual effects on the tissues of the candidate species. In addition, antibiotics may also leach into natural habitats, leading to modification of native bacterial flora and the emergence of antibiotic-resistant strains. The persistence of therapeutic agents in the aquatic environment may also cause adverse effects on the ecosystem (Anon 1988, Choo 1994). The best strategy in the management of aquaculture enterprises is to prevent the occurrence of disease. The industry in India, by and large, takes the following precautions to prevent disease in hatcheries and grow-out farms:

Disease Prevention Measures in Hatcheries:

1. Proper site selection. In choosing the location for a hatchery, due care should be taken to locate it in a place where good quality water is ensured for maintenance of broodstock, spawning, and larval rearing.
2. Water treatment. Disinfect sea water with calcium hypochlorite (20-30 ppm) or sodium hypochlorite (150 ppm) for 1-2 d. Remove excess chlorine from sea water by neutralizing with sodium thiosulfate. Filter or sterilize by UV treatment or other means, sea water used for all hatchery operations.
3. Maintenance of cleanliness of hatchery facilities. The tanks used for broodstock, spawning, and larval rearing should be kept thoroughly clean.
4. Disinfection of broodstock. For this purpose, 20 ppm formalin or other appropriate drugs can be used as short bath or dip treatment.
5. Observe appropriate care at the time of spawning by thoroughly removing the scum formed after spawning.
6. Stock only healthy nauplii at an optimal stocking density. The nauplii can be disinfected by dip treatment in 200-300 ppm formalin.
7. During larval rearing, siphon out unused feed, sediments, debris, and wastes accumulated at the bottom and sides of the tanks.
8. Feed the larvae with optimal amounts of good quality well-balanced feed.
9. Use antibiotics carefully and at the correct doses, preferably after ascertaining the *in vitro* sensitivity of the pathogens. Low doses of antibiotics lead to the development of antibiotic-resistant mutants of bacteria and higher doses may be toxic to the shrimp larvae or the other fauna and flora of the culture system.
10. Examine larvae microscopically every morning before changing water for any signs of abnormality, fouling protozoa, filamentous bacteria, fungal infections, and presence of swarming bacteria within the hemocoel. Maintain good water quality parameters at all times.
11. Disease outbreaks due to viral infection can be avoided by quarantine measures, and by destroying carriers and clinically diseased animals.

Disease Prevention Measures in Grow-out Farms:

1. Select farm sites properly, ensuring that they are far from industrial, agricultural and domestic sources of pollution.
2. Before stocking, drain and sun dry the ponds thoroughly. The black layer of soil formed during the previous crops should be removed and the pond tilled. Lime can be applied at the rate of 200-600 kg/ha depending on the pH of the soil.
3. Stock only healthy postlarvae after achieving an optimal algal bloom in the ponds. Maintain optimal density of shrimp larvae.
4. Good water quality in the pond should be maintained.

5. Feed the shrimp with a balanced diet at optimal quantity. Care should be taken to avoid overfeeding and accumulation of uneaten feed.
6. Routinely examine the health status of the shrimp. Frequent microscopic examination of gills, hepatopancreas and hemolymph for microbial infections or any disease signs should be done. Clinically diseased and infected shrimp should be destroyed by burning or burying with lime in soil away from the shrimp farm.
7. Practice adequate quarantine measures before transporting shrimp postlarvae or broodstock to different geographical locations. They may harbor pathogenic microorganisms, particularly viruses, without showing external clinical signs.
8. If available, use disease-resistant stocks for culture purposes. The resistance of shrimp to various infectious agents appears to be species specific and is probably a genetically acquired trait.
9. Vaccines may also be used for controlling specific diseases.

Therapeutic Measures

Disease control programs in aquaculture must consider various factors such as stocking density, environmental parameters, rate of water exchange, the type of feed used, and phytoplankton blooms. However, in spite of the best management practices adopted in hatcheries and grow-out systems, disease outbreaks will still occur, necessitating use of drugs for their control. Although some drugs have been advocated for treatment of diseases (see Tables 2 and 4), these should be employed only as a last option. Many aspects of the dynamics of drug use in aquaculture are yet to be studied. Various aspects of using drugs for disease control such as their dosages, intervals of administration, duration of exposure of fish, their effect and efficacy in controlling the disease, withdrawal period from the tissues, effects on non-target species, etc. remain to be clearly understood. As drugs are useful only if they are applied during the early phase of disease, correct diagnosis at an early stage is a very important aspect that will help to control the disease.

Criteria for Selection of Drugs for Disease Control:

The following criteria are used to select appropriate drugs for disease control:

1. The sensitivity of the pathogen to the drug or antibiotic based on *in-vitro* tests must be known.
2. The antibiotic or chemical should reach the pathogen and kill it without adversely affecting the host.
3. The antibiotic or drug should not adversely affect the user and the natural flora and fauna.
4. The drug should rapidly be broken down to avoid problems with tissue residues.
5. The metabolites of the drug should be harmless to the cultured animal and the consumer.
6. The drug should be stable under normal storage conditions.

Methods of Application of Drugs:

The treatment methods currently being followed include applying the therapeutic agent to the pond water or administering it along with feed. The various methods that are commonly followed are given below:

1. Oral route

The chemotherapeutant may be incorporated in the feed at the correct dose and fed to the shrimp. However, application of medicated feeds needs to be clearly understood, otherwise, the drug may diffuse into the water and create problems (Choo 1994). Drug therapy by this method should preferably start during the initial stages of the disease, since fish in the advanced stages of disease feed poorly. Compounds like antibiotics, sulfa drugs and nitrofurans are widely used along with feed to treat bacterial diseases, both in shrimp and freshwater carp culture systems in India (Tables 7 and 9).

In carp culture systems in the State of Andhra Pradesh, the required quantity of poultry feed supplement (poultry feed supplements with various proportions of antibacterial activity are commonly available to the fish farmers) is added to the normal fish feed by mixing 4:1 mixture of de-oiled rice bran and oil cake into a dough (Rao *et al.* 1992). Unlike the common practice of broadcasting the feed over the pond surface, the feed is kept suspended in perforated bags tied to bamboo poles. Normally, 10-20 bags of size 20 x 30 inches are used per ha, the bags being tied individually to bamboo poles fixed at regular intervals in the pond. Each bag has two rows of perforations and can contain up to 12 kg of feed. Typically, the feed within a perforated bag is eaten by the fish within 2 h. This method results in minimal feed wastage and reduced antibiotic leaching as compared to broadcasting the medicated feed over the pond (Rao *et al.* 1992).

2. Immersion treatment method

This method is followed to treat ectoparasitic diseases, bacterial surface ulcerative lesions and external fungal problems. The therapeutic agent is added directly to the pond water or sprayed over the surface. Agricultural grade pesticides sold under different brands have been regularly used to treat against helminth and crustacean parasites. The current method of pesticide application in carp farms in Andhra Pradesh involves dissolving the required quantity of pesticide in 10-20 L of water and spraying the solution over the pond surface with hand-held agricultural sprayers. In large fishponds, hand-held sprayers are operated from boats. Use of this method is very popular for the application of Nuvan and Malathion to combat infection by *Argulus* spp. (Rao *et al.* 1992).

3. Dip treatment

In this method, the fish or shrimp are held in containers with a strong solution of the chemotherapeutant for short durations. This method may be useful when only a small portion of the stock is affected with non-systemic infections such as fouling, shell disease, necrosis of appendages, etc.

4. Bath treatment

This method is applicable only when a small portion of the stock is affected with disease. The fish are given bath treatment in containers for 30-60 min in a solution containing the drug.

5. One-time application

In one-time application, a low concentration of the chemical is applied to the culture tanks or ponds for an indefinite period. However, this method poses pollution problems.

6. Injection

This method is practical to use when only a small number of large and valuable fish are to be treated.

7. Topical application

This method is also applicable only for a small number of valuable broodstock suffering from non-systemic diseases such as shell disease.

Hazards and Adverse Impacts on Culture Organisms and Farm Productivity

The adverse impacts of chemical inputs on farmed species and farm productivity will be discussed separately for carp culture and shrimp culture because of the inherent differences between the two industries. The interaction between the pond environment and the external environment, and the qualitative and quantitative differences in the use of chemical inputs in the two fundamentally different aquaculture practices in the country are obvious.

Freshwater Aquaculture

Freshwater fish culture contributes the bulk of production derived from Indian aquaculture. The dominant culture system is semi-intensive polyculture of Indian major carps and Chinese carps (CIFRI 1985). Most semi-intensive culture ponds are relatively isolated from the external environment. Being largely dependent on natural productivity, augmented by the use of organic and inorganic fertilizers and a supply of supplementary feed largely consisting of agricultural by-products, Indian freshwater aquaculture is environment-friendly in nature. However, in attempting to achieve higher productivity, aquaculturists have often exceeded the carrying capacity of their ponds and the sustainable limits of production. Overloading systems with fish biomass and excessive application of fertilizers and supplementary feed results in deterioration of water quality, increased plankton bloom, stress to farmed species and consequent outbreak of disease. Accumulation of unused feed and metabolites often leads to eutrophication and an inimical pond environment. The resulting outbreaks of disease, in turn, necessitate the use of prophylactic agents and chemotherapeutants. The recent outbreak of epizootic ulcerative syndrome is an example of this cycle of events.

Under the ADB/NACA/NABARD and Government of India-sponsored Regional Study on Aquaculture Sustainability and the Environment in 1995, a national farm-level survey was conducted in four states involving 1004 carp farmers covering 620 issues. The findings of the study corroborate the above views. The environmental problems encountered are indicated in Table 6.

Table 6. Occurrence of environmental problems encountered in carp-culture ponds surveyed (from FAO/NACA 1995).

Factor		Percentage of Occurrence	
		Extensive farms	**Semi-intensive farms**
I	Water quality deterioration		
	1. Dissolved oxygen	6	5
	2. Plankton blooms	3	2
II	Disease outbreak	4	9
III	Total loss	8	5
IV	Reduced harvest	78	62
V	Market rejections	5	15
VI	Reduced price	5	10

The losses were attributed to bacterial disease, EUS and other unknown causes. The treatments followed in the affected farms were quite varied; only 4-7% of farms did not attempt to give any treatment (Table 7).

Compilation of information on the effects on farmed species of the various chemicals used was outside the purview of the above study. However some related studies have been conducted by fisheries scientists in India.

Table 7. Use of chemotherapeutants in controlling diseases in carp farms in India (numbers are % values of farms surveyed) (from FAO/NACA 1995).

Chemotherapeutant	Extensive	Semi-intensive
None applied	7	4
Oxytetracycline	4	12
Chloramphenicol	2	1
Other antibiotics	0	3
Local herbs or medicines	7	0
Methylene blue	0	1
Copper sulfate	2	7
Trichlorofon	0	1
Sumithion	0	1
Potassium permanganate	35	45
Formalin	0	2
Medicated feed as prophylactic	0	1
Others	43	24

The negative effects of pesticides on fish are well known. Widespread use of pesticides, besides causing mass kills, may hamper growth and reproduction in fish, produce severe lesions in the vital organs, inhibit gut enzyme activity, affect hatching, and reduce feeding and respiratory rate. Extreme pH levels enhance the toxicity of organophosphorus pesticides (Konar *et al.* 1990).

There are reports of increased use of fertilizers altering the pH of water and soil, and the alkalinity of water. Application of muriate of potash (K_2O) at 20-80 kg/ha reduced the feeding rate, maturity index and fecundity of fish. High application rates of lime (2,250 kg/ha) in fish ponds reduced survival, growth, maturity index and fecundity of fish significantly (Konar *et al.* 1990).

Shrimp Farming

Semi-intensive and intensive shrimp farming systems are characterized by high inputs of fertilizers and supplementary feeds, and increased load of nutrients, organic matter and other wastes that can affect water quality in ponds and receiving waters. Feed is the most important input contributing to the waste, although fertilizers, chemicals, antibiotics, and drugs may also contribute.

The effects of waste materials can be seen both within and outside the pond. Within the pond, dissolved nutrients and organic solids stimulate growth of plankton, microbes and benthic organisms. A considerable amount of dead organisms and wastes accumulates at the pond bottom. This accumulation is associated with decreased redox potentials and the release of harmful gases including hydrogen sulphide and methane, causing stress and health risk.

The effects of these stressors on farmed shrimp were encountered during the national survey under the ADB/NACA-sponsored Regional Study on Aquaculture Sustainability and the Environment (Pathak and Palanisamy 1995). The survey included 966 shrimp farmers spread over four states in India. The results show that problems with water and soil affected 9-14% of the farms. Turbidity and filamentous algae were also important causes of problems. Plankton bloom was also reported to affect intensive farms (Table 8).

Table 8. Occurrence of water quality and soil problems in shrimp farms surveyed.

Nature of Problem		Occurrence (%)		
		Extensive	Semi-intensive	Intensive
1	Salinity	7	7	-
2	Temperature	2	2	-
3	Low dissolved oxygen	1	1	-
4	High turbidity	1	2	-
5	Plankton bloom	-	-	14
6	Filamentous algae	3	1	-
7	Soil problems	1	2	-
8	Others	-	1	-

Water and soil problems were reported to result in prawn disease. Shrimp disease was reported from 14% of extensive farms, 22% of semi-intensive farms, and 57% of intensive farms surveyed (Table 9).

Table 9. Disease problems observed in shrimp farms.

Particulars	Extensive	Semi-intensive	Intensive
Number of farms (%)	14.0	22.0	57.0
Frequency of occurrence (times/yr)	0.9	0.7	0.7
Total loss (%)	62.0	59.0	75.0
Reduction in harvest (%)	33.0	38.0	25.0

The causes of disease were unknown to farmers, thus no information was provided by the survey regarding the types of shrimp disease encountered. There were no reports of successful control measures; however, the treatments applied in attempts to control shrimp diseases are presented in Table 10. The great diversity of chemicals used by farmers and the limited success achieved reflect a need for proper extension service to educate the farmers regarding disease identification, prophylaxis and control.

Table 10. Treatments applied for shrimp disease control (values are % of farms surveyed).

	Extensive	Semi-intensive	Intensive
None attempted	25	5	33
Oxytetracycline	31	71	67
Chloramphenicol	0	5	0
Other antibiotics	13	2	0
Local herbs or medicines	7	0	0
Benzalkonium chloride (BKC)	13	2	0
Copper sulfate	1	2	0
Malachite green	0	5	0
Potassium permanganate	2	2	0
Formalin	6	2	0
Medicated feed as prophylactic	2	2	0

Impacts on Farm Workers and Consumers

Aside from reports of workers in shrimp hatcheries and farms suffering from over-exposure to bleaching powder or chlorine, incidences where toxic substances have affected farm workers or consumers, where residues have affected product quality or where pathogens resistant to chemotherapeutants have been encountered have not been reported in India.

Environmental Impacts

There are few environmental problems encountered in freshwater carp cullture, as in these inland fish farms the pond-culture units are typically closed systems. However, release of large volumes of water containing nutrients, organic matter, and wastes at the time of fish harvest was reported to have resulted in eutrophication of receiving waters and algal blooms (Pathak and Palanisamy 1995). The concentration of ponds in areas with limited water resources aggravated the situation. Development of semi-intensive pond culture for Indian major carps around Kolleru Lake in Andhra Pradesh has resulted in heavy discharge of pond effluents during harvest. This has contributed to the deterioration of lake water quality, leading to increased disease outbreaks (FAO/NACA 1995).

There has been considerable debate on the environmental impacts that shrimp pond effluents may have on the receiving waters and the ecosystem. A comparison of shrimp farm effluents with other discharges has shown that their pollution potential is considerably less than that of domestic or industrial waste water. However, effluents produced during pond cleaning have greater pollution potential, although for a much shorter period. Although shrimp farm effluents are less noxious than many other coastal effluents, water pollution problems arise because of the large volumes discharged. Pollution also results when shrimp farms are concentrated in areas with limited water supply or with poor flushing capacity. In such situations, the shrimp farms themselves are most severely affected, resulting in "self-pollution."

Although no detailed research on potential hazards due to the presence of chemicals and therapeutants in shrimp farm effluents has been done in India, studies have been conducted by the National Environment Engineering Research Institute, Nagpur (NEERI 1995) and the Central Institute of Brackishwater Aquaculture (CIBA 1995), in areas of heavy concentration of shrimp farms. The following hazards were identified:

- Contamination of drinking water source.
- Organic contamination of creek and nearshore sea water.
- Accumulation of heavy metals in creek sediments.
- Increase in bacterial and fungal count due to organic contamination of creek, discharge canal, and sea.
- Dominance of blue-green algae in receiving waters, indicating organic pollution.
- Change in soil characteristic in agricultural lands surrounding aquaculture farms.

Studies conducted by CIBA (1995) on the water quality of Kandaluru Creek in the Nellore District of Andhra Pradesh, the hub of aquaculture activity in India, in connection with the recent outbreak of shrimp disease, brought out certain interesting observations (Table 11). This work clearly indicates that the water quality parameters changed significantly as one progresses from the mouth of the creek (Station 1) to the upper reaches (Station 3). The highest level of deterioration in water quality was observed in the middle region (Station 2), where most of the semi-intensive shrimp farms are located. Even some four months after the disease outbreak, the water quality had not shown any perceptible improvement.

In April 1995, studies were also conducted by a team of 13 scientists who inspected the shrimp farms situated in coastal areas of Andhra Pradesh, Tamil Nadu and the Union Territory of Pondicherry (NEERI 1995).

Table 11. Water quality parameters in Kandaleru Creek, Andhra Pradesh.

Parameters	**Concentrations During Different Periods at Three Survey Stations Starting from Creek Mouth (S1) in the Creek to Field (S3)**								
	Pre disease outbreak			During outbreak			Post disease outbreak		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Total suspended solids (mg/L)	30	-	140	90	-	100	28	-	-
Chemical oxygen demand (mg/L)	7.5	103.2	29.4	11	120	90	12	-	180
Biochemical oxygen demand (mg/L)	3.8	76.6	12.6	3.5	60	14.5	4	52.3	92
Free ammonia (mg/L)	0.001	-	0.01	0.002	0.04	0.027	0.002	0.096	-

Impact on Well Water

The impact of shrimp farming on the quality of well water in a number of villages adjoining shrimp farms in both the states was studied. Findings from two such villages are presented in Table 12.

Table 12. Water quality characteristics of well water in two villages in Andhra Pradesh and Tamil Nadu.

Parameter[1]	**Kurru Village (A.P.)**		**Kuchipalam Village (T.N.)**	
	100 m from farm	**500 m from farm**	**100 m from farm**	**500 m from farm**
pH	8.0	7.9	7.9	7.8
Total alkalinity	290	275	310	260
Total hardness	276	250	260	235
Total solids	920	850	860	830
Chlorides	464	243	490	230
Ammonia-nitrogen	0.40	0.30	0.90	0.35

[1]All values are expressed in mg/L except pH.

It is evident that the water quality of the wells closest to the shrimp farms (100 m from the farms) was poorer than that of the wells which were located further away (500 m from the farms). Similar observations were recorded with respect to other villages studied by the team.

Organic Contamination of Creeks

The results of the study show organic contamination of creek water (Table 13).

Table 13. Physico-chemical characteristics of water samples from Kandaleru Creek.

Creek Water Sample Source	Concentration (mg/L)								
	Dis-solved Oxygen	pH	TDS	Sus-pended Solids	Dis-solved Phosphates	NH_3 Nitro-gen	Sul-fide	Total Nitrogen	BOD_5
1 M/s Swamy farms	5.5	7	25000	70	0.08	0.1	ND[1]	3.5	16
2 Star Marine	2.9	7.46	6000	1	0.02	0.82	ND	5.36	12
3 Siris Aqua	5.6	7.2	26000	100	0.02	0.82	ND	3.2	15
4 Far East Marine Products	5.7	7.5	28000	100	0.05	0.80	0.75	2.5	14
5 VKVR Raju	4.6	7.43	19200	480	0.14	0.86	0.76	2.47	-
6 Isnar Aqua	4.5	7.32	10000	470	0.12	0.56	ND	2.53	-

[1]ND = not determined.

Accumulation of Heavy Metals in Creek Sediments

The study showed the presence of some of heavy metals in the sediments of Kandaleru Creek adjoining various aquafarms (Table 14).

Table 14. Concentration of heavy metals in creek sediments in Andhra Pradesh.

Aquaculture Farm	Concentration of Heavy Metals (mg/gm)			
	Iron	Manganese	Copper	Zinc
1 VKVR Raju	50.22	0.243	0.038	0.086
2 Isnar Aqua	48.44	0.459	0.040	0.104
3 Ch.V.Surya Rao	62.23	0.111	0.085	0.012
4 Star Marine	58.39	1.007	0.084	0.114
5 K.Raghu	50.11	0.962	0.068	0.094
6 Choudhary Farm	58.32	0.640	0.089	0.104
7 Kalyan Sea Foods	50.23	0.366	0.049	0.074
8 Jagan Mohan Rao	ND[1]	0.224	0.024	0.067

[1]ND = not determined.

Bacterial and Fungal Contamination

The microbiological studies show high bacterial and fungal counts that were attributed to the contamination of creek, sea, and canal by the heavy discharge of organic effluent in the receiving water (Table 15).

Table 15. Bacterial and fungal contamination in the creek, sea, and Buckingham Canal water at Kakinada, Visakhapatnam and Nellore in Andhra Pradesh.

	Sampling Station	Total Bacterial Count CFU[1]/mL Sample	Total Fungal Count CFU/mL Sample
1	Swami Aqua Farm	1800	30
2	Visaka Aqua Farm	1300	2
3	Siris Aqua Farm	2400	20
4	Far East Marine Products	3200	6
5	Magunta Aqua Farm	1400	4
6	Rank Aqua Farm	4500	10
7	Carewell Investment Pvt Ltd.	1900	15

[1]CFU = colony-forming units.

Dominance of Blue-green Algae

A study on the phytoplankton composition of water samples showed dominance by blue-green algae (Cyanophyceae) which was attributed to organic pollution (Table 16).

Table 16. Phytoplankton population in creek water samples.

Sampling Station	Total Count/mL	% Organisms in Group[1] 1	2	3	Shannon-Weaver Index
1 Ms Swamy Farm	15	42	58	-	1.2
2 Visaka Aqua Farm	18	72	28	-	1.4
3 Siris Aqua Ltd.	45	33	67	-	1.5
4 Far East Marine Products Ltd.	11	65	35	-	1.6

[1]Group 1 = Bacillariophyceae, Group 2 = Cyanophyceae, Group 3 = Chlorophyceae.

Change in Soil Characteristics

The study of soil characteristics at different locations around shrimp farms in the states of Andhra Pradesh and Tamil Nadu reveals that there is usually an increase in soil pH and electrical conductivity on account of salinity intrusion in the vicinity of fish farms (Table 17).

Table 17. Soil characteristics at different locations around prawn farms in the states of Andhra Pradesh (A.P.) and Tamil Nadu (T.N.).

	Location	Parameter pH	Electrical Conductivity (mm/cm)
1	MS Swamy Farm (Visakhapatnam, A.P.)		
	100 m away	7.8	7.6
	500 m away	7.8	6.5
2	Rank Aqua Farm (Nellore, A.P.)		
	100 m away	8.0	7.6
	500 m away	7.4	6.0
3	Aqua Development India Ltd. (Prakasam, A.P.)		
	100 m away	8.0	8.2
	500 m away	8.2	6.3
4	Mayur Aqua Farm (South Arcot, Sirkhali, T.N.)		
	100 m away	8.5	8.1
	500 m away	7.3	6.2
5	Sriram Marine Harvests (Quaid-e-Milleth, T.N.)		
	100 m away	7.8	7.3
	500 m away	8.8	5.2
6.	Mac Aqua Farm (Chidambranar, T.N.)		
	100 m away	7.6	7.7
	500 m away	8.4	5.0

OTHER APPROACHES TO DISEASE PREVENTION

The approaches to disease prevention that have evolved in India after the outbreaks of shrimp disease in September 1994 and May 1995 are given below. The guidelines developed are exhaustive and only important aspects are described herein.

Crop Holiday

The widespread disease outbreak in Andhra Pradesh necessitated the declaration of a crop holiday. The idea behind the declaration of crop holiday was to allow a period long enough for the culture system and the water source with which it is associated to recover to a degree to permit successful shrimp farming. It was also envisaged that the farmers would dry their ponds thoroughly. This method is proving to be successful, as many farmers restarted farm operation without any problem after observing a crop holiday.

Adequate Pond Preparation

Removal of the accumulated black top soil, drying until cracks develop, plowing and replowing the ponds two or three times, and sun drying after each crop are now suggested to farmers as approaches to disease prevention. The importance of application of lime at the rate of 2 t/ha for disinfecting the soil has been emphasized. Farmers are advised to keep the application of organic fertilizers to a minimum.

Regulating Stocking Density

The ADB/NACA/GOI study conducted in 1995 found that stocking density has a strong influence on the performance of shrimp culture farms (Pathak and Palanisamy 1995). The survey results show some clear differences in the environmental problems in farms related to stocking density, as summarized in Table 6. The study also showed that both profit and production increase with increasing stocking density. However, the shrimp farmers faced increased occurrence of disease, environmental problems and conflicts with higher stocking densities (Table 18). A significant increase in problems is noted when stocking densities exceed 20 PL/m^2. This information appears to strongly support the government's policy of not promoting intensive shrimp culture (Government of India 1995).

Table 18. Relationships between stocking density and key performance indicators of shrimp farms.

Stocking density (PL/m^2)	No. of farms surveyed	Average stocking density (PL/m^2)	Profit ($/ha/yr)	Disease losses ($/ha/yr)	Environment Index	Conflict Index	Production (kg/ha/yr)
<5	333	2.9	1343	275	0.20	0	717
5-10	221	6.1	2822	326	0.20	0	1367
10-20	76	12.2	4588	466	0.26	0.05	2464
20-30	22	22.8	7453	1099	0.45	0.41	5209
30+	13	39.8	12272	3214	0.30	0.50	6627

Effluent Treatment Systems

Before the outbreaks of disease, no shrimp farm had put up an effluent treatment system, which was a great omission. It has been estimated that nearly 60% of the feed given turns into biological waste. Therefore, one can imagine the extent of organic load that is being discharged with the effluents in a given area. Such effluent treatment systems have now been made an integral part of farming activity.

NATIONAL REGULATIONS ON THE USE OF CHEMICALS IN AQUACULTURE

At present, there are no regulations to control the use of chemicals and drugs in aquaculture, mainly because the use of chemicals in aquaculture is a recent phenomenon in India and the issue was non-existent a decade ago. Only after the outbreaks of disease in shrimp culture farms has discussion on the need to introduce regulations commenced. The Central Pollution Control Board and State Pollution Control Boards have certain regulations on effluents containing hazardous substances, but they are not specific to aquaculture.

Recently, the Ministry of Agriculture issued guidelines in the form of management practices and recommended parameters for water discharges from various aquaculture systems such as hatcheries, ponds, feed mills and processing plants. The parameters are on pH, suspended solids, dissolved oxygen, free ammonia, biological oxygen demand, chemical oxygen demand, dissolved phosphate and total nitrogen. However, the guideline developed by the Government of India stipulates that "chemicals use should be avoided in shrimp culture ponds for prevention or treatment of disease as feed additives, disinfectants, for removal of unwanted fish, or for treatment of soil or water. However, chemicals may be used in hatcheries. Therefore, the entry of such chemicals into the natural waters from the hatcheries should be carefully monitored and steps should be taken to remove such materials from the waste waters."

The guideline from the Government of India (GOI 1995) also restricts the indiscriminate use of fertilizers, as both the organic and inorganic fertilizers that are widely used in semi-intensive culture systems contribute to the nutrient load of receiving waters. Therefore, as far as possible, only manure and other plant products should be used for such purposes.

Regarding the use of piscicides, the guideline says that "Piscicides and molluscicides are widely used for removing predators and competitors from shrimp ponds. It would be advisable for aquaculture to use only biodegradable organic plant extracts for this purpose as they are less harmful than the chemical agents. Use of chemicals in culture systems should be avoided."

On the use of chemotherapeutants, the guidelines of GOI state that " ...formalin and malachite green, which are commonly used as disinfectants, are known to be toxic and may affect adversely the pond ecosystem and the external waters. Hence their usage in the culture system should be avoided." Similarly on the use of antibiotics and drugs, GOI regulations state that "A number of antibiotics used in shrimp culture for preventing outbreak of diseases are harmful and incorrect usage may result in development of shrimp pathogens resistant to such drugs. The transfer of these pathogens into human beings might result in the development of resistance among human pathogens. Therefore, the use of antibiotics and drugs in the culture system should be avoided."

The GOI guideline also stipulates that any farm of 40 ha and above should obtain consent from the State Pollution Control Board under Sec. 25/26 of the Water (Prevention & Control of Pollution) Act, 1974. Farms with 10 ha or less watered area shall obtain a No Objection Certificate of the State Pollution Control Boards.

The guidelines are for compliance by the aquaculturists; however, there is no enactment of the regulation as yet.

ON-GOING RESEARCH ON CHEMICAL USE FOR AQUACULTURE

Because the use of chemicals in aquaculture is a recent development in India, research to date in this area has been very limited. The research institutions of the Indian Council of Agricultural Research (ICAR), the fisheries colleges of the state agricultural universities, and some of the traditional universities undertake research in this field. The recent outbreaks of disease in shrimp culture have led to enhanced interest in research on this topic. The agencies involved in research on chemicals are given in Table 19.

CONCLUSIONS

Although information on the quantity of chemicals and therapeutants used in aquaculture is not available at present, the tremendous upsurge in their use in the last five years is primarily due to the phenomenal growth in shrimp grow-out culture and hatchery operations and to the expansion of the carp industry. Considering the stagnation in fish harvest from nature, the future fish requirements of the country can only be met from expansion of freshwater and coastal aquaculture, and the utilization of the seaward side of the country's coastline, which is presently untapped for mariculture. This definitely would call for higher usage of chemicals in aquaculture and would require careful environmental planning and prudent usage of chemicals and therapeutants. The country at present lacks a suitable policy for the manufacture, sale and use of such chemicals. It is, therefore, absolutely necessary at this stage to frame suitable policies and legislation and to create the infrastructure for

Table 19. List of agencies undertaking research on the use of chemotherapeutants in aquaculture.

Institution	On-going Research Programs
Central Institute of Brackish Water Aquaculture (ICAR)	Shrimp diseases, their prevention and control Diagnosis and control of finfish and shellfish diseases Database on shrimp diseases Development of diagnostic tests and prophylactic vaccines Impact of brackishwater aquaculture on the environment
Central Marine Fisheries Research Institute (ICAR)	Finfish and shellfish diseases Monitoring the fishery environment
Central Institute of Freshwater Aquaculture (ICAR)	Finfish and shellfish diseases and their prevention and control
Central Institute of Fisheries Technology (ICAR)	Bacteriological studies on fish affected by EUS
Central Inland Capture Fisheries Research Institute (ICAR)	Studies on EUS
College of Fisheries, University of Agricultural Sciences, Mangalore	Use of chemotherapeutic agents in aquaculture Microbiological studies on pathogens Effects of antibiotics on immune response
University of Madras, Department of Zoology	Studies on viruses, bacteria, fungi and protozoans from cultured species
Department of Fisheries Science, Andhra Pradesh Agricultural University	Parasitology Use of chemotherapeutic agents in fish culture
Cochin University of Science and Technology	Bacteriology
Andhra University	Pathology

In addition to the above, many traditional and agricultural universities undertake research on the use of chemicals in aquaculture.

their implementation and monitoring. The indiscriminate use of such chemicals can pose serious hazards to public health and aquatic life. The most serious problem at the moment is a lack of information on the use of chemicals by the aquaculturists in India and their appropriateness. Most veterinary grade chemicals and biocides are freely available to the aquaculture sector. Often, farmers are unaware of the nature of a disease and its etiology, and easily fall prey to errant advisers. This leads to indiscriminate use of hazardous chemicals, which may prove dangerous. Hence, it is necessary to create an awareness among aquaculturists of the potential hazards of indiscriminate drug use, and to provide them necessary assistance through timely diagnosis and prescription of appropriate drugs. In order to achieve this, it is incumbent on the development agencies to provide mobile diagnostic laboratories at the district level and man them with adequately trained personnel. The diagnostic laboratories, together with pollution control agencies in the states, may be empowered to monitor the use of chemicals by the aquaculture industry, as well as to maintain information databases on the subject.

The need for further research to standardize prophylactic and control measures in aquaculture is real, since the industry is of recent origin. Research needs to be strengthened to develop safer and biodegradable chemicals for use in aquaculture. Extension services need to be strengthened to educate aquaculturists on the safe use of therapeutants and chemicals.

In order to provide adequate services and to carry out research in these areas, it may be necessary to evaluate our expertise in the field before steps are taken to strengthen our capabilities. It may be also be useful to share information with other countries in the region that have acquired expertise in the field. These steps may enable us to grow without endangering our aquatic habitat and human health.

RECOMMENDATIONS

The following recommendations are made in the larger interest of sustainable aquafarming.

For Farmers:

- Monitor closely various water quality parameters for proper farm management and early detection of adverse environmental factors.
- Avoid prophylactic use of chemicals in aquafarming, since most of them are ineffective and can lead to development of resistance among bacteria.
- Use only non-persistent chemicals.
- Strictly adhere to the "self-regulation and cluster approach" for maintaining an environmentally friendly aquaculture industry.

For Government and Aquaculture Institutions:

- Governments should frame suitable guidelines, rules, and regulations; and enforce them so as to reduce the hazards of chemical abuse.
- Disease diagnostic laboratories should be established in strategic areas to assist farmers in the identification, prevention and cure of diseases. Supply of drugs and chemicals should be effected with proper prescription from such laboratories.
- Education and training on the use of chemicals, their dosages and side effects should be imparted to the farmers and state government extension officers.
- Standards for aquaculture-grade chemicals and their use should be set and enforced.
- Regular monitoring should be undertaken to avoid overuse of chemicals in the environment. For this purpose, separate environmental monitoring agencies should be created.

For the Chemical Industry:

- Information on the efficacy, potency and effects of chemical products should be widely circulated and written on product labels.
- Separate medicines and preventive drugs suitable for the aquaculture industry should be prepared and supplied with specific directives regarding their use.

For Regional and International Agencies:

- Regional and international organizations should play a more active role in guiding and sharing information for environmental planning of aquaculture facilities and in assisting interested countries in the developmental planning of their respective aquaculture industries.
- International agencies should also assist member countries in framing drug regulations based on the latest available information.

- International collaborative research programs should be organized in areas of mutual interest.

For Research Institutions:

Future research should be concentrated in the following areas:

- Surveys to identify major fish health problems and to evaluate the procedures for chemotherapy presently being followed.
- Studies on the residual effects of antibiotics and piscicides in fish tissues and to establish environmentally safe levels of disposal.
- Identification and evaluation of less toxic and biodegradable compounds for use in aquaculture.
- Formulation of guidelines for environmentally sound aquaculture practices which can help prevent the indiscriminate use of chemicals.

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