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A STUDY ON THE USE OF CHEMICALS AND BIOLOGICAL PRODUCTS IN INDIAN AQUACULTURE

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Abstract: *The study was carried out to understand the current status of the use of chemotherapeutants and other chemicals and biological products in Indian aquaculture is presented. Over the past few decades, Indian aquaculture production has intensified rapidly through the adoption of technological advances, and the use of wide array of chemical and biological products to control sediment and water quality and to treat and prevent disease outbreaks. 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 anaesthetics. Other approaches to diseaseprevention (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. It is concluded that although chemicals and drugs will continue to play an important role in the development of Indian aquaculture, they must be used with caution to avoid adverse effects such as environmental damage and the development of resistant strains of pathogens. To minimize chemical usage, additional emphasis needs to be placed on developing good management practices for aquaculture systems. 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.*

Keywords: *Aquaculture, Chemicals, Aquatic ecosystems, Biological Products, water treatment, Diseases*

INTRODUCTION

Many millions of people around the world find a source of income and livelihood in the fisheries and aquaculture sector. According to UN Food and Agriculture Organisation aquaculture is growing more rapidly than all other animal food-production sectors (*www.fao.org*) Its contribution to global supplies of several species of fish, crustaceans and mollusks etc. Aquaculture has been practiced in India in both freshwater and coastal saline waters from time immemorial. These were

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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.

Table 1
Aquaculture Production by India: Quantity and percentage of World total production

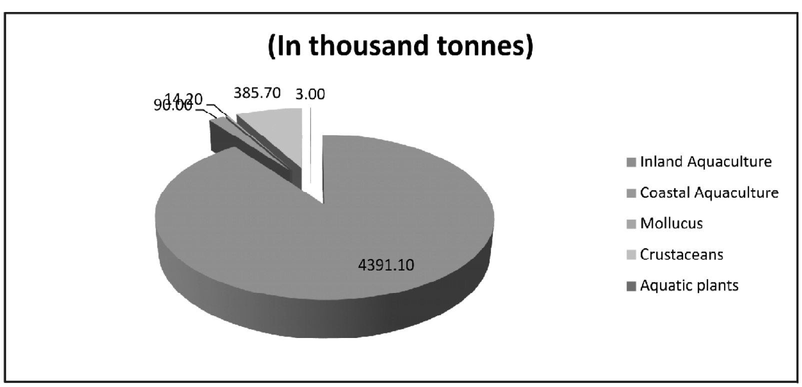
Aquaculture Production		*1995*	*2000*	*2005*	*2010*	*2012*	*2014*
India	(thousand tonnes)	1658.80	1942.50	2967.40	3785.80	4209.50	4881.00
	(Percentage)	6.80	5.99	6.70	6.42	6.33	6.62

Brackish water 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. 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.

Table 2
Main groups of farmed species in India 2014

India	*(In thousand tonnes)*
Inland Aquaculture	4391.10
Coastal Aquaculture	90.00
Mollucus	14.20
Crustaceans	385.70
Aquatic plants	3.00
Total Aquaculture Production	4884.00



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

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

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

OBJECTIVES OF STUDY

- To understand the use of chemicals and biological products of aquaculture in India
- To study the other approaches to disease prevention
- To study the environmental impact on chemicals usage in aquaculture
- To study the issues and challenges of chemicals and biological products in India
- To explicate the recommendations to farmers, Government, Aquaculture Institutions, Industry, Regional and International agencies and Research Institutions.

LIMITATIONS OF STUDY

- The study is conducted based on the secondary data available which is only a conceptual research and no empirical results are available.

METHODOLOGY

- The study is conducted based on secondary data base and it is conceptual research study.

USE OF CHEMICALS IN AQUACULTURE

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

four "Ks" must be considered:

- know the water
- know the aquatic animal
- know the chemical
- know the disease

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

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

The various chemicals used in grow-out farming and hatchery operations in both freshwater andcoastal 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.

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

Water and sediment treatment compounds

Different compounds were reported as being used to improve water and sediment quality in the production systems (Table 3). Liming compounds such as calcium carbonate (agricultural lime), calcium hydroxide (hydrated lime) and calcium oxide (quicklime) are applied during pond preparation to the water or sediment to neutralize acidity. To a lesser extent, however, some farmers have reported using them to kill potential pests and predators. Other compounds are used to reduce the bioavailability of heavy metals (e.g. EDTA) and to reduce turbidity in shrimp ponds (e.g. aluminium potassium sulfate).

In most of the states studied, zeolites were used to remove ammonia and other nitrogenous compounds in the water column, although the efficacy of this practice in brackish water systems has been questioned (Boyd 1995; GESAMP 1997). Many of these water and sediment treatment compounds are relatively innocuous inorganic substances with a short environmental life, and are not expected to result in toxic effects to aquatic organisms when applied according to recommendations (Boyd & Massaut 1999). They are, however, likely to alter, at least temporarily, water quality parameters of the ecosystems such as alkalinity, hardness and pH.

Soil and Water Treatment products

1. Lime
2. Dolomite
3. Chlorine
4. Organic and Inorganic fertilizers
5. EDTA
6. Zeolite
7. Water and Soil Probiotics

Table 3
Water and Sediment treatment compounds used in Indian Aquaculture

Compund	*Usage*
Lime	Lime is a major chemical used for soil and water treatment in Indian aquaculture. It is used to correct pond bottom and stabilize water pH. It is also reported to ensure a healthy plankton bloom (Chanrachakool et al. 1995). There are at least four types of lime used in India: • Agricultural lime/lime stone or crushed shell ($CaCO3$) • Hydrate lime or slake lime ($Ca(OH)2$) • Quicklime/burnt lime or burnt shell lime (CaO) • Dolomite or dolomite lime ($CaMg(CO3)2$) Each type of lime has a specific effect. Lime is also used in ponds with normal pH. It conditions the soil when applied at 0.5-1 t/ha spread evenly over the bottom.
Dolomite ($CaMg(CO3)2$)	Dolomite is another form of limestone which contains magnesium. It is primarily used to improve the buffering capacity and to supply Mg^{++}. The rate of application in low pH (< 5) ponds is 100 to 300 kg/ha per application.
Chlorine	Chlorine has been used routinely to disinfect water supplies in fish and shrimp hatcheries in India and elsewhere in the world. Recently, chlorination has become a standard procedure adopted by most Indian shrimp farmers for pond preparation. The purpose is to eliminate harmful organisms entering the pond with water. The most commonly used form of chlorine is powdered calcium hypochlorite (65% active chlorine content) at the rate of 180 kg/ha. However, the rate is by no means standard because of the variability in chlorine demand of the water.

contd. table 3

Compund	*Usage*
Organic and Inorganic Fertilizers	Fertilization is a basic part of pond preparation. Plankton as food for herbivorous fish such as tilapia and milkfish must be in adequate quantities before stocking fish. Fertilization is also included in a standard procedure for shrimp pond preparation after chlorination and before stocking. Chicken manure can be used at a rate of 300 kg/ha by suspending manure bags in the water away from pond dikes. Inorganic fertilizers such as urea and N-P-K mixture are widely used. Urea is applied at 15-30 kg/ha after fertilization. Water is added gradually at 10-20 cm daily until the desired depth is achieved. If the desired phytoplankton bloom is not achieved, more fertilizer is added.
Disodium Ethylene Diamine Tetraacetate (EDTA)	EDTA is a chemical used to improve water quality by reducing heavy metal concentrations. In shrimp larval rearing, it is applied at 10 mg/L prior to stocking of nauplii. Many hatcheries use EDTA as a treatment for ectocommensal fouling to stimulate juvenile molting. EDTA is normally applied at 1-5 ppm to remove organic substances in the water.
Zeolite	Zeolite is applied to shrimp ponds to remove hydrogen sulphide, carbon dioxide and ammonia, as it has a strong capacity to absorb molecules. Shrimp farmers use zeolite to clean pond bottoms. Zeolite is available in the market under various brand names, and it is supplied as fine grains in bags of 20 kg. The recommended dose is 180-350 kg/ha. The effectiveness of zeolite is still questionable.
Probiotics	Probiotics are classified as beneficiary bacteria. Different kinds of probiotic strains are used to maintain the water and soil quality for better production. Dosage 500gm/acre

CHEMOTHERAPEUTANTS

Disinfectants

A wide range of disinfectants are used in intensive cultures, particularly in finfish and shrimp hatcheries andgrow-out ponds, to disinfect the culture facilities andequipment, to maintain hygiene throughout the productioncycle and often to treat bacterial disease outbreaks.

The most commonly used disinfectants are

- Formaldehyde
- potassium permanganate,
- Chlorine
- Quaternary ammonium compounds (Glutraldehyde, BKC)
- Iodine

Formaldehyde: It is frequently used to kill filamentous bacteria in fish and crustacean grow-out ponds and hatcheries, and is also used at higher concentrations to treat fungal and ectoparasitic infections of protozoans and trematodes in finfish production (Boyd & Massaut 1999).

Potassium permanganate: Itis a strong oxidizing agent used as a broad-spectrum disinfectant in finfish and shellfish production, but can also be used to treat fungal infections and as a piscicide during pond preparation between production cycles.

Chlorine: Chlorine gas and powdered forms such as calcium hypochlorite and sodium hypochlorite are used to disinfect the water supplies in fish and shrimp hatcheries and for water and sediment disinfection between production cycles. Sodium chloride is used for the removal of external parasites and fungi from adult fish.

Quaternary ammonium compounds such as benzalkonium chloride are used in finfish and shellfish production to treat bacterial, protozoan and monogenean infections and as fungicides in shrimp hatcheries.

Iodine and iodophoressuch as providone-iodine are frequently used in egg disinfection, but should be used with caution because they are highly toxic to fish (Boyd & Massaut 1999). Ozonation has been recognized as one of the most important methods of disinfection in shrimp hatcheries (GESAMP 1997).

Overall, aquaculture disinfectants are moderately tohighly toxic to planktonic and macroinvertebrate species with acute L(E)C50s ranging between 1 and 100 000 lg L)1 (ECOTOX 2010). They are, however, characterized by high solubility and low persistence in the aquatic environment. Tis¡ler and Zagorc-Konc¡an (1997) demonstrated that formaldehyde might be harmful to phytoplanktonic organisms and crustaceans at the concentrations required to treat bacterial infestations in fish at recommended dosages (Tonguthai 2000). In addition, chlorine disinfectants (e.g. calcium or sodium hypochlorite) react with organic matter, giving rise to significant concentrations of organic chlorine compounds such as halogenated hydrocarbons, which are highly toxic to aquatic life and are persistent environmental contaminants (Emmanuel *et al.* 2004).

Table 4
Disinfectants and dosages used in shrimp culture in India

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

Feed Additives

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

Hormones

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

Vitamins

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

Immunostimulants

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

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

SUPPLY OF CHEMICALS

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

Commercial products to combat environmentally induced diseases

S.No.	*Product Name*	*Dosage*
1	Cleantox+ (Zeolite+Yucca)	For regular use: 25 Kg/ acre, For Pond Preparation: 50 Kg/acre
2	Toxiclean Aqua (HSCAS+Yucca)	For regular use: 25 Kg/ acre, For Pond Preparation: 50 Kg/acre
3	OxyPond Tablets	Low Oxygen level: 1 Kg/ha of pond, O2 deficiency : 3 - 5 Kg/ha of pond
4	Echo-Max	40 tablets/ha/MT for 15 days of use
5	Bio Marine	Add 8 lt of Bio Marine in 200 lt of water and mix together until homogenises
6	De Algae	2 - 3 lt/ha/mt
7	Bind gel	20 -30 g/kg of feed
8	Amsorb	250 gm/acre once in 15 days
9	Hydrosoft	1 -2 kg/acre
10	Minpure Aqua	20 - 30 kg/ha

Disinfectants

Disinfectants in use in India include TH4+, Sokrena, Kohrsolin TH, Safegill, Virunil, Virkon-S, CIFAX, BKC 80%, BKC 50%, Germicide, Aquasafe etc.

Minerals and Vitamins

Enrichmin, Minano Forte, Minbiotic, Minplus, Aquamin-R, Aquamin Forte, Nutrimin-R, Stresslev Gold, Complimin Aqua, Agrimin, Agrimin Forte, Watermin, Vitamin C, Mg/K etc

Immunostimulants

IM5, Seleyeast, E Care, BG MOS, Liv 52, Immuno more etc.

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

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.

OTHER APPROACHES TO DISEASE PREVENTION

The approaches to disease prevention that have evolved in India after the outbreaks of shrimp disease 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. 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 . A significantincrease in problems is noted when stocking densities exceed 20 PL/m2. This information appearsto strongly support the government's policy of not promoting intensive shrimp culture (Government of India 1995).

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 offarming 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, dissolvedoxygen, free ammonia, biological oxygen demand, chemical oxygen demand, dissolved phosphateand 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.

List of Banned Antibiotics in India

1. Chloramphenicol
2. Nitrofurans including Furazolidone, Nitrofurazone, Furaltadone, Nitrofurantoin, Furylfuramide, Nituratel, Nifursoxime, Nifurprazone and all their derivatives.
3. Neomycin
4. Nalidixic acid
5. Sulphamethoxazole
6. Aristolochia sp. And preparations thereof
7. Chloroform
8. Chlorpromazine

9. Colchicine
10. Dapsone
11. Dimetridazole
12. Metronidazole
13. Ronidazole
14. Ipronidazole
15. Other nitroimidazoles
16. Clenbuterol
17. Diethylstilbestrol (DES)
18. Sulfonamide (except approved sulfadimethoxine, silfabromomethazine and sulfaethoxyrphyidazine)
19. Floroquinolones
20. Glycopeptides

RECOMMENDATIONS

To Farmers

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

To Producers and Suppliers of Chemicals

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

To Government Agencies

- It is the government's responsibility to establish rules and regulations on uses of drugs and chemicals.
- The government should try to find effective means to raise awareness among farmers, not only to maximize their production, but also to make them aware of the impact of chemical use on the environment and public health.

- National drug and chemical regulating boards must be established to work closely with the aquatic disease research institutes.
- Enough disease diagnostic laboratories must be established to give adequate service to farmers.
- There is an urgent need to establish an information center within the country and internationally to update, distribute and exchange information.
- An effective quarantine system should be established to prevent disease transmission.

To Regional and International Organizations

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

To Scientists

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

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

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

CONCLUSIONS

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

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

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