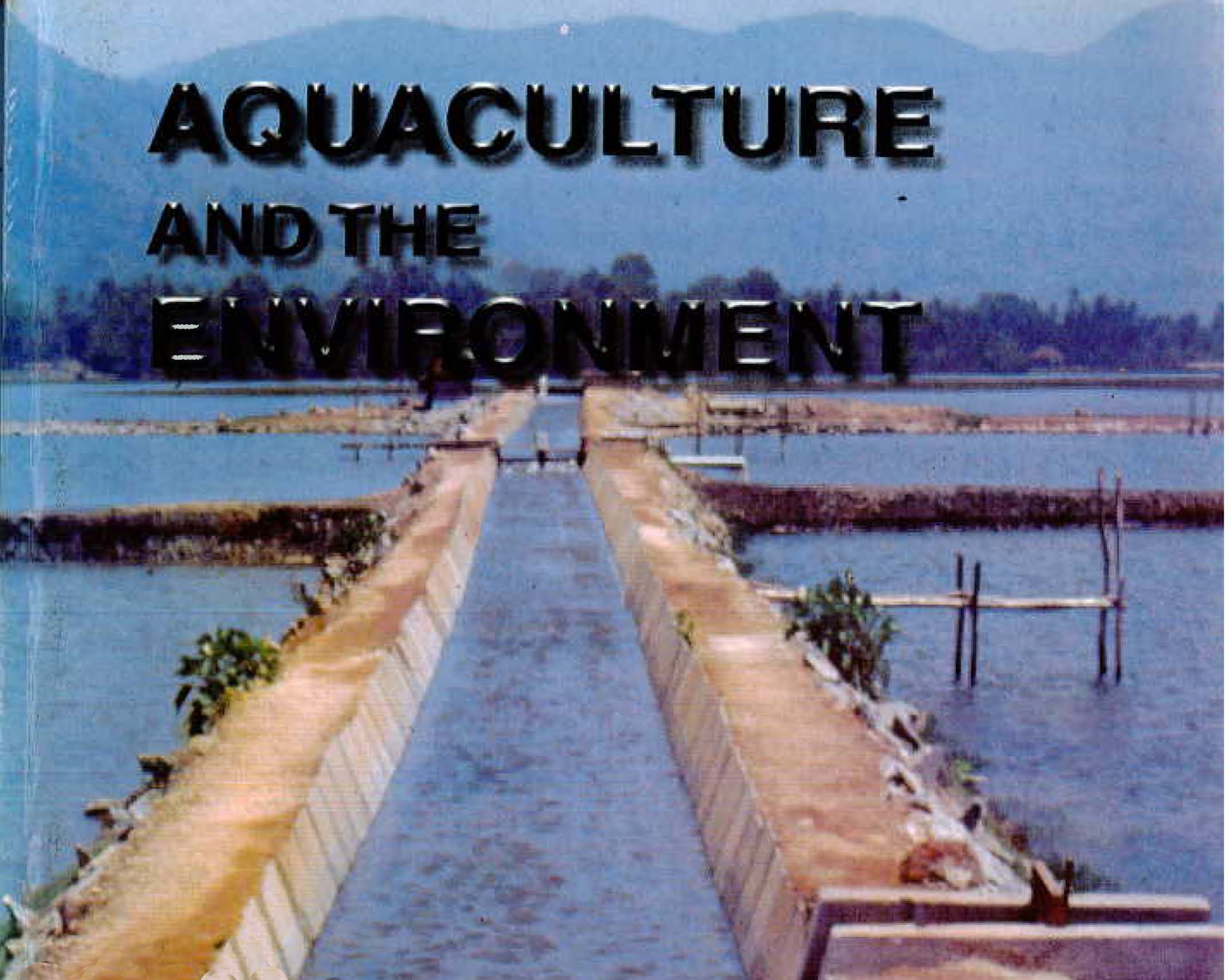
AQUACULTURE AND THE ENVIRONMENT



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Environmental Issues in Indian Freshwater Aquaculture

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1. Introduction

Aquaculture is assuming increasing importance in recent years on a global basis including the Indian subcontinent. With possibilities of obtaining high productivity levels among different farming system, there has been a flux between the farming practices and aquaculture is receiving greater investments both in public and private sector. The contribution of freshwater aquaculture to the total fish production has risen steadily from 17% a decade back to over 30% at present. It is common knowledge that with stagnating trends of marine fisheries as well as inland capture fisheries production levels, freshwater aquaculture is an attractive option for increasing fish production in the country. This substantiated by the growth rates of over 5% over the last few years. The sector, with the necessary R&D back-up for culture of different components of carps, catfishes, prawn

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and molluscs, entrepreneurial enthusiasm and the governmental support, is poised to realize the potential of about 4.5 million metric tonnes in the coming decade.

As with any developed process, freshwater aquaculture development too has several environmental issues if not concerns to be deliberated upon. They include biodiversity of fishes, land-water interactions, environmental pollution, feed and fertilizer-related water management, import of exotic fish and shellfish species and their quarantine, water budgeting and management, comparative energy budgeting for different farming systems, human pathogens associated with fish cultured in waste waters, fish marketing and hygiene, etc. It may be mentioned that freshwater aquaculture being compatible with other farming systems is largely environment-friendly and in fact provides for recycling, utilization and even treatment of organic wastes. Pollution due to effluents from the freshwater aqualculture systems is yet to assume any considerable proportions. However, due attention is being given to this aspect too in view of intensification of aquaculture practices in recent years. The paper discusses these issues in the context of the significant growth trends of freshwater aquaculture in the country.

2. Biodiversity of Fish Species

India has a rich and diverse fish fauna of 2200 species which is about 11% of the global fish faunal resources (about 20,000 fish species) occurring in cold and warm waters, both freshwater and marine. Of the country's fish species, 24.7% live in warm freshwaters, 3.3% in cold waters, 6.5% in estuaries and 65.5% in the sea. Since the past several years, indiscriminate fishing, habitat destruction, degradation of water quality through pollution, construction of dams and barrages across the rivers and deforestation resulting in siltation and rise of river beds have been threatening the fish biodiversity. The populations of some of the economically important fishes inhabiting the natural waters like carps in the River Ganges, catfishes in marshy lands, mahseers in cold water rivers, streams and reservoirs, migratory hilsa in Hooghly river are declining over the years, as revealed from the production trends of these fishes. It has been reported that out of 79 threatened species listed so far, 63 species belong to freshwater (46 from warm water and 17 from cold water). Among the listed threatened species (Table 1), species like *Ompok pabda*, *O. pabo*, *Tor mussullah* in warm water and *Gymnocypris biswasi* in cold water have become endangered (Mahanta *et al.*, 1994).

India is known for its rich and diverse population of gangetic resources of value. Even so, over 300 exotic varieties have been introduced into the country so far (Jhingran, 1989). While most of them are ornamental fishes which remain more or less confined to the aquaria, some have been introduced into the aquaculture systems and open waters. Among the species introduced, while a few have proved to be a boon to the aquaculture, the accidental or deliberate introduction of some others has caused havoc to the aquatic environment as a whole. The tilapia, *Oreochromis mossambicus* which was introduced into the country during 1952 made its presence in almost all the waterbodies within a few years. The main attraction for its introduction was its pond breeding and omnivorous feeding habits. However, its early maturation, prolific breeding and voracious feeding habits not only found to adversely affect the growth of carps in polyculture system, but also eliminated were other fishes including Gangetic carps in a number of reservoirs. The effects were well reflected in fisheries of many reservoirs of Tamil Nadu *viz.*, Vaigai, Krishnagiri, Amaravati, Uppar and Pambar. Similarly, introduction of *O. mossambicus* in Jaisamand lake of Rajasthan not only resulted in reduction of average weight of major carps, but also posed a threat to species like mahseers (*Tor tor* and *T. putitora*) which are on the verge of extinction (Bhatnagar, 1995). Its prolific breeding resulting in inadequate growth

Table 1. List of threatened freshwater fishes of India

Warmwater Fishes		Location
Endangered		
1. *Ompok pabda*	-	Ganga, Brahmaputra river system
2. *Ompok pabo*	-	Freshwaters of Assam, West Bengal
3. *Tor mussullah*	-	Cauvery, Bhawani river
Vulnerable		
1. *Ailia coila*	-	Freshwater of Krishna, Darjeeling, Assam, Orissa, Madhya Pradesh
2. *Anguilla bengalensis*	-	Throughout India
3. *Bagarius bagarius*	-	Ganga river and its tributaries
4. *Eutropiichthys vacha*	-	Freshwaters of Punjab, Uttar Pradesh, Bihar, Orissa
5. *Labeo dyocheilus*	-	Doon valley, Kashmir, Poonch, Assam
6. *Ompok bimaculatus*	-	Freshwaters of Kashmir, Punjab, Uttar Pradesh, Bihar, Manipur, Assam, West Bengal.
7. *Puntius sarana*	-	Throughout India except Peninsular India
8. *Semiplotus semiplotus*	-	Freshwater of Assam and Darjeeling
9. *Cirrhinus cirrhosa*	-	Cauvery, Godavari, Krishna river system, Narmada & Pench river in Madhya Pradesh
10. *Osphronemus nobilis*	-	Rivers of north east Bengal and Assam
11. *Labeo dero*	-	All along Himalayan foot hills, Darjeeling, West Bengal
12. *Labeo dussumieri*	-	Western Ghats upto North Canara
13. *Osteobrama belangeri*	-	Manipur (previously found in Bengal from where it has disappeared)
Rare		
1. *Horaglanius krishnai*	-	Kottayam, Kerala State
2. *Schistura sijuensis*	-	Throughout India
Indeterminate		
1. *Notopterus chitala*	-	Freshwater rivers, streams of India
2. *Pangasius pangasius*	-	Freshwater of Uttar Pradesh, Bihar, Madhya Pradesh, Darjeeling, Assam, Orissa and Madras
3. *Tenualosa ilisha*	-	Indian oceans, coastal waters, estuaries, rivers
4. *Thynnichthys sandkhol*	-	Freshwater of South India, Krishna and Godavari river system
5. *Tor khudree*	-	Freshwater of Uttar Pradesh, Orissa, Kerala Peninsular India
6. *Balitora brucei*	-	Darjeeling, Assam
7. *Barbus dukai*	-	Eastern Himalaya and Assam
8. *Chagunius chagunio*	-	Brahmaputra and Ganga drainages along the Himalaya foot hills
9. *Crossocheilus latius*	-	Drainages of the Ganga and Brahmaputra in river drainage in Orissa and Western ghats, south to the head waters of Krishna river
10. *Gadusia chapra*	-	Ganga, Brahmaputra river system, Mahanadi river, Bay of Bengal
11. *Glyptosternum maculatum*	-	Sikkim
12. *Labeo fimbriatus*	-	Northern hills of Nepal border, Sindh, Punjab, Orissa, Southern India except Malabar and Canara
13. *Labeo gonius*	-	Freshwater of Assam, Darjeeling, West Bengal, Bihar, Uttar Pradesh, Orissa
14. *Mastocembalus armatus*	-	Throughout India
15. *Mystus tengara*	-	Through North India
16. *M. aor*	-	River Ganga, Yamuna, Brahmaputra, Mahanadi
17. *Nandus nandus*	-	Throughout India
18. *Olyra logicaudata*	-	Base of Darjeeling, Himalaya, Meghalaya and Assam
19. *Psylorhynchus homaloptera*	-	Assam, Brahmaputra drainage
20. *Puntius carnaticus*	-	Freshwater of Nilgiri, Wynaad, Canara hills
21. *Puntius conchonius*	-	Brahmaputra, Uttar Pradesh, Bihar
22. *Rasbora rasbora*	-	Freshwaters of all the Indian States, most common in the valley of Ganges
23. *Setipinna phasa*	-	Ganga river system and Orissa
24. *Silonia childreni*	-	Freshwaters of Krishna, Godavary, Cauvery river system
25. *Silonia silondia*	-	Freshwater of Punjab, Uttar Pradesh, Bihar
26. *Tor mosal*	-	Hill streams of Himalayas
27. *Xenentodon cancila*	-	East coast of India
28. *Bengala elonga*	-	Bihar, Uttar Pradesh, West Bengal, Assam
COLDWATER FISHES		
Endangered		
1. *Gymnocypris biswasi*	-	Chusul, Ladakh
Vulnerable		
1. *Tor putitora*	-	All along the Himalaya, Darjeeling
2. *Psilorhynchus balitora*	-	Yamuna river in Delhi, river Gomati
3. *Raiamas bola*	-	India, confined to the hilly areas of the northern provinces (Haryana, Himachal Pradesh, Uttar Pradesh, Bihar, Assam, West Bengal, Orissa)
4. *Schizothorax kumaonensis*	-	Kumaun hills
Indeterminate		
1. *Botia almorhae*	-	Kumaun hills specially in Kosi river
2. *Lepidophygopsis typus*	-	Periyar river and Lakes of Kerala
3. *Noemacheilus rupicola*	-	West Himalaya, Kumaun through Garhwal Himalaya to Yamuna Sutlej and Beas drainages of Himachal Pradesh
4. *Tor tor*	-	Uttar Pradesh hills, Darjeeling, Madhya Pradesh, Bihar, North Bengal, Assam
5. *Noemacheilus elongatus*	-	Meghalaya near Shillong
6. *Schizothorax richardsoni*	-	Sub-Himalayan range
7. *Puntius chillinoides*	-	Himalayan foot hills, Ganga river system
8. *Schizothorax plagiostomus*	-	Along the Himalayan foot hills
9. *S. progastus*	-	Jammu and Kashmir Valley, Ganga river in Uttar Pradesh and Brahmaputra river in Assam
10. *Schizothoraichthys esocinus*	-	Indus river and its tributaries in Ladakh & Kashmir
11. *Schizothoraichthys longipinnis*	-	Kashmir valley and Indus river system
12. *Schizopygopsis stolickekae*	-	Leh and headwaters of Indus, also tributaries of the Yarkand and Oxus river

Source: Mahanta *et al.* (1994) and Anon (1994) prompted the Fisheries Research Committee of India to ban its propagation in 1959. In spite of such regulations, the species has spread itself not only into most of the freshwater reservoirs and other water bodies but also has found its way into many brackishwater bodies of the country. The fish is considered as a pest and menace to the freshwater aquaculture development.

Silver carp, *Hypophthalmichthys mollitrix* was introduced in India in 1959 and unlike tilapia, it has not strayed into many reservoirs. However, silver carp has attracted more attention from the ecologists and fishery managers generating more animated debates. Most spectacular performance has been reported from Govind Sagar reservoir, where after an accidental introduction, the fish formed a breeding population and brought about a phenomenal increase in fish productivity. This drastically reduced the fishery of the native catla and *T. putitora.* In 1974-75, when silver carp was not here, *T. putitora* contributed as much as 20.62% of the total yield, but constituted only a meagre amount of 2.23% during 1984-85 with silver carp introduction. Common carp, *Cyprinus carpio* was also responsible for a similar situation (Johal and Tandon, 1983). The near extinction of snow trout, *Schizothorax* spp. and *Oreinus sinceatus* is also attributed to the exotic common carp. The mirror carp, a strain of common carp has already jeopardised the population of a number of native fish species after its introduction in some upland lakes of Kumaon Himalayas, the Dal lake in Kashmir, Govind Sagar in Himachal Pradesh and reservoirs of the north-east. In Dal lake, common carp found a favorable environment by virtue of its shallow lake basin, extensive submerged vegetation and rich food resources. The fish propagated profusely by virtue of the specific ecological advantage and threatened the fishery of indigenous snow trout's like *Schizothoraichthys nigor, S. esocinus* and *S. carvifrons.* The extinction of *Osteobrama belangeri* in Loktok lake of Manipur has also been documented due to the exotic common carp.

Recently, *Tilapia zilli* a herbivorous cichlid has been introduced in the Indira Gandhi Canal of Rajasthan for controlling the aquatic weeds (Bhatnagar, 1995). The control of floating macrophytes like *Eichhornia* and emergent vegetation like *Typha* by *T. zilli* is doubtful (Sreenivasan, 1995). Besides this when grass carp, another exotic species which has proved to be a voracious feeder of many aquatic vegetation and native *Puntius pulchelus* which too is a potential species for weed control are already available in our waters, the introduction of *T. zilli* needs to be evaluated.

Import of seed of sea bass and sea bream from abroad for cage culture in Indian waters is being proposed for which there is a justifiable objection form the environmentalists, that has resulted in a stay order by the Calcutta High Court (Sreenivasan, 1995). The introduction of Nile perch (*Lates niloticus*) into the Lake Victoria would be an apt comparison, which has resulted in extinction of about 50% of the 400 indigenous species available in the lake.

India possesses good varieties of catfishes like *Clarias batrachus, Heteropneustes fossilis, Mystus seenghala, M. aor, M. gulio, Wallago attu, Silonia silondia, Pangasius pangasius, Bagarias bagarias, Ompok bimaculatus,* etc. that are potential candidate species for culture. Introduction of exotic catfish species like *Ictalurus spp.* needs to be considered in details including the possible hazards of introducing associated viral pathogens.

The African catfish, *Clarias gariepinus,* is another exotic catfish which has made its way into the Indian waters through Bangladesh. The availability of the species has already been reported form Orissa, Bihar, West Bengal and Andhra Pradesh. The species which grows to large sizes (beyond 1.5 m/10 kg) is known to be highly predatory as also cannibalistic. The consequence could be disastrous when they find entry into the neighboring ponds and any other open waters like major riverine and reservoir systems.

Japanese rainbow trout and sock eye salmon were imported from Japan and Canada respectively into the Nilgiris streams of Tamil Nadu. Not only they did not survive, but brought in diseases like whirling disease, white spot (Ichthyophthyriasis), costiasis, etc. for the first time in the Nilgiris.

It is learnt that the exotic carp bighead, *Aristichthys nobilis* has made its entry into the Indian waters from Bangladesh. According to the available information, the fish is now available in states like West Bengal, Bihar, Orissa and Andhra Pradesh, and some private hatcheries of West Bengal are producing its seed on a large scale. In spite of the instructions issued by the Union Department of Agriculture to the various States requesting them to destroy the fish and not to encourage its culture, the species is spreading into other States too. It may result in threatening the fishery of catla in our reservoirs and rivers.

3. Fish Genetics Research - Implications

Genetic improvements in fish species could be brought about through genome manipulations, incorporation of an external gene for producing transgenic varieties or hormonal manipulations to achieve higher growth rates. The biohazards of genetic manipulation in the form of mutants, deformed specimens and those with an imbalance in the gonadosomatic functioning are to be considered in breeding programmes. A major aspects of concern in farm breeding programmes is with regard to inbreeding depression that has not taken care of by the fish farmers in the country. Success in milt cryopreservation offers a tool in brood stock replenishment and improving progeny. Indiscriminate use of hormones for breeding, production of monosex populations for somatic growth is an issue to be considered in the wake of intensifications of fish culture practices in recent years.

4. Land-water Interactions

The unplanned expansion of aquaculture in some parts of the country has resulted in degradation and in certain cases destruction of the natural resource systems and environment in which aqua culture is practised. Conversion of over 60,000 ha of paddy fields into aquaculture ponds in Andhra Pradesh over the last two decades, as also unplanned conversion of Kolleru lake area into fish ponds are a few examples.

In India, nearly 5334 million tonnes of soil are eroded from the cultivable lands and forests annually. On crop land, the erosion can range from 7 to 120 t/ha/yr. The rivers carry an approximate 2050 million tonnes of soil of which nearly 480 million tonnes is deposited in reservoirs and 1,570 million tonnes is washed into the sea every year (Gupta, 1975). For example, River Ganga with only a drainage basin of 1.1 million sq. kms carries an annual sediment load of 1.46 billion tonnes of soil. The siltation of the rivers and reservoirs not only results in destruction of breeding grounds of several fishes but also leads to reduction of overall productivity. The deforestation of catchment area resulting in sitation and often change in river course have also affected the fish catch.

Though most of the aquaculture farms use surface run-off water, ground water and spring water are also used during lean season that cause depletions in ground water table. Further, injudicious exploitation of underground freshwater may lead to salination and soil degradation. Salination of soil due to effluent discharge from freshwater prawn hatcheries being established in large numbers in recent years is also an area of concern.

5. Environmental Pollution

The rapid industrialization and population explosion have resulted in ever-increasing disposal of toxic wastes and sewage respectively to the open water bodies, polluting the major river systems, that are ultimately used as source of water for aquaculture. It is estimated that nearly 33 million tonnes of sewage are generated daily in India (1981 census). The amount of sewage pollution in the country is very well reflected by the River Ganga, in which more than 70% of the pollution load is contributed by sewage. The sewage generated in 692 cities and large towns all along the basin is estimated at 1,528.1 million tonnes. The resultant BOD load in Ganga basin is estimated at 2,504 million kg/day of which domestic source contributes 1,338 million kg/day. The sewage obtained from the highly industrialized cities like Delhi, Calcutta, Kanpur, etc. is also found to contain synthetic detergents to the tune of 0.02 - 2.0 ppm (Jhingran, 1991). Sewage disposal today is the foremost problem in many of our water courses. Most of the treatment plants remove a good part of the solid particles, but only a part of phosphates and nitrates. This leads to eutrophication in water bodies, low dissolved oxygen level and high BOD levels.

In India, although the industrial development has not reached the level attained in the developed countries, the toxic compounds, hitherto unknown, are being detected in increasing numbers in our water courses owing to their indiscriminate application. It is largely because the production of chemicals resulting in the generation of toxic and hazadous substances has been continuously on increase for last three decades (Table 2). Among the industrial effluents discharged into the water bodies, while the pulp and paper, dairy, distillery and cotton textile industries generate putrescible organic wastes, the industries manufacturing organic chemicals, pesticides, fertilizers, dyes and pigments, paints and varnish, nonferrous metals and steels, etc. generate toxic and hazadous wastes (Jhingran, 1991). These industrial effluents even at comparatively low concentrations cause menace to aquatic environments and the biotic communities including fish and ultimately affect man through the food chain. The industrial effluents contain wide variety of chemical toxicants and heavy metals. Apart from this, they contribute substantially to the BOD loads. For example, the fertilizer wastes at Allahabad have adversely affected the population of carps, catfishes and murrels. Plankton and benthos are known to disappear upto a strech of 300 km downstream, due to high pH and ammonia toxicity. Besides this, a few other reports are also available regarding fish mortality due to hazadous and toxic wastes discharged from various industries which are illustrated in Table 3.

Aquaculture at present is characterised by indiscriminate use of a wide spectrum of organic and inorganic chemicals to prevent or control the diseases. Further, the major source of pesticides in

Table 2. Growth of industries generating hazardous wastes

(Production in thousand tonne)

Industries	1960	1970	1980	1986-87
Pesticides	1.46	3.0	40.68	56.2
Dyes and pigments	1.15	13.55	30.85	-
Organic chemicals & petrochemicals	580	17,100	24,100	42,500
Fertilizers	153	1059	3005	7000
Steel (Ingots)	1500	3400	8000	9000
Non-ferrous metals	8.5	34.6	82.9	123.4
Caustic soda	101	304	457	764
Pharmaceuticals	1.23	1.79	5.07	-

Source: Jhingran (1991)

Table 3. Some fish kill incidences in Indian waters

Place	Year	Pollutants
Kankarai lake, Ahmedabad	1982	Domestic
Naini lake, Naintal	1980,1981	Domestic waste
R. Gomti, Lucknow	1983, 1984, 1986	Distillery waste
R. Chaliyar, Alwaye	1974	Pesticide
R. Tungabhadra, Harihar	1984	Rayon polyfibre
R. Ganga, Monghyr	1968	Oil refinery
R. Adyar, Madurai	1981, 1982	Tannery
Rihand reservoir	1970, 1978, 1980	Chemical and thermal effluents

Source: Jhingran (1991)

most o the water bodies is the agricultural run-off. The production and consumption of pesticides have been strikingly increasing ever since they were first introduced. Sharma (1987) reported that 44 kinds of pesticides are in use in the country. The average consumption of pesticides in our country increased from 3.2 g/ha in 1954-55 to 336 g/ha in 1980 (Chottoraj, 1987). The increasing use of pesticides and insecticides in the agriculture system, for example, to the tune of 25,000 tonnes only in the State Andhra Pradesh, is polluting the major water system due to surface run-off that is ultimately used as a source of water for aquaculture. Further, it is reported that about 2600 tonnes of pesticides are used in an year in the Ganga basin. A good part of its is bound to enter the river system and subsequently the food chain of the fishes in the river itself as also in aquaculture farms drawing water from the reverine source. The demand for pesticides in the year 1983 and 1987 were 72,000 tonnes and 100,000 tonnes respectively and it is estimated to reach 200,000 tonnes by the turn of the century. With the intensification of agriculture sector, the use of pesticides has reached as much as 1490-1870 g/ha in USA and Europe, providing basis for their increasing use in our country in the coming years. Besides this, as the country does not possess at present an alternative sound method for control of pests like biological control, the projection given seems to be realistic.

Among the insecticides, organochlorines (DDT, DDD, Aldrin, Dieldrin, Toxophane, etc.) are most widely used, sharing about 40%, followed by organophosphates (Malathion, Parathion, Methyl parathion, Fenthion, Thimet, etc.) and carbamates (Sevin, Sevimox, Carbofuran, Carbaryl, etc.). Many of these pesticides/insecticides are non-biodegradable with slow decomposition rates. Highly toxic non-biodegradable chlorinated hydrocarbon and organophosphorus pesticides not only accumulate in the aquatic biota but are often biologically magnified through food chain and ultimately affect the human population. Moreover, they often combine with other compounds in the environment to produce additional toxins (Bandyopadhayay, 1995). Among the toxicants used, organochlorines and carbamates are most toxic and found to persist in soil and water for long time. For example, DDT and DDD have half life of 10-14 years and DDE has been known to have existed for 10 years, and aldrin and dieldrin require about 2.5 years for 95% degradation in soil (Chottoraj, 1987). Further, the carbamate insecticides though known to be less persistent than the organochlorine compounds, are highly toxic to wide varieties of invertebrates such as insects, prawns, crabs, and crey fishes. The study showed that both finfishes and shellfishes are extremely sensitive to chlorinated hydrocarbons and die from suffocation due to interference with oxygen uptake at gills as well as effect on central nervous system (Rudd, 1964). It is proved these chemicals destroy larval stages of various aquatic food organisms as also depress photosynthesis of plankton (Odum, 1971).

High doses of pesticides cause oedema especially at the base of the secondary lamellae due to increased capillary permeability. Under sublethal or chronic exposures, the changes observed in gills are swelling of lamellar epithelium, necrosis, hyperplasia, epithelial lifting, cell swelling and hyper secretion of mucus. Studies with endosulfan by Najmi *et al.* (1992) showed rupture of epithelial cells of mucosal folds of *Clarias batrachus.* Experiments conducted by Dutta *et al.* (1992) showed malathion exposure to *Heteropneustes fossilis* causes formation of two new proteins of very low mobility in blood serum associated with noticeable differences in RBC and WBC counts. Liver being the primary organ for detoxification of organic zenobiotics, the pesticides tend to accumulate to a high concentration in it resulting in focal necrosis, swelling, pyknosis, cytoplasmic vaculation, etc. Studies conducted on tilapia, *O. mossambicus* with five chlorinated hydrocarbons DDT, BHC, Endosulfan, Sonatox and Termax, concluded that aquatic environment contaminated with pesticides gradually imports abnormalities in the brood fish causing mortality of spawn, fry and fingerlings (Pandey and Bhattacharya, 1995). Sukumar and Karpagaganapathy (1992) working with *Colisa lalia* showed decline in number of mature oocytes followed by retrogressive nature of ovary, hypertrophic and wrinkled lamigenous lamellae when exposed to carbofuran.

Some pesticides such as DDT and BHC even at very low concentrations have been found to be biomagnified by the aquatic food chain ending up in very high levels in fish tissues. Studies carried out at CIFRI have shown biomagnification of DDT in plankton, fish, gastropods and bivalves from Hooghly estuary in the order of 2500, 7500, 3660 and 15800 times of the ambient levels of DDT in water. Another classical example of biomagnification of DDT has been presented by Woodwell *et al.* (1967) as follows: Water (0.000005 mg/l) (Plankton 0.04 mg/l) - Silverside minnow (0.23 mg/l) - Sheephead minnow (0.94 mg/l) - Pickerel (predatory fish) 1.33 mg/l) - Needle fish (predatory fish) (2.07 mg/l) - Heron (3.91 mg/l) - Herring gull heron (3.57 mg/l) - Herring gull (scavanger) (16 mg/l) - Fish chawk (Osprey) egg (13.8 mg/l) - Margemer (fish eating duck) (22.8 mg/l) - Cormorant (feeds on larger fish) (26.4 mg/l). It is evident from the above fact that the concentration factor (ratio in organisms to water) is about half million times for fish eaters.

The indiscriminate use of antibiotics in aquaculture to combat the disease problems without understanding their modes of action is another area of concern today. At present, an array of wide spectrum antibiotics are used in aquaculture to prevent or control several diseases. Most of the drugs are bacteriostatic where, bacterial multiplication is inhibited. Further, the prolonged, repeated and widespread use of antibiotics lead to the development of resistance in bacterial populations. In the same way, the rotating use of several antibiotics contributes to multiple drug resistance patterns. In aquatic system, the antibiotics are applied either in the medium or through feed unlike the direct administration to the infected ones only in case of terrestrial animals. In such cases, the organisms, both infected and healthy ones are subjected to the antibiotics administration and thereby stress. It has been reported that the antibiotics not only affected the physiological state and further the immune system of the animals but also result in bioconcentration and later in biomagnification in the higher trophic levels. A study showed that a congeneric derivative of the polycyclic nophthacane carboxamine, used extensively in aquaculture not only as prophylactic but also in controlling several bacterial diseases at present, resulted in 60% reduction in standard metabolism and about 50% reduction in protein synthesis in case of carps at the end of 96 hours of administration at 24 h interval dose frequency (Rao, 1995). Studies also showed the ability of antibiotics to bind with a number of elements, particularly metal ions, thereby affecting the modes of action and often become ineffective in its bacterial action.

6. Supplementary Feeding - Issues

The profitability of any modern and scientific aquaculture practice largely depends on the supplementary feeds provided to the system. These aquafeeds and feeding practices followed also cause some wastes which are generally ignored and not given due attention considering the profitability of the aquaculture. The environmental problems are seldom emphasised till the effects are felt. The lure of high production rates over 20 t/ha/yr at least for few years resulted in prolification of shrimp farming in many south-east Asian countries, as in Thailand and Taiwan. This continues in other countries to this day despite the much reported long-term problems in those that were the pioneers (New, 1995). Without exception, India too had to face the consequence of the much talked problem of white shrimp disease even during a short span of 2-3 years.

The major impact of feeds and feeding techniques used in intensive aquaculture consists of hypernutrification, the most important pollutant being the nutrients which normally limit primary productivity, namely inorganic phosphate and nitrogen. Though both have an impact, phosphate is generally more important in freshwaters and nitrogen in marine waters. Large amounts of nitrogen and phosphorus accumulate in the environment in the case of intensive aquaculture practices derived from aquafeeds provided to the system. For example, at a FCR of 1.5:1, salmonids utilize only 25% of the nitrogen and phosphorus in aquafeeds (De Silva and Anderson, 1995). 10% of the aquafeed phosphorus dissolves in the effluent and is immediately available for primary production. the rest 65% is particulate and released slowly. The corresponding values for nitrogen are 65% dissolved and 10% particulate forms. According to Macintosh and Phillips (1992), close to 80 and 90% of the nitrogen and phosphorus inputs of the feeds respectively are not utilized by the cultured organisms and as a result are wasted. They in turn pollute the water and accumulate at the bottom of the pond as toxic wastes. Toxic wastes stress the growing conditions and environment of the cultured organisms.

With the extensive and semi-intensive systems progressively intensified over the years, feeds designed for more intensive systems are often utilized in less intensive systems. Such feeds are formulated for conditions where little or no natural food is available and unnecessary for less intensive system resulting wastage and pollution (FAO, 1995). Further, the feeds available for shrimps are often used for fish culture ofrvice-versa, which are extremely diverse in character and their nutritional requirements. The practice is more common in case of freshwater prawn farming. At present, though the farming of freshwater prawns like *Macrobrachium rosenbergii* and *M. malcolmsonii* is gaining momentum and practised in a large scale, no specific commercial feed is available for the same. The feed provided is either restricted to ricebran-oil cake mixture or the available commercial formulation of shrimps. Similar is the case for catfish farming. In spite of the fact that they require lower protein levels than the marine shrimps, the prevalent practice of using shrimp diets containing high protein levels needs to be reviewed.

The use of single or multi-ingredient moist feeds in aquaculture has been one of the practices followed largely by most of the farmers in the country. In spite of the fact that carp culture has become an organised industry in recent days with production levels of 5-8 t/ha/yr recorded by many farmers of Andhra Pradesh and Punjab, the supplementary feed provided is limited to bran-oil cake mixture. The intensive production of carps resulting in production levels as high as 17.3 t/ha/yr, was also obtained through use of feed in the moist form (Tripathi *et al.,* 1994). Very little attention has been given to estimate level of consumption and wastage of feed supplements when provided in moist form. The experiments conducted with salmonids showed much higher levels of nutrients in the discharge when provided in wet form over dry from (Warrer-Hansen, 1992). (Table 4).

Pillay (1992) noted that the discharge from 50 t/yr marine fish farm is similar to that from the purified sewage from a community of 7000 people. Bingham (1991) reported that 45,000 t of trash fish is used in Hongkong to produce 3000 t of high value food fish in marine cages, while about 13,500 t of the trash fish pases through the cages uneaten. A survey conducted by NACA also reported large proportion of carp farms using moist formulated feeds (New, 1995). Moreover, most of the simple feed mixtures which are

Table 4. Discharge levels in kg per tonnes of salmonids produced

	Low energy dry feed	High energy dry feed	Wet feed
Total N	60-80	25-45	180
Total P	8-10	3-5	20
Solids	300-400	150-300	600
BOD	200-300	150-250	600

Source: Warrer - Hansen (1992)

commonly used in many contries under carp culture are in moist form (Tables 5 & 6). Moist feeds, besides polluting environment possess the risk of disease transfer through the use of unprocessed animal ingredients. To overcome such problems, Denmark has banned the use of trash fish sine 1985 (Kiaerskolu, 1992). New *et al.* (1993) also stressed the necessity of ingredient processing and improvement of moist feed for reduction of wastage and improved efficiency. Besides the discharge of nutrients into the environments through feed, increasing use of various additives in aquafeeds is also causing concern now-a-days. The discharge of antibiotics in the effluents or their carry-over into the aquaproducts may affect disease resistance in fishes and human beings. The antibiotics usage is particularly prevalent in shrimp feeds because shrimp have a nonspecific immune system. With the increasing fears about antibiotics residues in human food, Japan, USA and Europe, the major importers of farmed shrimp have imposed strict quality definitions on south-east Asian feed stuff industry (New, 1995).

Though aquafeeds are generally blamed for causing pollution, poor feed management is also equally responsible. Feed ingredients, form of feed, proximate composition, etc. along with the feeding schedule, feed ration as also feeding style decide the profitability of the culture practices. In many cases of carp farmings feed dough is dumped into the water. Rarely the feeds are provided in trays or baskets. Feeding quantity estimation should be given more attention. In many cases, the amount of feed provided is never actually consumed by the farmed organisms. Biomass estimation at periodical intervals should also be given due attention for feeding quantity estimation.

There has already been a realization for the importance of low-pollution feeds, especially in case of salmon farming. The new salmonid feeds that have emerged depend on selecting ingredients with high phosphorus bioavailability and high digestibility, reducing the feed losses by improved water stability and balancing diets to prevent excess of certian nutrients. Reducing protein and increasing lipid levels have improved growth rates and FCR and reduced faeces and ammonia nitrogen excretion. For low-pollution diets, although protein levels are not necessarily being reduced, lipid levels are being raised to provide high energy and low FCR feeds. For example, increasing lipid levels of Atlantic salmon feeds from 22 to 30% reduced the effluent nitrogen load by 35% and phosphorus by about 20% (Johnsen and Wandsvik, 1991). Lall (1991) suggested selection of low phosphorus fish meal in feed for reduction of phosphorus discharge. The use of partially deboned fish meal was also found to reduce the phosphorus discharge significantly (Jauncey, 1995).

Unlike fish, shrimp can utilize carbohydrate to a considerably high level to spare protein, as in lipids. Though the inclusion levels of lipid in shrimp feed are unlikely to reach levels as in case of salmon, the information already available showed that the values are two to three times higher than 20 years ago (New, 1976). In most dietary studies, optimal protein requirement is over estimated. Feeding strategy as well as dietary protein quality, particularly digestibility and amino acid profile influence the quantity of nitrogen excreted (Kaushik and Cowey, 1991). Moreover, the correct protein and energy ratio for each species has become an important consideration in feed management.

Table 5. Percentage of carp farms in Asian countries feeding formulated feeds in moist form in 1995

Country	Extensive	Semi-intensive	Intensive
Bangladesh	50	87	-
China	-	6	-
India	7	34	-
R.O. Korea	-	-	4
Malaysia	3	-	-
Myanmar	-	6	-
Pakistan	33	76	-
Thailand	-	25	-
Vietnam	6	12	-

Source: Warrer - Hansen (1992)

7. Fish Quarantine

The major diseases associated with fish culture in south and south-east Asia include protozoan and microbial diseases. The protozoan diseases affect mainly fry and juveniles whereas microbial diseases affect both young and adult fishes. The most prevalent protozoan diseases of freshwater fish are caused by the holotrichus ciliates, *Ichthyophthirius*, trichodinids and myxosporidians (primarily *Myxobolus*). These protozoans are most detrimental and cause great losses of cultured fishes, be it freshwater or marine species. Many protozoans are cosmopolitan and their spread is made easier by the transportation of live fish across the national boarder which generally is done in fry or juvenile stage without quarantine (Seng, 1987). Research findings have shown that many of the fish pathogens that cause sporadic mortalities or serious epizootics were previously unknown to the region and were introduced along with exotic fish species (Shariff, 1987).

Quarantine examinations based only on visual examinations are not effective in detecting pathogens associated with fish that are leaving or entering a country. These factors have resulted in ineffectiveness of the whole exercise. Certificates issued to the exporters of fish are now merely

Table 6. Materials used as simple feeds in semi-intensive(s) and intensive (I*) carp farms using simple (non-formulated) feeds in Asian countries in 1995

Country	Bran/oil cake		Kitchen/food processing wastes		Fresh Fish/meat		Plant materials		Others	
	S	I	S	I	S	I	S	I	S	I
Bangladesh	99	-	11	-	2	1	19	-	5	-
Cambodia	100	-	58	-	1	-	84	-	88	-
China	88	11	2	-	13	-	85	100	7	22
Hong Kong	56	11	6	-	-	-	75	-	69	-
India	99	-	13	-	1	-	15	-	8	-
Indonesia	-	96	-	14	-	4	-	-	-	-
R.O.Korea	-	-	-	-	-	-	-	-	100	-
Malaysia	22	-	49	-	1	-	88	-	13	-
Myanmar	100	-	-	-	-	-	1	-	-	-
Nepal	94	-	11	-	3	-	9	-	11	100
Pakisthan	75	-	25	-	1	-	23	-	25	-
Thailand	79	-	40	-	5	-	51	-	8	-
Vietnam	90	71	21	7	19	-	85	86	9	7
Philippines	-	50	-	-	-	-	-	-	-	50

* Extensive and semi-intensive are ponds; intensive are pens and cages.

Source: New (1995)

looked upon as a permit or license of export rather than as a document of declaration that fish meant for export are actually free of disease causing agents.

Legislation for quarantine and certification procedures does not exist as yet in our country. Upon arrival, the fish are released immediately to the importer. No holding or disease screening procedures are undertaken at present. Steps are being taken for the formulation of quarantine and certification procedures and it is proposed that Central Institute of Freshwater Aquaculture, Bhubaneswar would be assigned to co-ordinate the quarantine activities of the country with centres located at different regions or points of import.

8. Integrated Fish Farming

Intensification of fish farming practices is bound to produce adverse impact if not optimised with reference to inputs. Continued application of inputs like fertilisers and feed, not properly utilized in the pond system leads to eutrophication, resulting in oxygen depletion, increase in NH_4 level and ultimately the disease outbreak.

Integrated fish farming on the other hand efficiently recycles all the wastes from the animals, agricultural crops and related processing industries, resulting ultimately in protein-rich food at considerably low investments. It comprises various models in fish-livestock-crop farming activities, the combinations being biologically harmonious, quantitatively optimal and economically feasible as approved, fish-crop, fish-livestock and fish-processing systems, etc. make use of the left overs of the wastes which have feed and fertilizers value. With integrated fish farming considered to be an economically profitable, technologically sound and environmentally congenial farming practice, it is necessary to maintain the inputs at optimal levels for sustainability without adverse impacts. While the aquatic environments can process a large amount of wastes, their continuous application results in silting up of pond basins and anaerobic conditions. In order to achieve a good production, supplementary feeds are provided over and above the application of organic input which in turn leads to greater accumulation of pond mud year after year. This leads to serious outbreak of fish diseases and oxygen depletion, and threaten the fish life. Examples of such incidence in Zhejiang province of China had resulted in a fish loss of over 500 tonnes from about 500 ha area during 1989 due to disease incidence, while in 1990 in Wuxi, Jhiangsu province, oxygen depletion resulted in fish death causing 30% loss of the total farming areas including those species which have high environmental tolerance as common carp, crucian carp and other bottom dwellers (Kuanhong, 1995).

Integrated fish farming however provides for recycling of organic wastes, both plant and animal-based and could be a potential tool for waste recycling. In this context, the design of a wastewater treatment system by CIFA at Cuttack, Orissa using a series of duckweed and fish pond provides for waste utilization and treatment of domestic sewage (Fig. 1, 2 and 3). The sewage-fed fish culture, having a long tradition in the country actually provides for positive environmental impact of the aquaculture systems. Organic farming comprising recycling of domestic sewage, processed plant and animal residues, etc. has been the recent trend, highly suitable for an agrarian economy like India, providing for sustainability in aquaculture as also environmental upkeep.

9. Water Budgeting

The country receives an annual rainfall of about 400 million hectare metre (mhm) water, of which 230 mhm goes back into the atmosphere through evapotranspiration. The remaining 170 mhm is carried into the sea by the rivers every year, much of it (110 mhm) during rainy season and rest after percolation to underground and subsequent emergence into streams. Further, the ground water

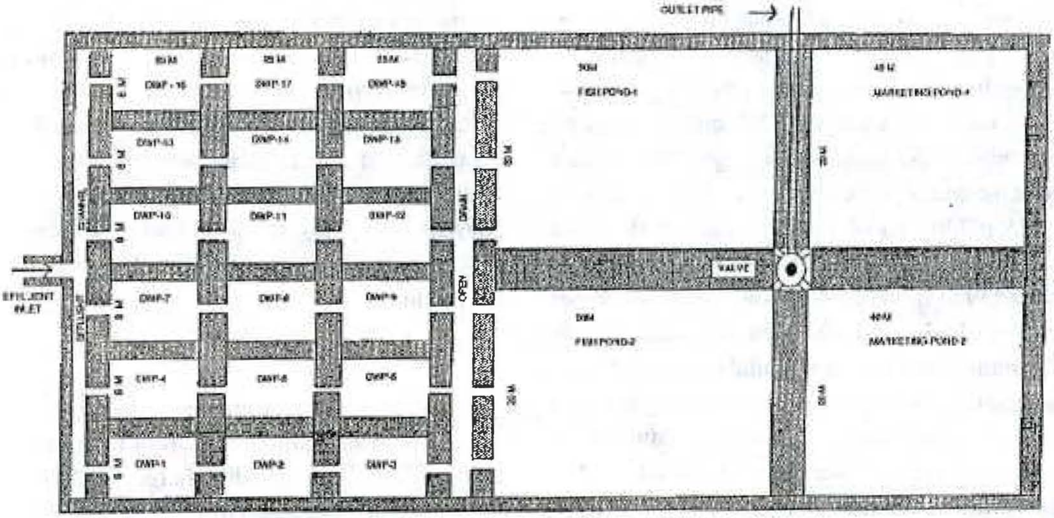

Fig. 1. Plan of aquaculture treatment system for domestic sewage at Matagajpur, Cuttack, Orrisa, India

upto 300 m contains 3,700 mhm, about 10 times the annual rainfall (Parameswaran, 1995).

Theoretically, a large quantum of 170 mhm water is available in India for irrigation and other uses, which is estimated to be enough to meet the entire irrigation needs of the country. However, irrigation systems of 40 mhm (30 mhm canal water + 10 mhm well water) only has been developed so far, which irrigate only 25% of the aerable land while the streams carry rest 130 mhm annually. Further, considering various limitations, it is estimated that it is not possible to harness more than 70-80 mhm water.

One of the important items in freshwater aquaculture is the water requirement, either in hatcheries or in grow-out systems, the information on the quantitative aspects being however lacking. Several states treat aquaculture as an industry as in Maharashtra and charge exhorbitantly for water from reservoirs, while other treat it as an agricultural activity. Even where the irrigation water is given for aquaculture, it is only the surplus and extra water after meeting the needs of agriculture, industries, etc. The left-over water is the only one over which aquaculture can claim (Dehadrai, 1995). It is estimated that freshwater aquaculture at present is utilizing 9.5 billion m^3 water under the existing 0.745 million ha pond area, which is expected to increase to 36.2 billion m^3 at the complete development of the remaining 1.755 million ha of existing water bodies and additional creation of 25% of them as new ponds *i.e.* 0.439 million ha. thus, considering the water availability of 70-80 mhm, a share of 5% (3.6 mhm) must be made available for freshwater aquaculture, by adopting parity and equity between agriculture and fisheries especially aquaculture and allotment of water as national policy guidelines. Further, scientific studies have established that irrigation water could be nutritionally enriched if it passess through fish farms. The conjuctive use of water for agriculture and aquaculture in possible by passing irrigation canal water through aquafarms to fields. Thus the quantity of water required for water exchange in aquaculture is not considered as additional water demand from the country's water source, other than the evaporation and seepage losses.

10. Depuration of Fish Cultured in Waste Water

Indian sewage-fed fisheries started in West Bengal around 1925, which presently is being practised over an area of about 4000 ha. Earlier waste water was arbitrarily used in fish culture without taking into consideration the health aspects, but gradually precautionary measures are being incorporated with regard to health and hygiene. There are potential threats to public health from the fish raised in wastewaters and the degree of risk varies considerably with the types of pathogens concerned. There is little danger of disease from eating of well-cooked fish since the heat destroys pathogens, but the consumption of raw, partially cooked or improper preserved products can be a serious health hazard, generally overlooked. It is generally believed that fish carry human pathogens passively only in their intestines and in their body surface. Prior waste treatment pathogen destruction is being suggested. Further, it is essential to eliminate the potential risk to health posed by the presence of several pathogenic faecal micro-organism in fish reared in waste water. Thus, certain measures need to be undertaken, as depuration of fish in clean water ponds before final harvesting. The normal depuration measure consists of holding the fish cultured in sewage waters for a period of 48-72 hours before marketing the produce.

11. Energy Inputs

The viability of any farming system depends on the economy of returns, in terms of land, capital, labour and entrepreneurship. In recent years, this aspect is being evaluated in terms of total energy inputs-environmental, manual and mechanical. Some farming systems are even being threatened due to high energy demands in terms of manual labour, in which context, mechanisation is assuming increasing importance. Attempts have

Fig. 2. Duckweed

Fig. 3. Treatment of domestic sewage

been made to quantify the energy inputs and evolve the energy budgets for plant and animal-based farming systems. Such an exercise is totally lacking in freshwater aquaculture and efforts are presently underway at preparation of energy budget models for different freshwater aquaculture systems.

12. Fish Marketing and Hygiene

With most fish, both marine and freshwater included, marketed fresh in the country very little post-harvest processing is carried out. Even the meagre processing of marine fish is confined to drying, salting, etc. though icing is a common practice for short distance transport. With a boom in freshwater aquaculture, this aspect is receiving greater attention in recent years.

Improper fish handling including transport of fish in baskets and containers that are repeatedly used is a source of contamination. Ice used for temporary preservation often is a source of contamination of human pathogens. The absence of a cold chain with hygienic selling places is of major concern and an environmental issue in fish marketing. Aquaculture planning needs to consider not only the development of facilities for culture *per se*, but also the post-harvest preservation and marketing measures. Necessary quality standards have to be evolved and enforced as in the case of processing and export of marine produce.

13. Environmental Modification and Recovery

Biopurification of sewage wastes employing aquatic vegetation has been found to be an effective and environment-friendly means to combat the pollution hazards. Bryopohytes, mosses with their delicate and uncuticularised plant body have a marked capacity for absorbing and accumulating pollutants. Some aquatic plants that grow well in wastewaters like *Eichhornia, Wolffia, Lemna, Spirodela, Hydrilla, Ceratopohylum, Phragmites, Scirpus* and *Typha* absorb considerable amount of nutrients and heavy metals, as also reduce the BOD levels. It has been calculated that 20-40 tonnes of *Eichhornia* is capable of removing the nitrogenous waste of over 1000 people and phosphorus waste of over 800 people (Jhingran, 1991). Biofertilizers, processed organic material and biofilters are some of the inputs with high application potentials in aquaculture systems, providing for environmental modifications as also products that could be substituted for chemical inputs or mechanical devices.

Processed organic input in aquaculture

With a dominance of organic inputs in freshwater fish culture, cattle dung and poultry droppings are the two major animal excreta used for the purpose. As a large fraction of the organic matter applied in the ponds has been observed to remain unutilized with associated environmental problems, the advantages of processing the organic matter prior to application are being considered. They incldue higher mineralisation and nutrient release rates, reduced in-pond oxygen demand for manure processing, marginal increase in the nitrogen content of the substrate due to microbial processing, low siltation rates, etc. (Ayyappan, 1994). Apart from cowdung that is traditionally used, several organic inputs like animal excreta, straw, green fodder, water hyacinth, etc. have been used as inputs in biogas plants. Further, the saving in fertilization practices with biogas slurry over the recommended manurial schedule in carp culture amount to 13.3 - 40.5%. This assumes significance in view of the increasing costs and scarcity of inorganic fertilizers, as also associated environmental impacts of long term use of inorganic fertilizers. Besides these, the biogas plant suitably process and recycle several natural organic resources like aquatic macrophytes and agricultural byproducts that are otherwise wasted.

Azolla - A new biofertilizer

Azolla, a free floating aquatic fern fixing atmospheric nitrogen through the cyanobacterium, *Anabaena azollae*, present in its dorsal leaves, is one of the potential nitrogenous biofertilizers. Its high nitrogen-fixing capacity, rapid multiplication and decomposition rates resulting in quick nutrient release rates have made it an ideal biofertilizer for farming systems. The normal, doubling time of *Azolla* is three days and one kilogram of phosphorus applied results in 4-5 kilogram of nitrogen through *Azolla i.e.* about 1.5 - 2.8 tonnes of fresh biomass. For fertilizing 1 ha of water area at the rate of 40 t/ha/yr (providing 100 kg nitrogen, 25 kg phosphorus, 90 kg potassium and 1500 kg organic matter) as a total substitution for the traditional organic manures and inorganic fertilizers recommended in carp polyculture, about 550 m^2 water spread area is required (1.5 kg/m^2/week, 42 t/yr), with total area of 800 m^2, accounting for 8% of the area to be fertilized (Ayyappan *et al.*, 1993). While *Azolla* is useful in aquaculture practices primarily as a nitrogenous biofertilizer, its high rates of decomposition also make it a suitable substrate for enriching the detritus food chain or for microbial processing such as composting prior to application in ponds. It can also serve as an ingredient of supplementary feeds and as forage for grass carp. A saving to the extent of 48.5% over the recommended manuring schedule is estimated through *Azolla* biofertilization (Ayyappan, 1994).

Waste utilization

Biological treatment of wastewater, already occurring in nature, but standardised with introduction of specific microbial inoculants or scaled-up designs is a potential area compatible with freshwater aquaculture. The objectives of using sewage for fish culture are two folds: utilization of nutrients in wastewater for fish production being the earlier concept, and using aquaculture as a tool for treatment of sewage and wastewaters being the recent trend. Further, the aspect of reduction of nutrient and bacterial loads through fish culture has been considered and shown effective with regard to counts of total and faecal coliforms, faecal streptococci and *Salmonella*. Fish culture not only reduces the nutrient load in the waters, but also causes a reduction in bacterial load, as evidenced by the works in a Nigerian sewage-fed fish culture systems. The reduction rates in the bacterial populations from the influent to the effluent during a retention time of 12 days were total viable counts 4.5 x 10^9 to 1.7 x 10^6/ml, total coliform counts 2.7 x 10^7 to 2.7 x 10^5/ml, faecal coliforms 4.5 x 10^6 to 1.3 x 10^4/100 ml, faecal streptococci 1.4 x 10^4 to 3.3 x 10^2/100 ml and *Salmonella* 2.7 x 10^2 to 1.2 x 10^2/100 ml. The reduction might have been brought about by a combination of natural inactivation processes, adsorption to sediments and uptake by fish. It may be emphasised that all these culture systems are independently economically viable units and as such would provide considerable returns (Ogbondeminu and Okoye, 1992).

Distillery effluents are also a major resource in the country with about 150 distilleries producing 900 million litres of alcohol annually resulting in 10,000 million litres of spent wash. The efficacy of aquaculture as a tool for treatment of such wastes has been demonstrated at Madras, where the effluent after undergoing the biomethanation process, is fed into fish ponds. With production rates of 50 t/ha/yr, about 6 ha of land area has been shown to be adequate for treating 100m^3 of effluents. This has opened avenues for utilising a variety of agro-based industrial effluents as also for treating them through aquaculture practices, largely based on microbial processes, in terms of oxidation or nutrient removal through algae and other macrophytes.

In terms of solid wastes also, the resource in the country is huge in terms of agro-residues amounting to 321 million metric tonnes per year (Ramachandran and Sinha, 1993). As already mentioned, on bioconversion of these lignocellulosic wastes, they can be applied to fish ponds as manure/feed which process also results in usable products like single cell protein and biogas.

14. Epilogue

With environmental issues being discussed with reference to any developmental activities, agricultural or industrial, it is relevant and essential that the freshwater aquaculture related environmental issues are also analysed for formulating guidelines for the development of the sector. Unlike other areas where these issues were take-up often as a post-mortem, they have been discussed even when the sector has not caused serious problems. With intensification of culture practices being the trend in recent years, issues as listed have been foreseen and remedial measures implemented properly would pave way for not only increasing productivity but also sustainable aquaculture. Farming systems approach providing for utilisaltion of wastes from one culture system as an input or resource for another system, with proper designs is being discussed for sustainable agricultural practices including freshwater aquaculture.

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