Chapter 7
Fish Diseases in Wastewater Aquaculture and Remedial Measures

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Abstract Water quality and biological factors strongly affect the growth of fish in aquaculture ponds. Deterioration of water quality and adverse biological factors, regardless of the nature of aquaculture ponds, would cause poor ecosystem health and disease occurrence in the cultured fishes. Wastewater-fed aquaculture is a well-established climate-resilient practice that contributes substantially to inland fish production in India and elsewhere. Enhancement of fish production in such systems is, however, limited by suboptimal conditions of water quality and disease occurrences. Investigations in wastewater fish culture wetlands revealed various stressors that affect fish growth and production. These stressors are (1) suboptimal diurnal as well as seasonal water quality with DO level fluctuating from 0 to 18.0 mg/l, high CO_2 (nil–16.0 mg/l), high unionized ammonia (0.11–0.42 mg/l) and low transparency ($<$14 cm) throughout the culture period and (2) biological stressors manifested by the abundance of urceolariid ciliates (*Trichodina*, *Tripartiella* spp.) in the hyper-mucus-secreting fish gills. The stress caused by the multiple stressors are physiologically manifested in the resident fish populations by significant changes in the levels of stress-sensitive blood parameters such as haematocrit, plasma cortisol, cholesterol, glucose, chloride and lactic acid levels. Morphological alterations are exhibited in the form of hyperplasia, hypertrophy and oedema in the gills, proliferation of mucous cells and decrease in chromatophores in fish skin. These factors affect the growth of fish as reflected by the reduced condition factor. Stressed fish in such systems become prone to various infectious and noninfectious diseases such as fin and tail rot, dropsy, bacterial gill disease, saprolegniasis, trichodiniasis, myxosporean diseases, dactylogyrosis, argulosis, ergasilosis, hypoxia and algal toxicosis. Rapid assessment of the fish health needs to be conducted using the health assessment index (HAI) method and necessary remedial measures be adopted.

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7.1 Introduction

The production of fish in ponds fertilized with wastewater is a common practice in many parts of Asia. Nowadays the sewage-fed fishery is well established because it is more attractive than that of the intensive fish farming practices using supplementary feeds (WHO 2006). The biodegradability of these wastes forms the basis for sewage treatment converting waste into economic resource for recycling. The tropical climate is ideal for the conversion of human wastes into high-protein microalgae due to favourable temperature and light throughout the year. The sewage effluents in fish ponds mediated by diverse groups of microorganism act in the manner as organic fertilizers and liberate nitrogen, phosphorus and trace elements which stimulate the production of fish food organisms in the aquatic systems. It is estimated that at present there are more than 130 wastewater aquaculture units in India covering above 10,000 ha water area. Almost 80% of these are located in West Bengal where sewage is extensively used as fertilizer for fish ponds (Bhowmick et al. 2011). One of the major sewage-fed fisheries is the East Kolkata Wetland (EKW) fisheries . In this system of culture, domestic sewage and storm water within the city of Kolkata are mostly carried through combined sewers, and nearly 4000 ha of wetlands (bheries) are used for aquaculture (Jana 1998; Das 2002). Normally, multiple stocking and multiple harvesting are adopted, and fishes are reared for 3–5 months, depending on the growth of the fishes to reach marketable size. However, deterioration of water quality and adverse biological factors are frequently encountered in these wastewater-fed aquaculture ponds rendering them prone to occurrences of fish diseases. The fish health problems limit the fish yield ranging from 1500 to 2000 kg/ha in EKW systems. Therefore the major management constraint in such system is to maintain optimal water quality for reducing the stress-induced disease outbreak. The present chapter is an attempt to highlight the causes of different fish diseases encountered in wastewater-fed systems and their remedial measures for development.

7.2 Fish Habitat Characteristic and Culture Practices in Wastewater Farms

Habitat characteristics of sewage-fed waterbodies are important for the culture practices adopted by fish farmers. In general culture operations commence with the entry of initially screened raw sewage into the ponds. This effluent requires stabilization for a few days (5–7 days), and after 12 days the pond contents are disturbed by repeated netting and manual agitation with split bamboos for oxidation, mixing for quick recovery of desirable water quality for fish farming. After 25 days of initial filling with sewage when sufficient plankton population is observed, the bheries are stocked at 7000–10,000/ha with fingerlings (10–25 g) of catla (*Catla catla*), mrigal (*Cirrhinus mrigala*), rohu (*Labeo rohita*), common carp (*Cyprinus carpio*) and tilapia (*Oreochromis mossambicus*). Thereafter, sewage is applied 7 days/month for 3 h during morning hours to fertilize the ponds at an estimated rate of 130 m^3 sewage/ha/day. In low and medium saline bheries, *Liza parsia* and *Mugil gulio* are also cultured. In some bheries, where scientific method is followed, stocking density may go up to 15,000/ha. Intermediate harvesting is done after 120 days of rearing and continued up to pond draining after 300 days in March and April.

The water quality parameters in wastewater-fed waterbodies are subjected to diurnal and seasonal variations during the year. These variations often act as stressors of short or long duration and cause physiological and morphological deleterious changes in fish, predisposing them to disease outbreaks. In studies conducted year round in a typical wastewater-fed East Kolkata Wetland (EKW), the Kantatala bheri revealed clear-cut diurnal and annual variations of water quality (Dutta et al. 2005).The physico-chemical parameters recorded in this wastewater system (Table 7.1) showed that the variations of total alkalinity, hardness, dissolved oxygen, unionized ammonia and pH are in the range of 175–204 mg/l, 180–210 mg/l, 2.3–8.6 mg/l, 0.11–0.42 mg/l and 7.8–9.2, respectively. Diurnal study of these parameters exhibited high fluctuation in

Table 7.1 Physico-chemical characteristics of Kantatala bheri in East Kolkata Wetland (EKW)

Months	Parameters							
	Air temp. (°C)	Water temp. (°C)	Transparency (cm)	Total alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)	pH	Unionized Ammonia (mg/l)
Jan'01	20.0	18.0	15.0	204.0	210.0	8.6	8.0	0.27
Feb'01	21.0	19.0	13.0	190.0	196.0	7.3	8.4	0.29
Mar'01	30.0	28.0	14.0	195.0	200.0	7.0	8.7	0.39
Apr'01	32.0	30.0	14.0	190.0	194.0	5.1	8.8	0.42
May'01	35.0	32.0	15.0	192.0	201.0	3.7	9.0	0.35
Jun'01	36.0	33.0	12.0	186.0	192.0	5.1	8.1	0.12
Jul'01	32.0	30.0	12.0	190.0	210.0	8.3	8.3	0.11
Aug'01	32.0	30.0	11.0	178.0	188.0	2.3	7.8	0.18
Sep'01	31.0	29.0	13.0	175.0	180.0	3.4	8.3	0.25
Oct'01	30.0	28.0	10.0	190.0	198.0	5.7	8.6	0.26
Nov'01	25.0	22.0	14.0	185.0	196.0	4.6	9.2	0.30
Dec'01	20.0	19.0	11.0	182.0	194.0	8.0	8.7	0.28
Range	20.0–36.0	18.0–33.0	10.0–15.0	175.0–204.0	180.0–210.0	2.3–8.6	7.8–9.2	0.11–0.42
Mean	28.6	26.5	12.8	188.0	196.5	5.7	8.4	0.2
S.D	5.710	5.435	1.642	7.716	8.404	2.076	0.416	0.095
S.E	1.648	1.569	0.474	2.227	2.426	0.599	0.120	0.027
C.V%	19.919	20.511	12.796	4.102	4.275	36.067	4.906	35.774

Source: Dutta et al. (2005)

pH (6.7–8.5) during the post-monsoon period. The 18 h cycle exhibited a wide difference in dissolved oxygen (nil–18.0 mg/l), pH (6.7–9.0) and free CO_2 (nil–16.0 mg/l).

The average transparency of 13 cm recorded is lower than the optimum requirement of 15–40 cm for fertilizer-based aquaculture systems (Boyd 1982). High organic loadings of sewage resulting in massive algal bloom are responsible for low transparency throughout the culture period. Accumulation of carbon dioxide recorded after sunset is an important factor causing stress to fish. High concentration of carbon dioxide causes the lowest values of DO available to the fish particularly during the early morning when highest concentration of carbon dioxide is accumulated. High levels of unionized ammonia (0.11–0.42 mg/l) present in these culture ponds throughout the year are sufficient to cause gill damage and retard fish growth. Boyd (1982) suggested that free ammonia concentration of 0.52 mg/l would cause 50% reduction in fish growth.

The bacterial load at bottom soil ranged from 10^5/g to 10^7/g. This is due to higher concentration of nutrients of soil water interphase. The comparatively high bacterial load in the soil and water is an indication of eutrophic condition. The high microbial consumption of dissolved oxygen (1.8 mg/l/h) observed by Das et al. (2002) in sewage-fed bheries indicates exhaustion of DO for a few hours at night, creating stressful conditions for fish.

7.3 Fish Stress in Wastewater Aquaculture

Stressors in wastewater-fed fish ponds are manifested by the abiotic as well as biological stressors, and their interactions have pronounced detrimental impacts on fish.

7.3.1 General Impact on Stress-Sensitive Haematological Parameters of Fish Population

Extensive studies on the impact of various abiotic stressors of low dissolved oxygen and high unionized ammonia on the stress-sensitive physiological parameters of fish (*Labeo rohita*) reared in wastewater system (Table 7.2) conducted by Das et al. (1999) and Dutta et al. (2005) reveal that the fishes in sewage-fed bheries are exposed to long-term hypoxic condition due to low dissolved oxygen levels especially during the nightfall. As a result, the haemoglobin and haematocrit levels in fishes increase to cope with the stressful conditions. It is suggested that the reduction in fish growth in the wastewater systems was due to an increase in energy expenditure for ventilation that decreases the amount of energy available for growth (Soivio and Oikari 1976; Kramer 1987). The increase in the blood sugar level of

Table 7.2 The mean, standard error and CV% of physiological parameters of *Labeo rohita* fingerlings reared in Kantatala bheri (EKW)

Parameters	Jun'01	Aug'01	Oct'01	Dec'01	Mean	SD	SE	CV%
Haemoglobin (gm/dl)	8.0	6.2	8.9	6.2	7.3	1.169	0.584	15.84
	(6.9–9.5)	(4.2–8.0)	(6.0–10.0)	(5.5–6.9)				
Haematocrit (%)	35.0	45.0	40.0	33.0	38.2	4.656	2.328	12.17
	(30.0–40.0)	(38.0–52.0)	(33.8–46.5)	(26.0–40.0)				
Leucocrit (%)	1.1	1.4	0.9	0.7	1.0	0.256	0.128	24.85
	(0.9–1.3)	(1.3–1.4)	(0.7–1.4)	(0.6–1.0)				
Plasma cortisol (ng/ml)	109.0	205.0	280.0	201.0	198.7	60.623	30.311	30.50
	(90.0–220.0)	(120.0–290.0)	(250.0–377.0)	(170.0–230.0)				
Plasma glucose (mg/dl)	122.0	114.0	70.4	80.0	96.6	21.851	10.925	22.61
	(80.0–145.0)	(80.0–138.0)	(50.0–117.0)	(30.0–100.0)				
Plasma chloride (mEq/l)	101.0	107.0	113.0	85.0	101.5	10.428	5.214	10.27
	(90.0–106.0)	(100.0–120.0)	(93.6–117.0)	(72.0–95.0)				
Plasma cholesterol (mg/dl)	191.0	184.0	150.0	221.0	186.5	25.243	12.621	13.53
	(178.6–228.0)	(120.0–218.2)	(89.6–199.0)	(175.0–285.0)				
Plasma protein (gm/dl)	1.9	2.6	3.4	3.0	2.7	0.553	0.276	20.29
	(1.7–2.0)	(2.2–2.7)	(2.0–3.5)	(2.5–4.2)				
Plasma lactic acid (mg/dl)	92.0	64.0	85.0	125.0	91.5	21.914	10.957	23.94
	(80.0–120.0)	(50.0–100.0)	(75.0–126.0)	(100.0–130.0)				
Fish length (mm)	115.0	145.0	182.0	215.0	164.2	37.705	18.852	22.92
	(110.0–121.0)	(145.0–158.0)	(165.0–200.0)	(190.0–300.0)				
Fish weight (gm)	14.0	42.0	62.0	95.0	53.2	29.524	14.762	55.44
	(13.0–20.0)	(39.0–47.0)	(58.0–82.0)	(70.0–100.0)				
Condition factor	1.0	1.2	1.1	0.9	1.0	0.169	0.084	16.39
	(0.9–1.1)	(1.1–1.3)	(0.7–1.1)	(0.7–1.0)				

Source: Dutta et al. (2005)

L. rohita in such system could be the effect of decrease in oxygen percentage of water and increase in ammonia levels (Hattingh 1976). It is known that low oxygen might considerably increase the toxicity of ammonia to fish, probably by its effect on respiratory flow, and ammonia reduces the oxygen-carrying capacity of the blood which increases the overall oxygen consumption (Lloyd 1961; Sousa and Meade 1977; Smart 1978). In such systems fishes are frequently subjected to concentrations higher than the optimum limit. Elevated CO_2 levels reduce the oxygen affinity and oxygen-binding capacity of the blood (Basu 1959) resulting in a reduced efficiency of oxygen uptake from the environment, thereby inhibiting fish growth (Klontz 1973).

It is evident that in sewage-fed waterbodies, considerable scope exists for interactions between reduced dissolved oxygen, elevated CO_2 and ammonia on respiratory physiology of freshwater fish (Pickering and Pottinger 1987). High plasma cortisol level recorded in the fishes enhanced their disease susceptibility by decreasing lymphocytes (Pickering 1984). Correlation between unionized ammonia and fish length and weight indicates that presence of high ammonia level in sewage fertilized wetlands adversely impacted on the growth of *L. rohita*. Reduced condition factor (0.7–1.3) of the reared *L. rohita* indicated poor health condition of fishes in these wastewater fish culture systems.

7.3.2 Effect of Ammonia and Crowding Stress on Fish Skin in Wastewater Ponds

The fish skin is multifunctional and involved in excretion, osmoregulation, defence against disease and adjustment of fish to a wide variety of environmental factors. It is therefore vulnerable to damage caused by water quality changes and infection. It is observed that the fishes from wastewater-fed farms have excessive secretion of slimy mucus on the surface. Examination of the skin revealed a proliferation of mucous cells in the epidermis indicating a stress condition. Fishes in such culture systems are subjected to sublethal concentrations of ammonia more so under high stocking densities.

L. rohita fingerlings exposed to unionized ammonia level of 0.13 mg/l for 24 h and crowding for 4 h showed a gradual increase in the number and decrease in the area of the chromatophores, whereas the mucous glands gradually decreased in their number and increased in area during the experimental period (Figs. 7.1 and 7.2). It indicated that the morphological changes of mucous glands and chromatophores resulted in excessive mucous secretion in *Labeo rohita* in response to the stress. Further studies revealed the activation of the hypothalamic-pituitary-interrenal (HPI) axis with increase in the hormones prolactin and cortisol. Pickering et al. (1982) showed that handling, confinement and water quality deterioration could all stimulate the HPI axis in teleost fish.

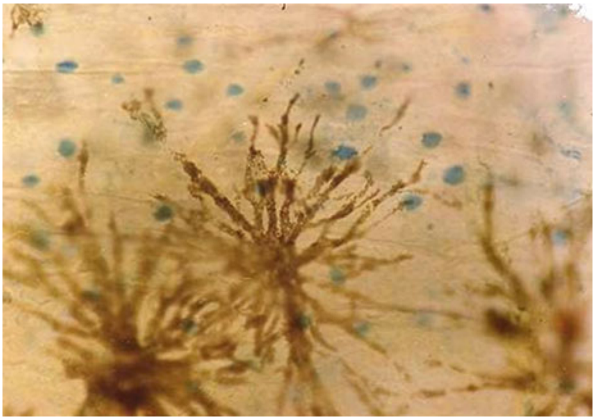

Fig. 7.1 A normal skin of *L. rohita* showing Alcian blue-stained mucous cells and dark branching chromatophore

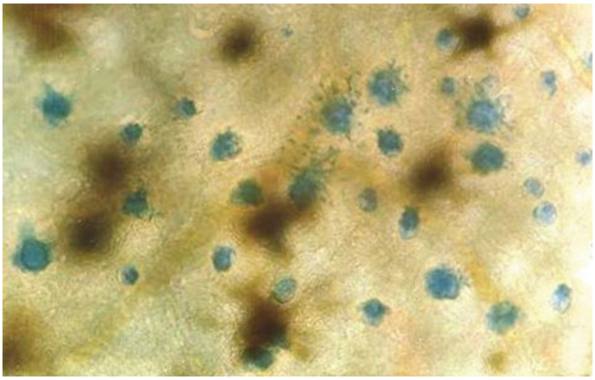

Fig. 7.2 Increase in area of mucous glands and decrease in area of chromatophores

7.3.3 Morphological Impact on the Gills of Fish

As the gills of fish serve as good indicator of water quality status of the habitat, alteration in the histological structure of the gills of cultured *L. rohita* serves as a good indicator for assessing health status of fishes in the wastewater-fed culture system. Investigations conducted by Das et al. (1994) and Acharya et al. (2005) on cultured *L. rohita* exposed to high ammonia and low oxygen levels in such systems showed varying degree of histological damage in the gills. Hyperplasia was more pronounced at the bases of secondary lamellae which led to formation of interlamellar bridges. Hyperplasia of the distal ends was also visible. Oedema was found at the bases of some secondary lamellae as respiratory epithelium of lamellae got detached from underlying tissue resulting in a space filled with fluid. Some swollen tips of secondary lamellae with leucocytic infiltration of matrix of primary lamellae were also observed. The presence of haematoma was found where pillar cell system was completely broken down and the epithelium enclosed a disorganized mass of cells and erythrocytes. Generally the epithelium remained intact but in some instance had ruptured and haemorrhage occurred (Figs. 7.3, 7.4 and 7.5).

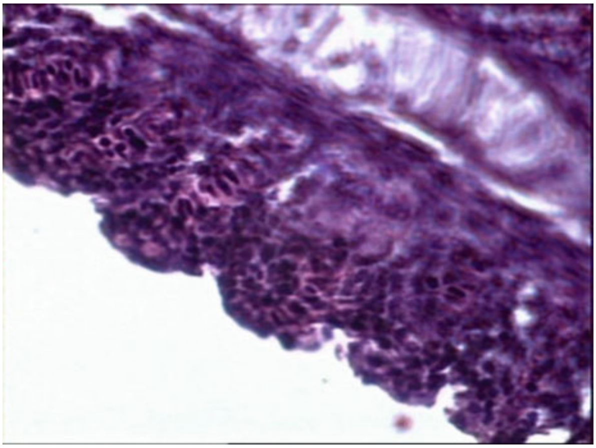

Fig. 7.3 Hyperplasia at the bases of secondary lamellae with interlamellar bridges

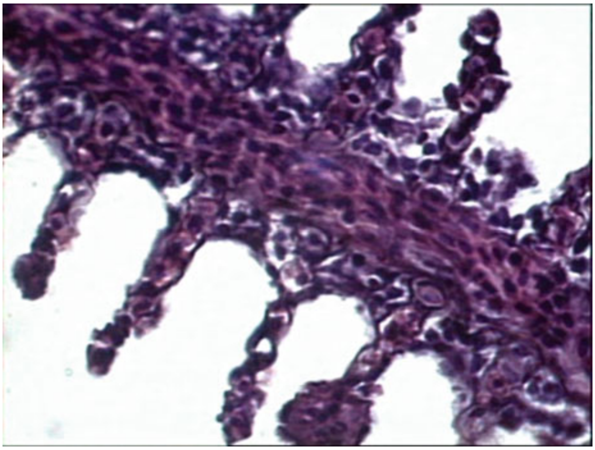

Fig. 7.4 Some swollen tips of secondary lamellae

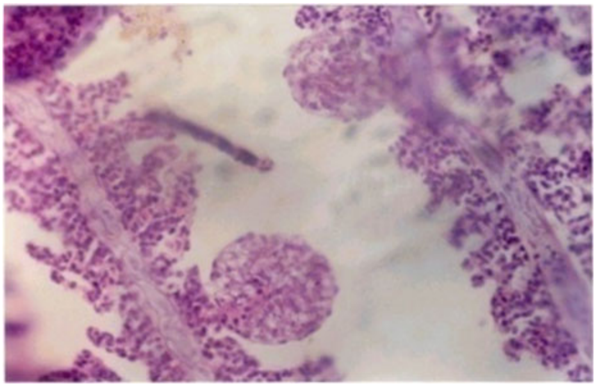

Fig. 7.5 Presence of haematoma in a fish raised in wastewater-fed system

Table 7.3 Percentage-wise alterations in the histological structure of gill tissues of *L. rohita*

Characteristics	Waterbodies	
	Suguna beel (normal)	Kantatala bheri (sewage fed)
Hypertrophy	1%	5%
Epithelial lifting	–	2%
Hyperplasia	2	15%
Fusion of lamellae	–	6%
Mucous hyper-secretion	5%	25%
Haematomona	–	–
Formation of aneurysm	–	1%
Proliferation of chloride cells	–	4%
Formation of interlammelar bridges	–	5%
Leucocyte infiltration of gill epithelium	–	4%
Necrosis	–	–

A comparative assessment of fish cultured in a waterbody with optimal water quality condition and fish cultured in wastewater-fed wetlands revealed pronounced histological alteration in the gill structure of *L. rohita* in the latter. The suboptimal water quality prevailed in wastewater-fed wetlands affected higher percentage of cellular alterations such as hypertrophy, hyperplasia and fusion of lamellae in gills compared to the fish cultured under optimal conditions (Table 7.3).

7.3.4 Biological Stressors and Impact on Fish in Wastewater Fish Farms

Fishes cultured in wastewater ponds recorded high infestation of urceolariid ciliates of the genera *Trichodina* and *Tripartiella* in the gills of fish tested. The suboptimal water quality in such aquatic systems mainly due to high levels of ammonia accelerates the amount of mucous production from fish gills and causes changes in its consistency. As a result, greater amount of mucous substrate is available as feed for the ciliate parasites and consequently their number increase. Das et al. (1997) observed that the presence of trichodinids above 20 numbers in 1 drop (0.05 ml) of pooled fish gill mucus is indicative of suboptimal water quality and stress to fish.

7.3.5 Stress Due to Fish Cultural Practices and Impact on Fish in Wastewater Fish Farms

Fishes cultured in wastewater-fed aquaculture system are subjected to the stresses caused by handling, crowding and transportation. These effects often become additive or synergistic with those of other stimuli (low unionized ammonia and dissolved oxygen) already existing in the wastewater farms and can place a stress of considerable magnitude on the homeostatic mechanism of fishes (Wedemeyer et al. 1984). By conducting an experiment with crowding, handling and transportation stress on *L. rohita*, Dutta et al. (2002) observed gradual depletion of dissolved oxygen from initial 6.8 mg/l to 1.8 mg/l, UIA from nil to 0.1 mg/l and CO_2 from 2.0 to 6.6 mg/l resulting in hypoxia and ammonia toxicity during transportation. These stressors significantly altered the blood parameters creating stress to fish (Table 7.4). It is important that fish farm managers should understand the severity of stress due to cultural practices and the period needed for recovery in fish (Das 2011).

The plasma cortisol and plasma glucose levels increased significantly after 1 h of stress and continued to be so up to 24 h of recovery period. After 48 h, regulation of cortisol values occurred. On the other side, a significant decrease in plasma chloride was observed after 1 h of stress and continued up to 24 h of recovery period. Both glucose and chloride recovered its normal values within 48 h of recovery period. Thus the cultural practices of handling, crowding, transportation or a combination of all the three factors act as stress on the fish. It is suggested that for proper fish health management, fishes subjected to such stresses should not be further stressed within 48 h for metabolic recovery and then stocked into wastewater ponds (Das 2011).

7.4 Fish Diseases Encountered in Wastewater Fish Farms

Health problems arising due to stress in fishes cultured in sewage-fed wetlands are very common. Though mortality of fish may not always be encountered, physiological disorders would occur. This resulted in retarded growth and serves as a predisposing factor for various disease outbreaks. Investigations conducted in sewage-fed waterbodies recorded predominantly six types of disease (Das et al. 1994; Das 2011).The incidence of fish diseases in these waterbodies is higher in comparison to normal intensive fish-rearing farms using inorganic and other organic fertilizers and supplementary feeds. A comparison (Table 7.5) showed higher incidence of disease occurrence in the fishes reared in sewage-fed ponds than in fertilized composite fish culture ponds.

7.4.1 Infectious Diseases

7.4.1.1 Fin Rot and Tail Rot

Fin rot and tail rot diseases are very common in sewage-fed ponds. The tail and fin get necrosed and discoloured in affected fishes. This is mostly caused by mixed infections with *Aeromonas hydrophila* and *Pseudomonas fluorescens*. Improvement in water quality and reduction in stocking density are essential for long-term management of the disease.

Table 7.4 Physiological alteration in *L. rohita* subjected to handling, crowding and transportation stress and recovery

	Stress		Recovery			
	Control/hr	1 h	1 h	3 h	24 h	48 h
Parameters	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Haemoglobin (gm/dl)	6.9 ± 0.117	7.5 ± 0.165*	7.6 ± 0.221*	7.2 ± 0.104	7.1 ± 0.081	7.0 ± 0.064
Haematocrit (%)	34.2 ± 0.634	38.6 ± 0.998*	36.5 ± 0.06*	36.0 ± 0.9233	35.9 ± 0.635	33.5 ± 1.16
Leucocrit (%)	1.3 ± 0.063	1.14 ± 0.084	1.02 ± 0.089	1.03 ± 0.1022	0.95 ± 0.028*	1.04 ± 0.093
Plasma cortisol (ng/ml)	90 ± 3.17	180 ± 9.08**	185 ± 12.19**	170 ± 11.07**	140 ± 1.22**	90 ± 4.48
Plasma glucose (mg/dl)	95.18 ± 4.48	269.5 ± 4.75*	273 ± 3.38**	230.9 ± 7.090	150.2 ± 6.34**	100.9 ± 2.95
Plasma chloride (mg/dl)	117.6 ± 1.022	102 ± 0.634**	100 ± 1.022**	102.1 ± 1.418**	108 ± 1.112**	116 ± 1.268
Plasma protein (gm/dl)	2.3 ± 0.2156	2.7 ± 0.063	2.8 ± 0.141	1.8 ± 0.181	2.2 ± 0.152	2.0 ± 0.141
Plasma cholesterol (gm/dl)	274 ± 3.054	2.97 ± 4.634	321.5 ± 8.04**	290 ± 4.158	287.4 ± 2.172	285.2 ± 3.170
Plasma lactic acid (gm/dl)	102.4 ± 2.338	122.7 ± 2.159	108.2 ± 2.675	105.3 ± 1.445	103.8 ± 2.675	99.1 ± 1.902
Glycogen (mg/gm)						
Liver	8.0 ± 0.288	7.0 ± 0.317	7.2 ± 0.179	7.1 ± 0.147*	6.0 ± 0.152**	5.5 ± 0.158**
Muscle	4.2 ±0.442	3.2 ± 0.213	3.0 ± 0.487*	2.5 ± 0.165	3.2 ± 0.1022	4.3 ± 0.2156

*$P < 0.05$, ** $P < 0.01$ (*Source*: Dutta et al. 2002)

Table 7.5 Comparative prevalence of major fish disease in normal composite fish culture and sewage-fed fish culture facilities in North 24 Parganas, West Bengal

Disease	Host	% incidence	
		Normal composite fish culture ponds	Sewage-fed bheries
Gilldisease/gill rot	*Labeo rohita*,*Cirrhinus mrigala*	14.6	16
Dropsy/gas bubble disease	*Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*	7.2	15
Tail and fin rot	*Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*	4.6	15
Trichodiniasis	*Cirrhinus mrigala*, *Labeo rohita*	6	30
White gill spot disease	*Catla catla*, *Cirrhinus mrigala*	3	6
White scale spot disease	*Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*	4	10

Source: Das et al. 1994; Das 2002 and Paria and Konar (1999)

7.4.1.2 Dropsy

Dropsy is frequently encountered in late winter. Clinically, there is abnormal reddish fluid accumulation in the abdomen and in scale pockets leading to enlargement of the abdomen, ruffled loose scales, lethargy, pinpoint haemorrhages on the skin, etc. There may be terminal septicaemia. It is caused by virulent *Aeromonas hydrophila* and few other motile *Aeromonas* species. Remedial measures that reduce the morbidity are bath treatment to fish in 5 mg/l potassium permanganate for 2 min and application of 1–3 mg/l $KMnO_4$ in pond water.

7.4.1.3 Bacterial Gill Disease

Gills of Indian major carp cultured in wastewater ponds are affected by a number of bacteria, but *Flavobacterium branchiophila* is the most important one. Gills of affected fishes become discoloured, and gill fringes become uneven or torn, with grey patches of necrosis (Fig. 7.6). Morbidity and mortality go up to 100% and 50%, respectively. To control the disease problem, avoid overstocking and give aeration. Careful bath treatment with 1–2 mg/l $KMnO_4$ can control the disease.

7.4.1.4 Saprolegniasis

Saprolegniais is caused by various *Saprolegnia* species and is one of the major health problems in young carps cultured in wastewater. This disease in fish is characterized by a white to brown cotton-like growth consisting of colonies of

Fig. 7.6 Bacterial gill disease in *L. rohita* raised in wastewater-fed system

mycelium and filaments which appear as small to large patches on various parts of the body like fins, gills, mouth, eyes or muscle which can be treated by bath treatment with 3–4% common salt or 1:2000 $CuSO_4$ daily for 3–4 days or 1:1000 malachite green for 30 s.

7.4.1.5 Trichodiniasis

Various life stages of Indian major carp are frequently affected by this disease. Affected fishes exhibit pale-coloured gills with a creamish coating due to excessive mucous secretion and mild hyperplasia. Fishes loose condition and gasp for air on surface. The causative agents are urceolariid ciliate species of the genera *Trichodina* (Fig. 7.7), *Tripartiella* and *Trichodinella*. The treatment methods adopted are (1) water quality improvement, (2) diminishing stocking density of fish and (3) bath treatment of fishes with 2–3% NaCl or 100 mg/l formalin (4) pond treatment with 4–5 mg/l $KMnO_4$ or 25 mg/l formalin.

7.4.1.6 Myxosporean Disease

Myxosporean disease is most commom in wastewater aquaculture. Indian major carp gills are infested with white to creamish cysts ranging from 1 to 4 mm or more (Fig. 7.8). In heavy infection, the cysts assume a cauliflower shape blocking the entire respiratory surface of gill with excessive mucous secretion and hyperplasia. The causative agents are the encysted spores of *Myxobolus bengalensis*, *M. catlae*, *M. hosadurgensis* and *Thelohanellus catlae*. Besides the gills, scales and body surfaces are also heavily infected with the cysts in *C. mrigala* and *L. rohita*. The infective stage of the myxosporeans is the mature spore which is ingested by the fish from the waterbody. The spore though exposed outside is very resistant to chemicals. Thus the control measures are limited to prophylactic measures like

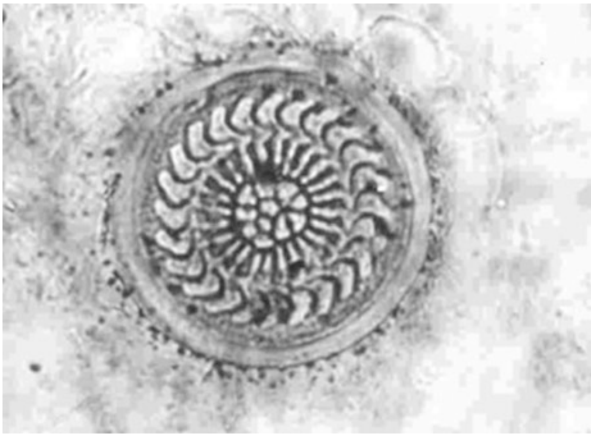

Fig. 7.7 Gill-infesting *Trichodina* sp. in a fish raised in wastewater-fed system

Fig. 7.8 Myxosporean gill spot disease in a fish raised in wastewater-fed system

(1) control spores from entering fish ponds and (2) segregation of age groups as fry and juveniles are more susceptible. Therapeutic measures done are disinfections of pond after dewatering with calcium oxide and drying for a month.

7.4.1.7 Dactylogyrosis and Gyrodactylosis

Fingerlings and adults of the cultured fishes are affected by trichodinids in general, and there are growth reduction and morbidity in affected fishes. The parasites can be controlled by therapeutics: (1) bath treatment with 3–5% NaCl for 10–15 min or 100 mg/l formalin with aeration and (2) pond treatment with 25 mg/l formalin or 5 mg/l $KMnO_4$.

7.4.1.8 Argulosis

The disease is quite common in wastewater ponds. Indian major carps are often affected by this parasite. The causative agent is the branchiuran parasites (Fig. 7.9) *Argulosus foliaceus*, *A. bengalensis* and *A. siamensis* in Indian fishes. The minimum period required for completion of the life cycle of *Argulus* sp. varies between 3 and 6 weeks. Argulosis occurs when parasitized fishes enter unaffected water areas. It is controlled by (1) bath treatment with 3–5% NaCl or 100 mg/l KMnO4 or 2000 mg/l lysol for 5–10 s, (2) pond treatment with $KMnO_4$ at 5 mg/l and (3) mechanical removal of *Argulus* sp. sticky eggs by hanging bamboo mats or corrugated sheet in the water area and its removal and drying in the sun after a week for killing the eggs. Pesticides are generally used by farmers, but it is often not advisable.

7.4.1.9 Ergasilosis

The predominance of the disease is witnessed in *L. parsia* cultured in low-saline sewage-fed bheries and less frequently in Indian major carps. Infestation occurs in gills, buccal cavity, operculum and gills. The parasitic copepods look like white bodies less than 2 mm long. Surfacing, lethargy and restlessness occur in affected fish. Infection increases with size of the fish causing damage to the gill tissue and retardation in growth. The causative agent is the species of genus *Ergasilus*. The parasites are controlled by pond treatment with potassium permanganate at 5 mg/l or bath treatment of affected fish with 2–3% sodium chloride. Bath treatment with 1:1000 glacial acetic acid for 5 min immediately followed by dip in 1% NaCl for 1 h is also effective.

Fig. 7.9 *Argulus* sp. in a fish raised in wastewater-fed system

7.4.2 Noninfectious Diseases

7.4.2.1 Hypoxia or Oxygen Deficiency

Sewage input, algal bloom, excess presence of organic matter, high stocking density, etc. often lead to serious oxygen depletion and surfacing, gasping and mortality of fish stock in wastewater bheries. The remedial measures are aeration of water by beating water surface, use of aerator or throwing water into waterbody from heights.

7.4.2.2 Gas Bubble Disease

The gas bubble disease is very common in wastewater bheries caused by excess nitrogen and oxygen. Small fry and fingerlings of *C. mrigala* and *L. rohita* are frequently affected by the disease. The abdomen is swollen. The balance of the fish is lost due to accumulation of large gas bubbles in the intestine. It indicates that the environmental factors act as a predisposing factor for disease outbreak.

7.4.2.3 Algal Toxicosis

There is clogging of the gills by the algae causing respiratory distress and mortality to fish in sewage-fed ponds. The causative agent is the bloom condition of blue-green algae, *Microcystis* and *Anabaena* spp. It is often encountered under eutrophic conditions. The dead and decomposing cells release enough breakdown products or toxins harmful for fish. The bloom condition can be controlled by (1) copper sulphate application at 0.5 mg/l and (2) sprinkling cow dung at 200 kg/ha over the surface of water or covering it with water hyacinth, thereby blocking sunlight.

7.5 Rapid Method for Evaluation of Fish Health in Sewage-Fed Fish Farms

The effect of stress and disease on the general health of fish population is evaluated by a variety of approaches. Each type has its own advantages and disadvantages, but most of them cannot be rapidly and inexpensively applied to field studies. The HAI (health assessment index) developed by Adams et al. (1993) allows a statistical comparison of fish population health. The method was applied by Das (2005) to

Table 7.6 Health assessment index (HAI) values for *L. rohita* from three waterbodies along with their water quality parameters

Environmental quality	Static freshwater pond (S1)	Freshwater wetland (S2)	Freshwater sewage-fed pond (S3)
Transparency(cm)	28	59	14.0
Alkalinity mg/l	200	170	194
Hardness mg/l	187	160	182
Dissolved oxygen mg/l	6.0	6.5	4.2
pH	8.2	8.0	8.2
Unionized ammonia mg/l	0.03	Nil	0.2
HAI	17.3	29.3	51
SD	20.8	25.3	31.4
CV	120.0	86.4	61.6

Source: Das (2005); the average HAI values for the sewage-fed bheri (S3) were high (51) indicating that the health of *L. rohita* population was in a relatively poor condition compared to S1 and S2

comparatively assess the health condition of fish population (*Labeo rohita*) in a wastewater bheri and found that conditions are suboptimal (Table 7.6).

7.6 Emerging and Persistent Issues Related to Fish Health Management in India

7.6.1 Environmental Aspects

Environmental deterioration as a result of pollution and other anthropogenic activities has been one of the major causes of fish kills, public health problems, limitations on aquaculture development and declining production. These problems and inevitable and future conflicts and competition for aquatic resources should be solved as a matter of urgency.

7.6.2 Public Health and Aquaculture Products

Public health issues very often get associated with aquaculture production especially in wastewater aquaculture and the treatment of disease in fish. The problems arise from contamination of products as a result of pollution or risks to consumers, farm workers and the environment posed by some of the chemicals present in wastewater or the chemotherapeutants used to control disease in fish farms.

7.6.3 Use of Drugs, Chemicals and Antibiotics

Use of antibiotics in aquatic environments poses serious threats to the consumer and to the sustainability of the aquaculture system. In natural environment bacteria rapidly develop resistance to the antibiotics. Many of the human pathogenic bacteria like *Aeromonas*, *E. coli*, *Samnonella*, *Vibrio* and *Listeria* are often present in aquatic environments, and these pathogens may develop resistance to antibiotics very fast. Development of resistant strains implies that newer and newer antibiotics need to be developed to control resistant bacteria, which is an expensive and never-ending process.

7.6.4 Impact of New Fish Culture Methods on Fish Health

The native aquatic habitat like river harbours many parasites of fishes in apparently harmless condition. These parasites very often convert into causative agent of serious epizootics to the same host when cultured in closed waterbodies. *L. parsia* extensively cultured in sewage-fed bheries (wetland) are attacked by the disease ergasilosis in epizootic proportion causing growth retardation and mortality. It is therefore essential that each new species of fish proposed for cultivation in a new culture system ought to be studied from the epizootical point of view and estimation of parasites infecting it in the natural waterbodies be done.

7.6.5 Introduction of Exotic Fishes

Introduction of exotic carps has enhanced fish production significantly, but serious attention needs to be given to the possibility of introduction of new pathogens. Introduction of various exotic fishes in wastewater-fed culture ponds needs to be taken care for avoiding unintended introduction of pathogens.

7.6.6 Development of Disease Surveillance Mechanism

Surveillance is an integral component of aquatic health management for early warning of risk factors and disease onset, emergency disease preparedness including health advice to farmers, monitoring of disease control measures, health certification for freedom from infection and reporting to national and international organizations on fish/animal health. Efforts have been taken to strengthen the aquatic animal disease surveillance mechanism through general and targeted surveillance in wastewater-fed system.

7.6.7 Quarantine and Certification of Fish

Quarantine and certification of fish stocks as a means of preventing the spread of pathogens are becoming important. The existing legislation and quarantine system are very weak and do not act as a deterrent against introduction of serious pathogens especially in wastewater-fed system. Legislation must be realistic and should be based on adequate diagnostic facilities in the country.

7.7 Conclusions

Wastewater use for agriculture and aquaculture is practised in many countries. The major limitations to its reuse in aquaculture are (1) accumulation of silt and high organic matter in pond bottom, (2) incidence of pathogen and fish diseases, (3) possibilities of pathogens being transmitted to human beings and (4) accumulation of heavy metals in the ecosystem. There is an urgent need for concerned government agencies to restrict unplanned wastewater reuse in aquaculture by putting in place adequate health safeguards and environmentally sound aquaculture practices. Wastewater-fed aquaculture in a scenario of imminent water crisis should be part of an integrated water resource management plan of the government.

References

Acharya S, Dutta T, Das MK (2005) Physiological and ultrastructural changes in *Labeo rohita* (Hamilton-Buchanan) fingerlings exposed to sublethal acidic and alkaline pH for long duration. Asian Fish Sci 18:297–307

Adams SM, Brown AM, Goede RW (1993) A quantitative health assessment index for rapid evaluation of fish condition in the field. Trans Am Fish Soc 122:63–73

Basu SP (1959) Active respiration of fish in relation to ambient concentration of oxygen and carbon dioxide. J Fish Res Bd Can 16:175–212

Bhowmick ML, Jena JK, Ayyappan S (2011) Wastewater aquaculture. In: Shashi VA, Kumar Aruna T, Obaidur R, Sudhir P (eds) Handbook of fsheries and aquaculture, 3rd edn. Director of Information & Publication of Agriculture, I CAR, New Delhi, pp 449–468

Boyd CE (1982) Water quality management for pond fish culture. Elsevier Scientific Publishing Company, Amsterdam

Das MK (2002) Social and economic impacts of disease in inland open water cultured based fisheries in India. In: Arthur JR, Philips MJ, Subasinghe RP, Reantaso MB, Rae IHM (eds) Primary aquatic animal health care in rural, small scale, aquaculture development, vol 406. FAO Fisheries Technical Paper, Rome, pp 333–344

Das MK (2005) Application of the health assessment index (HAI) for rapid evaluation of fish health. J Inland Fish Soc India 37(2):87–92

Das MK (2011) Fish and shrimp health management. In: Shashi VA, Kumar Aruna T, Obaidur R, Sudhir P (eds) Handbook of fisheries and aquaculture, 3rd edn. Director of Information and Publication of Agriculture, ICAR, New Delhi, pp 763–793

Das MK, Das RK, Ghosh SP, Bhowmick S (1994) Fish disease its relation with environmental factors in sewage fed wetland. J Inland Fish Soc India 26(1):100–105

Das MK, Das RK, Ghosh SP et al (1997) Urceolariid ciliates of fish as indicators of water quality. In: Vass KK, Sinha M (eds) Proceedings national seminar changing perspectives in inland fisheries. Inland Fisheries Society of India, Barrackpore

Das MK, Manna S, Bhowmick S, Ghosh SP (1999) Changes in the haematological profile of fish in response to some abiotic and biotic stressors. In: Sinha M, Kumar D, Katiha PK (eds) Eco-friendly management of resources for doubling fish production- strategies for 21st century. Proceedings of national seminar, December 1999, Inland Fisheries Society of India, pp 63–67

Das MK, Das RK, Mondal SK (2002) Measurements of some stress sensitive parameters of young major carp *Labeorohita* (Hamilton-Buchanan). Indian J Fish 49(1):73–78

Dutta T, Acharya S, Das MK (2002) Some changes in juvenile *L. rohita* (Ham.-Buch.) subjected to handling, crowding and transportation stress. In: Proceedings of national seminar on recent advances in molecular physiology. University of Kalyani, Kalyani, West Bengal, 4–6 February 2002

Dutta T, Acharya S, Das MK (2005) Impact of water quality on the stress physiology of cultured *L. rohita* (Ham.-Buch). J Environ Biol 26(3):585–592

Hattingh J (1976) Blood sugar as an indicator of stress in the freshwater fish *Labeo capensis* (smith). J Fish Biol 10:191–197

Jana BB (1998) Sewage-fed aquaculture: the Calcutta model. Ecol Eng 11:73–85

Klontz GW (1973) Syllabus of fish health management: fish culture methods. Texas A & M University/Sea Grant Program, Texas

Kramer DL (1987) Dissolved oxygen and fish behaviour. Environ Biol Fish 18:81–92

Lloyd R (1961) Effect of dissolved oxgen concentrations on the toxicity of several poisons to rainbow trout (*Salmo gairdneri*). J Exp Biol 38:447–455

Paria T, Konar SK (1999) Management of fish ponds and its relation to fish diseases in West Bengal, India. Environ Ecol 17:962–970

Pickering AD (1984) Cortisol induced lymphocytopenia in brown trout, *Salmo trutta* L. gen. Comp Endocrinol 53:252–259

Pickering AD, Pottinger TG (1987) Poor under quality suppresses the cortisol response of salmonid fish to handling and confinement. J Fish Biol 30:363–374

Pickering AD, Pottinger TG, Christie P (1982) Recovery of brown trout, *Salmo trutta* L., from acute handling stress: a time course study. J Fish Biol 20:229–244

Smart GR (1978) Investigations of the toxic mechanisms of ammonia to fish gas exchange in rainbow host (*Salmo gairdneri*) exposed to acutely lethal concentrations. J Fish Biol 12:93–104

Soivio A, Oikari A (1976) Haematological effects of stress on ateleosts, *Esoxlucius* L. J Fish Biol 8:397–411

Sousa RJ, Meade TL (1977) The influence of ammonia on the oxygen delivery system of coho salmon haemoglobin. Comp Biochem Physiol A Comp Physiol 58:23–58

Wedemeyer G, Mcleay DJ, Goodyear CP (1984) Assessing the tolerance of fish and fish populations to environmental stress: the problems and methods of monitoring. In: Cairns VW, Hudson PV, Nriagu JO (eds) Contaminant effect on fisheries. Wiley, Toronto, pp 163–195

WHO (2006) Guidelines for the safe use of wastewater, excreta and greywater, vol 2: wastewater use in agriculture. World Health Organization, Geneva