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Water quality characteristics of mariculture farms and effect of effluent discharge on receiving water bodies

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Abstract

Changes in water quality characteristics of semi-intensive and modified extensive type aquafarms in Nagapattinam coastal area were studied for three crop periods to assess the impact of farm effluents in the nearby water bodies. The *p*H of the pond water steadily increased from early phase to harvest period both in extensive and semi – intensive farms. The salinity did not show much variation from inlet to outlet. The dissolved oxygen level of outlet water was found to be 40% less than the inlet water. The concentration of ammonia and nitrate in aquafarm discharges were slightly higher in semi-intensive farms when compared to extensive farms. The concentration did not cause any eutrophication or planktonic bloom in and around the farming area indicating that its environmental impact is very less. The biological oxygen demand, chemical oxygen demand and hydrogen sulphide values were within the permissible level in both extensive and semi-intensive farms.

Key words: Aquaculture, Water quality in aqua ponds and impact of effluent discharge.

Introduction

The adverse effect of aqua farming discharges on environment has acquired increased interest in recent years. The water in aquaculture ponds is often enriched with nutrients, suspended and soluble organic matter and when discharged cause adverse effects on the environment and receiving water bodies. Considering the international and national scenario and issues of debate on this subject a study was carried out in aquafarms of Nagapattinam area along the southeast coast of India. This study mainly aimed at analyzing the variation in physico-chemical characteristics of pond waters during the culture processes and attempted to assess the impact of farm discharge on receiving water bodies.

Materials and methods

The investigation was carried out covering three crop periods between September 1997 and February 1999 in two extensive type and two semi-intensive type of shrimp farms situated at Nagapattinam, Nagoor and Velankanni in Tamil Nadu. Modified extensive farms consisted of 0.5 ha. ponds and in semi-intensive farms the pond size was 1.2 ha. Water samples were collected once in a month from all the aqua farms at the inlet, pond and outlet, from the 10^{th} day of culture till the harvest day. Parameters such as *p*H, temperature, transparency, salinity, dissolved oxygen, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrite, nitrate, ammonia, phosphate, carbonate, bi-carbonate and hydrogen sulphide were estimated following American Public Health Association (1995) methods.

Results and discussion

Variations in fourteen water quality parameters during the culture operations were monitored monthly for three successive crop periods (i.e. From Sep. '96 to Feb. '97; from Mar. '97 to Jul. '97; Sep. '97 to Jan. '98). The effect of effluent discharge from these farms is discussed.

p*H*

*p*H of pond water ranged from 7.9 to 8.3 during the 1^{st} crop period and 8.1 to 8.5 during the 2nd crop period and 7.7 to 8.4 during the 3^{rd} crop period. It showed a steady increase from the early phase to harvest period. In all the aquaculture ponds the *p*H of discharged waters was well within the limits prescribed for discharge standards. t- test showed a difference existing between the extensive and semi-intensive systems ($P<0.01$, Table 1) and between summer and monsoon seasons ($P<0.01$, Table 2). ANOVA – was performed for identifying the different source (i.e. inlet, pond and outlet waters) of variation (Table 3). There was no significant difference between the mean values of pond and outlet ($P>0.01$) but that of the inlet significantly differed from that of the other two ($P<0.01$).

Salinity

Wide variations in salinity occurred in the farms. The salinity of inlet waters was reduced to 1ppt level and stayed in the range of 7.2 to 11 ppt during monsoon periods from September to December. After December, it gradually increased during March to May (Figs.1 and 2). In all four farms, no attempts were made by the farmers to change the salinity level. In both these farms there is no significant difference in salinity between pond and outlet waters. No changes were observed in the salinity of receiving water bodies due to aqua farm discharges. ANOVA - showed (Table 3) no difference between the mean values of pond and outlet ($P>0.01$) whereas, that of the inlet significantly differed from the other two ($P<0.01$). In both these systems, the mean value showed no significant difference between pond and outlet waters (Tables 4 and 5).

Water temperature

The temperature in the farms ranged from 30°C to 32°C, 30°C to 34°C and 29°C to 32°C during 1st, 2nd and 3rd crop periods respectively (Figs. 3 and 4). The correlation matrix of temperature showed a positive correlation with all the parameters except transparency. It was observed that there was no change in temperature of receiving water bodies (Table 6). ANOVA - performed to identify the differences among the inlet, outlet, and pond water

Table 1. *t-test for testing difference between the means of parameter in extensive and semi-intensive system*

Parameters	Extensive. Mean	Semi – intensive. Mean	t – value
*p*H	8.0	8.02	0.08 NS
‰ ppt	23.6	27.25	-3.66**
T° C	30.4	30.60	-0.42 NS
DO	4.2	4.21	0.36 NS
NO_2	0.09	0.01	-5.02 **
NO_3	0.01	0.02	-7.43 **
NH_3	0.46	0.57	-2.60 *
PO_4	0.02	0.03	-3.07 **
H_2S	0.001	0.00	-2.60 **
BOD	6.17	9.63	-3.27 **
COD	17.6	18.76	-0.78 NS
CO_3	28.4	30.53	-0.78 NS
HCO_3	141.0	148.21	-1.72 NS

Table 2. *t-test for testing difference between the means of parameter in monsoon and summer*

Parameter	Monsoon Mean	Summer Mean	t - value	P – value
*p*H	7.9	8.19	-4.69	**
‰ ppt	22.7	31.12	-9.49	**
T°C	29.7	32.11	-9.04	**
DO	4.3	3.98	2.49	*
NO_2	0.004	0.006	-1.94	*
NO_3	0.022	0.026	-1.88	NS
NH_3	0.507	0.535	-0.63	*
PO_4	0.031	0.033	-0.75	NS
H_2S	0.001	0.002	-1.86	NS
BOD	7.1	9.48	-2.04	*
COD	17.2	20.1	-1.82	NS
CO_3	28.9	30.61	-1.28	NS
HCO_3	131.1	173.03	-4.32	**

showed no significant difference among the sources ($P>0.05$) (Table 3).

Dissolved oxygen

In both modified extensive and semi-intensive farming the dissolved oxygen concentrations were regulated by providing aerators. In extensive aquaculture farms the DO concentration varied from 3 mg/l to 6 mg/l and in semi - intensive farms it ranged from 3 to 5.6 mg/l (Figs. 5 and 6). During the summer season, the discharge waters had very low oxygen concentration. When this low oxygen water reached receiving water bodies, the resident organisms were not found affected. The results showed significant difference between two types of culture and the DO mean value was more in semi - intensive system (Table 1, $P<0.01$).

Ammonia

The toxicity of ammonia to a large extent is controlled by *p*H of pond water. At *p*H 8.0, in the salinity range of 18- 30 ppt only 4.5% of total ammonia existed as ammonium ions and at 8.4, it increased to 10% at a temperature of 24°C. At 8.8 *p*H and 24°C, the concentration of ammonia ion was about 24% of the total ammonia. Ammonia content of the discharge water showed a marked pattern in the distribution from the 10th ± 3 day

Table 3. *ANOVA – different sources (inlet, pond and outlet)*

Parameters	F-value	Pond	Mean values	
			Inlet	Outlet
*p*H	11.77	8.21	8.17*	8.26*
‰ ppt	17.04	27.48	22.48*	27.66*
T°C	3.16	29.31 NS	29.23 NS	29.75 NS
DO	55.22	4.40*	4.70**	3.14*
NO_2	42.41	0.005	0.002*	0.008**
NO_3	37.45	0.02	0.01*	0.03**
NH_3	80.32	0.58	0.29*	0.77**
PO_4	39.79	0.034	0.021*	0.04**
H_2S	20.9	0.001	.001*	0.03**
BOD	52.79	8.77	3.16*	14.9**
COD	57	18.37	12.32*	28.13**
CO_3	10.42	29.44	26.90*	34.00*
HCO_3	25.73	146.26	114.56*	194**

Table 4. *ANOVA –extensive system*

Parameters	F-value	Pond	Mean values	
			Inlet	Outlet
*p*H	21.01	8.12	7.83*	8.22*
‰ ppt	7.21	25.48	20.42*	25.99*
T°C	3.93	30.25 NS	30.65 NS	29.55 NS
D O	23.37	4.5	4.64**	3.14*
NO_2	29.52	0.004	0.002*	0.006**
NO_3	31.67	0.18	0.01*	0.024**
NH_3	43.72	0.52	0.27*	0.77**
PO_4	11.31	0.03	0.02*	0.04**
H_2S	13.04	0	0.001	0.001
BOD	26.59	6.63	2.84*	14.9**
COD	19.31	17.69	12.55*	28.13**
CO_3	6.48	28.51	25.65*	34.00**
HCO_3	15.08	143.75	110.73*	194**

of the culture period to the end of the culture practice in both type of farms (Figs.11and 12). ANOVA (multiple ranges) showed significant difference among the mean values of pond, inlet and outlet (P<0.01, Table 3). t- test results showed that the mean values of the ammonia were higher in semi - intensive system outlet water (Tables 4 and 5) when compared to the other type.

Nitrite

Nitrite concentration ranged from 0.001 to 0.009 mg/l in extensive farms and 0.001 to 0.018 mg/l in semi intensive farms (Figs. 7 and 8). The discharge waters showed a maximum value of 0.018 mg/l in semi intensive farms and 0.009 mg/l in extensive farms. Its concentration in the pond water steadily increased from the start of culture period to the end and attained a peak value in 70 ± 10 days of culture and then declined towards end of the culture. However, at the time of harvest, nitrite values of the pond water were higher compared to inlet water. t- test indicated no significant difference between the mean values of pond and outlet (P>0.01) whereas that of inlet significantly differed from the other two (Table 3). In the present study, nitrite toxicity was not observed in both type of farms and coastal waters of Nagapattinam District.

Nitrate

The concentration of nitrate in the ponds ranged from 0.008 to 0.058 mg/l. Semi-intensive farms showed a high concentration (0.058 mg/l) (Figs. 9 and 10). Its level increased from the beginning to end of culture period compared to inlet, pond and outlet waters. Outlet waters showed higher values of nitrate 0.059 mg/l. ANOVA showed significant difference among the mean values of inlet, pond and outlet values (P<0.01, Table 3).

Phosphate

Concentration of phosphate was more during monsoon (0.077 mg/l). The semi - intensive system contained comparatively more amount (0.077 mg/l) (Figs. 13 and 14). t- test showed significant difference between extensive and semi - intensive systems (P<0.01, Table 1). The results of correlation matrix of phosphate carried out, revealed that there was no negative correlation with other parameters. ANOVA - showed no significant change between inlet, pond and outlet waters (Table 3).

Biological oxygen demand

The BOD values were more in semi-intensive farms than in extensive farms (Figs. 17 and 18.). The increase in BOD values of semi - intensive farms, was probably due to the higher input of feed and metabolic wastes of the shrimp. Paulraj (1997) also carried out similar studies and reported that the outlet water showed higher BOD than the inlet water. ANOVA showed a significant difference among the inlet, pond and outlet waters (Table 3). According to Pruder (1992) the BOD values in Nagapattinam aquaculture farms were within the

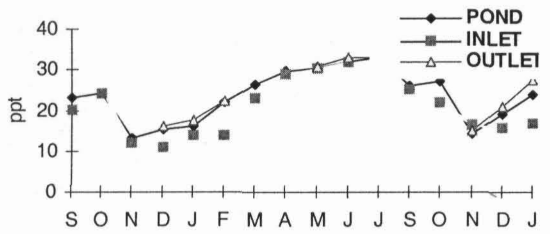

Fig.1. Salinity in extensive system

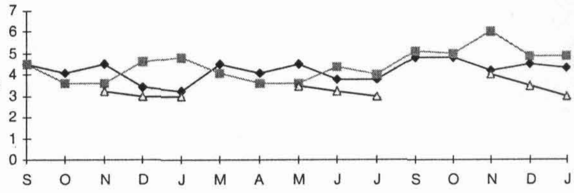

Fig. 6. DO in semi-intensive system

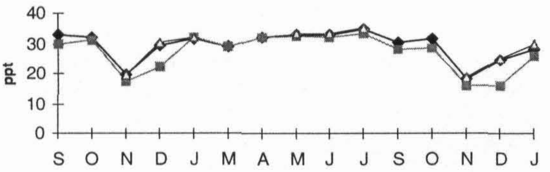

Fig. 2. Salinity in semi-intensive system

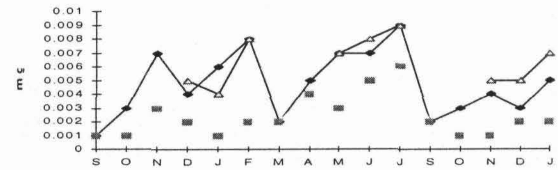

Fig.7. Nitrite in extensive system

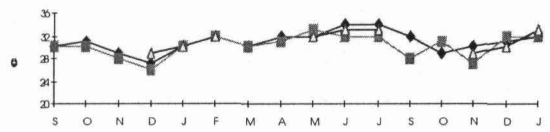

Fig. 3. Temperature in extensive system

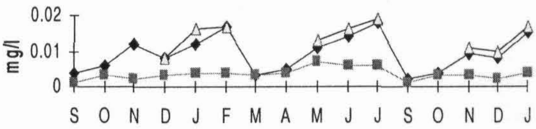

Fig. 8. Nitrite in semi-intensive system

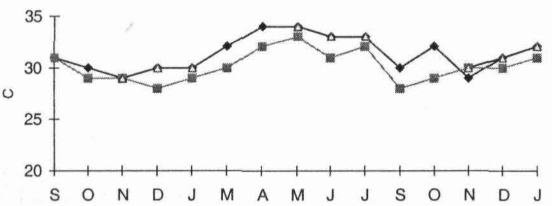

Fig. 4. Temperature in semi-intensive system

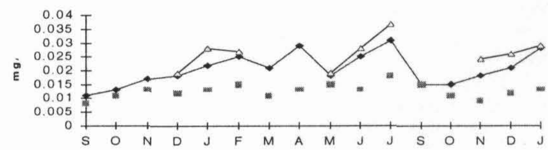

Fig.9. Nitrate in extensive system

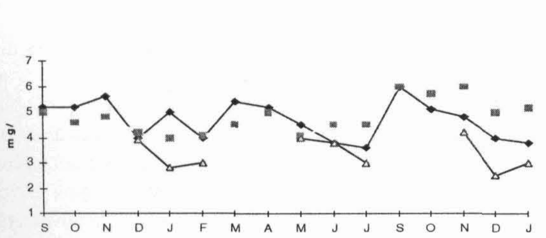

Fig. 5. DO in extensive system

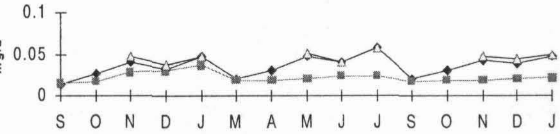

Fig.10. Nitrate in semi-intensive system

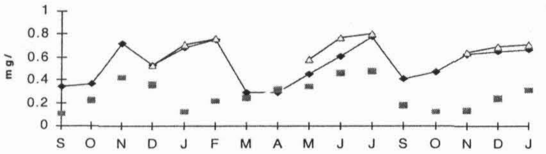

Fig.11. Ammonia in extensive system

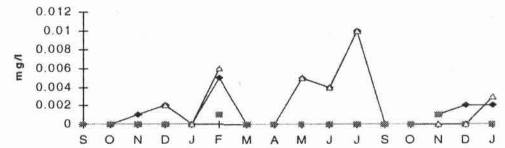

Fig.15. H_2S in extensive system

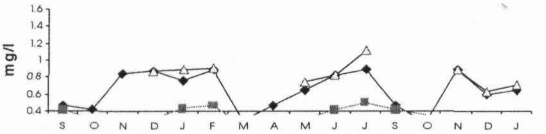

Fig.12. Ammonia in semi-intensive system

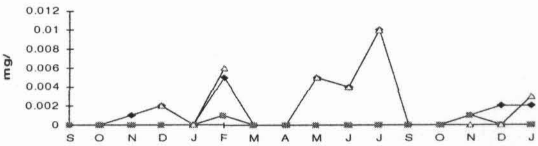

Fig. 16. H_2 S in semi-intensive system

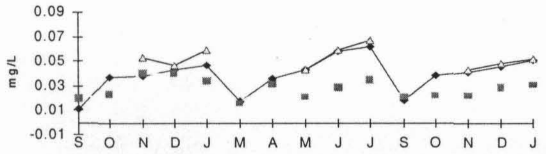

Fig.13. PO_4 in extensive system

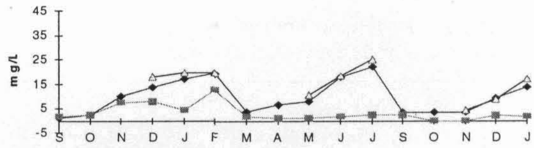

Fig. 17. BOD in extensive system

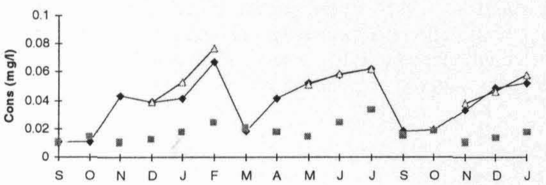

Fig.14. PO_4 in semi-intensive system

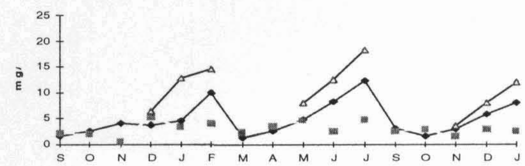

Fig. 18. BOD in semi-intensive system

permissible limits. The present results also corroborate his findings.

Chemical oxygen demand

The COD values in ponds varied from 6 mg/l to 36 mg/l, 13.6 mg/l to 42.2 mg/l in outlet and from 3 mg/l to 30 mg/l in the inlet. During the investigation chemical oxygen demand had its minimum value of 6 mg/l during the initial period and gradually increased and reached a maximum of 42 mg/l at the end. In semi-intensive farms during the harvest time the effluent water contained a maximum of 42 mg/l and in extensive farms 38.4 mg/l. Similar studies were carried out by Alavandi *et al.* (1995), Butz and Ven (1982) and Chen (1985). ANOVA showed a significant difference between the inlet and outlet water values in both type farms (Tables 4 and 5). Water in the pond and outlet showed higher values when compared to inlet. However, in the present study COD values were within the permissible level in both extensive and semi-intensive systems.

Hydrogen sulphide

The H_2S concentration in inlet water, pond and outlet ranged from 0- 0.002 mg/l, 0- 0.1 mg/l and 0.10 mg/l respectively. Its concentration was more in semi - intensive farm (0.1 mg/l) (Figs. 15 and 16). Its concentration depended on *p*H, temperature and salinity and was mainly affected by the first factor. However, in the present study, the H_2S concentration was within the permissible levels.

Carbonate and bicarbonate

The concentration of carbonate ranged from 6 to 48

Table 5. *ANOVA – Semi-intensive system*

Parameter	F-value	Pond	Mean values	
			Inlet	Outlet
*p*H	74.14	8.21	7.8*	8.3*
‰ ppt	5.42	28.57	24.6*	29.34*
T°C	3.70	29.9 NS	29.9 NS	29.9 NS
D O	33.21	4.30	4.70**	3.1*
NO_2	31.03	0.007	0.01*	0.03**
NO_3	38.69	0.03	0.19*	0.43**
NH_3	45.11	0.65	0.31*	0.87**
PO_4	36.39	0.039	0.02*	0.53**
H_2S	12.26	0.002	.001*	0.004**
BOD	35.06	10.99	3.48*	17.89**
COD	42.03	19.08	12.10*	29.70**
CO_3	4.44	30.09	28.19*	35.33**
HCO_3	10.86	148.87	118.51*	198.22**

Significant at 5%, ** Significant at 1%, NS Not Significant

Table 6. *Comparison of admissible levels (in mg/l except pH and Heavy metals) of different parameters*

Parameter	Admissible level (PC B)	Estimated range (present study)	
		Extensive	Semi-intensive
*p*H	5.5-9	8.4	8.5
T°C	45	34	35
DO	3	3	3
NO_2	3	0.009	0.01
NH_3	1	0.095	1.40
PO_4	5	0.59	0.77
BOD	30	22.6	32.5
COD	250	38.4	42
H_2S	0.05	0.05	0.1
Cu (ppm)	3	0.07	0.27
Cd (ppm)	2	0.03	0.06
Ld	2	BDL	BDL
Zn (ppm)	1	0.060	0.063

PCB : Pollution Control Board, BDL: Below detectable level

mg/l and bicarbonate from 60 to 325 mg/ and showed high variations in both the culture systems. Carbonate values steadily decreased whereas that of bicarbonate increased from the early period to harvest period. However, no negative impact was observed during the study period. There was no significant difference between extensive and semi-intensive system. The results showed pronounced seasonal water quality variations in aqua farms both extensive and semi intensive types. However, no significant adverse effects due to the aquafarm discharges in the receiving water bodies were noticed. The concentrations were well within the discharge standard prescribed. ANOVA indicated no significant changes among the inlet, pond and outlet waters.

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