*International Research Journal of Environmental Sciences*_____ ISSN 2319–1414
Vol. **6(8),** 1-6, August **(2017)** *Int. Res. J. Environmental Sci.*

Study on the quality of water and soil from *L. vannamei* shrimp farming in coastal Districts of Andhra Pradesh, India

Prathibha Bharathi, Chittem and Sumanth Kumar Kunda
Department of Zoology and Aquaculture, Acharya Nagarjuna University Nagarjuna Nagar-522 510, India
prathibach9@gmail.com

Available online at: www.isca.in, www.isca.me
Received 24th February 2015, revised 12th July 2017, accepted 10th August 2017

Abstract

Shrimp aquaculture especially Litopenaeus vannamei farming in India is reporting promising growth rate for the past decade and more than 14 million people were depending on this sector. The present study was conducted at L.vannamei cultured ponds, located at various coastal districts of Andhra Pradesh state, India, where vannamei farming was practicing at commercial level in semi intensive systems of aquaculture. The aim of the study was to establish the beneficiary role played by the water and soil quality parameters in vannamei culture as well as environment. A total of 3 districts were selected out of 13 districts of newly formed Andhra Pradesh state for the present study and a total of 60 vannamei farms were selected both randomly and purposively and 20 vannamei farms were selected from each district. The study was conducted during the period of October to January (second crop of vannamei culture).Water and soil samples were collected from the selected vannamei farms and analysis was carried as per the procedures of APHA. A total of 11 water quality parameters such as color, pH, phosphates, total alkalinity, total hardness, chlorides, TDS, salinity, ammonia, nitrite and nitrate and 6 soil quality parameters such as color, pH, Total Organic Carbon, Nitrogen and Phosphorus were analysed for all 60 vannamei farms. The results showed that majority vannamei farms were maintaining optimal water and soil quality parameters and few of the selected water and soil quality parameters had shown deviation from the optimal values. As the water and soil quality were maintaining at optimal levels and the discharged water is safe and non hazardous and more fertile and in turn beneficial to the environment. The maintenance of optimal water and soil quality parameters could be attributed to the implementation of Better Management Practices (BMP's)on suggested by MPEDA, Govt. of India. The study conclude that the maintenance of optimal water and soil quality parameters in all the vannamei culture systems helps the environmental friendly practices of shrimp aquaculture in India.

Keywords: Physico and chemical, Soil, Water and Andhra Pradesh.

Introduction

Indian fisheries and aquaculture is an important sector of food production, providing nutritional security to the food basket, contributing to the agricultural exports besides engaging more than 14 million people in different activities. Constituting about 6.3% of the global fish production, the sector contributes to 1.1% of the GDP and 5.15% of the agricultural GDP. In India, shrimp farming areas are mostly located in the coastal states of Gujarat, Maharashtra, Karnataka, Goa, Kerala, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal.

Litopenaues vannamei is the most commonly cultured shrimp in southeast Asia and India is the second shrimp producer is the world. The Andhra Pradesh state is the largest vannamei farming area amongst the shrimp farming stats of India. Litopenaues vannamei was introduced is 2009, since then its production and culture area has gradually increased replacing penaues monodan culture, was the mainstay of Indian aquaculture during 1995-2008. Andhra Pradesh produces more than half of the country's farmed shrimp and has a lot of potential to export unutilized waste lands. Andhra Pradesh is the fifth biggest state of India. Andhra Pradesh is considered to be important states in the consumption and production of shrimp. Due to the high cost involved in cultivation and agriculture practices and due to commercialism, consumption strategies the farmers of Andhra Pradesh are shifting to the new type of practices to solve the problem of food production *i.*e the aqua culture ponds.

Apart from vast development of vannamei farming and the impressive growth rate, the Litopenaues vannamei farming is facing severe setback for the past couple of year due to diseases outbreak, lack of availability of quality seed, climate change etc. in view of these, the present study was carried out to evaluate the maintenance of water and soil quality parameters, as they are the main reasons for spread of disease out breaks and crop fail as well as environmental issues.

Materials and methods

Locale of the study: The present study was conducted during the year 2013-14. The newly established Andhra Pradesh state has 13 districts and Krishna, Guntur and Prakasham districts

were purposively selected for the present study. The study area represents the different agro-climatic zones including Krishna and Prakasam regions. The study was conducted in existing ponds licensed by Department of Fisheries, Andhra Pradesh, which adopted BMP's in *vannamei* farming by the shrimp farmers.

The Andhra Pradesh state has 9 coastal districts covering 974 km of coastline from Srikakulam to Nellore, having rich marine resources. Within the Bay of Bengal States of India, Andhra Pradesh occupies the first position in respect of number of fishing vessels, freezing plants and peeling sheds. The present study was conducted during the crop year 2013-14 in the districts of Prakasam, Guntur and Krishna, which falls under Southern Andhra Pradesh state.

Total 60 shrimp ponds have been selected from three districts. This study area was chosen for this study as aquaculture has been developed extensively in this area for the last 2 decades due to suitable environmental parameters. The areas of the selected ponds were ranged between 0.2 – 5 ha with average depths of about 1 to 1.5 m and had been used for *vannamei* culture. An attempt was taken to select ponds that are similar with respect to stocking densities, fertilization and feeding regimes and other management inputs.

The APHA[1] procedure will be adopted for the analysis of water and soil quality parameters. The water and soil samples will be collected from the selected 60 respondents of the *vannamei* farms having more than 120 days of culture period.

Method of water sample collection: Samples were collected by dipping one liter polythene bottles 10-cm beneath the water surface. Water pH was measured with a portable pH meter at the time of sample collection. Water samples collected during field work have been analysed for various chemical parameters like pH, phosphates, total alkalinity, total hardness, chlorides, TDS, salinity, ammonia, nitrite and nitrate. The water samples were collected from 60 different intensive *L.vannamei* culture ponds. The water sample was collected before 6 am and after 7 pm of cultures in all 60 ponds. Sixty ponds were located at different places of Andhra pradesh (20 samples from Prakasam district, 20 sample from Guntur district and 20 from Krishna district).

Method of soil sample collection: Bottom soils were collected from the selected ponds with 5 cm diameter core tube at a depth of 0-10 cm of the pond bottom. Approximately 1 kg samples were collected from each pond at a 10 m distance for every replication. Then soil samples were put in tight plastic bags and transported to the laboratory. In the laboratory the samples were air dried at 60°C, broken into smaller size particles with mortar and pestle and sieved through a 2 mm sieve.

Analysis of collected samples: Hydrogen ion concentration was obtained by a soil pH meter. Soil texture was detected following the procedure described[2]. Soil organic matter was detected following the Boyd[2] method. Total alkalinity of the taken sample was determined by following the titrimetric method according to APHA[1]. Soil samples collected during field work have been analysed for various chemical parameters like pH, Total Organic Carbon, Nitrogen and Phosphorus.

Results and discussion

The results obtained in the present study were analysed statistically and presented as follows.

Analysis of water parameters: pH of water samples: pH of the shrimp pond is influenced by many factors, including pH of source water, acidity of bottom soils, prawn culture inputs and biological activity pH of water samples is influenced by variations in CO_2 concentrations. The pH of pond water is slightly basic in nature and the pH of the water samples falls in the desired range of 7.3 – 8.7 (Table-1). The mean value of total pH in the test ponds was 8.11±0.39 and the mean was significantly different ($P<0.001$).

Table-1: Water quality parameter levels in *L.vannamei* shrimp ponds at different places of Andhra Pradesh.

Parameter	Measured Ranges	Obtained value (mean ± SD)
Appearance	Clear	Clear
Colour	Green	Green
Odour	Odorless	Odorless
Temperature	25 – 32°C	28.08±2.11
pH	7.3 – 8.7	8.11±0.39
Dissolved oxygen	4 - 6.0 ppm	4.95±0.81
Ammonia	0.01 – 0.1 ppm	0.05±0.032
Alkalinity	110 – 180 ppm	146.58±21.97
Carbon di-oxide	0.9 – 1.5 mg/l	1.12±0.16
Total hardness	118 -120	119.2±0.2
Nitrite	35 – 113 mg/l	68.6±27.7
Salinity	18 – 32 ppt	26.13±4.41

The best range of water pH for shrimp culture is 7-9 [3]. The pH values in all ponds in the present study were within this range 7.3 – 8.7. Chiu[4] noted that optimum range of pH is 6.8-8.7 for shrimp culture. Chiu[4] mentioned that the optimum range of salinity for *P. monodon* farming would be 10 ppt to 25 ppt. According to this the salinity level was within the suitable range in the study.

According to Arrignon[5] the optimum pH level for prawn culture is between 7.0-8.5. The pH which lower than 5.0 and higher than 9.0 are lethal for prawn, it is depend on the duration of exposure extremes and rapid change. Allan and Maguire[6] showed that the minimum lethal pH to *P. monodon* in water of 32 ppt was about 3.7 and the minimum "acceptable" pH was 5.9. The pH values in all ponds in the present study were within this range 7.3 – 8.7. Azhar[7] found the similar results that the water pH in the range of 7 to 8 in shrimp farms of Ratnagiri, Maharastra. Rahman[8] found the similar results that the water pH in the range of 26.8±3.96°C 7.9±0.26, 5.46±1.60 and 5.12±01.61 in three shrimp farms in Bangladesh.

Nitrites of water samples: Nitrites is formed through nitrification process is oxidation of NO_2 by the action of aerobic bacteria. It is generally stable over a large range of environmental conditions and highly stable in water. It is less toxic the Nitrites in the present study is high and it is observed in the pre seedling and post seedling stage. These values should be lowered otherwise they will affect the cultural species. . In the present study Nitrites range is the 35 – 113 mg/l. The mean value of total nitrites in the test ponds was 68.6±27.7 and the mean was significantly different (P<0.005) (Table-1).

Nitrite, an intermediate product during the two-steps oxidation of ammonium through the highly aerobic, gram negative, chemoautotrophic nitrifiers such as Nitrosomonas and Nitrobacter, is occasionally accumulates in aquaculture systems and can be toxic to aquatic animals[9,10]. Nitrite is routinely found in intensive pond aquaculture systems because large amounts of nitrogen are added in the form of manufactured feed, fertilizer, or manure. Although it is appears that most of the nitrite found in aquaculture is derived from the nitrification process, there is evidence that nitrite in aquaculture ponds may be derived from denitrification of nitrate in bottom mud. Nitrite may also accumulate in water after sudden increases in ammonia concentrations following phytoplankton die-off. Boyd and Tucker[9] stated that decomposition of the dead plant material releases large amounts of ammonia into water. The increased availability of ammonia stimulates the activity of ammonia-oxidizing bacteria, and nitrite is produced. Juvenile *P. monodon* are relatively more tolerant than larvae and postlarvae, with estimated "safe" concentration of 3.8 mg NO2-N/L in water of 20 ppt salinity[11].

Ammonium of water samples: The Ammonium – Nitrogen in the shrimp ponds from the decomposition of organic wastes resulting in the breakdown of decaying organic matter such as algae, Plants animals and uneaten foods. In the present study Ammonical nitrogen range is the 0.01 – 0.1 ppm. The mean value of total Ammonium in the test ponds was 0.05±0.032 and the mean was significantly different (P<0.001) (Table-1).

The importance of ammonia excretion to water quality in aquaculture system is well appreciated. In decapods crustaceans, nitrogen is mainly excreted as ammonia (60-70%), with relatively small amounts of amino acids, urea, and uric acid[12]. Burford and Williams[13] noted that the main source of dissolved nitrogen (DN) is ammonia excreted from shrimp gills. Ammonia excretion rate typically has been used to evaluate the effects of various factors on total nitrogen excretion by crustaceans[14]. Toxic concentrations of ammonia for short term vary 0.6 and 2. 0 mg/L for many fish and some effect can be seen at 0.1-0.3 mg/L[15]. In the present study water ammonia was found to fluctuate between 0.01 – 0.1 ppm which was suitable for shrimp culture.

Ammonia in water presents in two forms, as ammonium ions (NH_4^+), which are nontoxic, and as the un-ionized toxic ammonia (NH_3). The advantageous range of ammonia for shrimp farming is < 0.1 ppm and for prawn farming is 0 ppm. Mazid[16] was reported that the half of shrimp production was reduced in Bangladeshi farms due to the presence of ammonia > 0.45 ppm. Azhar[7] found the similar results that the water ammonia in the range of 0.001 to 0.01 mg/lit. in shrimp farms of Ratnagiri, Maharastra.

CO_2 of water samples: CO_2 is an odorless, colorless gas produced during the respiration cycle of animals, plants and bacteria. Green plants absorber CO_2 is determined during the day time and it will not affect the shrimp as it is present in low concentration. In the present study CO_2 range is the 0.9 – 1.5 mg/l. The mean value of total CO_2 in the test ponds was 1.12±0.16 and the mean was significantly different (P<0.001) (Table-1). Krishnani[17] reported that concentration of carbon dioxide below 20 mg/lit Azhar[7] found the comparable results that the carbon dioxide in the range of 6.1 to 10 mg/lit in shrimp farms of Ratnagiri, Maharastra.

Temperature of water samples: Temperature is one of the most important physico-chemical parameters (others are salinity, pH, water transparency and water depth) that have direct effect on the growth of marine shrimp[5]. Chiu[4] reported that the optimum temperature for *P. monodon* culture is 25°C to 32°C. Apud[18] mentioned a range of water temperature from 25°C to 30°C would be favorable for *P. monodon* culture. In the present study water temperature was found to fluctuate between 25°C to 32°C which was suitable for shrimp culture.

Rowland[19] pointed out that many species suitable for aquaculture will survive over a wide range temperature range, but the temperature range for maximum growth is narrower. The best growth of *P. vannamei* is obtained between temperature of 25 and 35°C. In the present study water temperature was found to fluctuate between 25°C to 32°C which was suitable for shrimp culture.

Similar observations were recommended by Krishnani[17] the best level of temperature for most of the brackish water penaeid shrimp is 28 to 32^{0}C. Azhar[7] found the similar results that the water temperature in the range of 28 to 30^{0}C in shrimp farms of Ratnagiri, Maharastra. According to Mazid, the optimum

temperature range of both shrimp and prawn found at 25-30°C. Rahman[8] found the related results that the water temperature in the range of 26.8±3.96°C in shrimp farms in Bangladesh.

Dissolved oxygen of water samples: Oxygen is required for shrimp respiration and taken from water by diffusion across the gills. The availability of dissolved oxygen frequently limits the activities and growth of aquatic animals. In the present study DO level varied between 4-6 ppm in semi-intensive ponds. Shingh[3] considered 4-8 ppm or more to desirable range. Lethal dissolved oxygen levels for penaeid shrimp range from about 0.5 to 1.0 mg/L, depending on species, size, and other environmental factors[9]. Juvenile of *P. monodon* that survived a single, short-time exposure to low dissolved oxygen concentration (0.5 mg/L) recovered rapidly, and exposure did not reduce subsequent growth or food conversion efficiency[20]. McGraw et al[21] revealed that minimum dissolved oxygen concentration should be 3.8 mg/L to support shrimp culture.

Lazur[22] reported that DO values higher than 5 mg/L have often been recommended for improve extensive culture system. This is very similar to finding of the present study. Azhar[7] found the similar results that the water DO in the range of 3.5 to 6 mg/l in shrimp farms of Ratnagiri, Maharastra.

Salinity of water samples: The salinity values in all ponds in the present study were within this range 18 – 32 ppt. Salinity is important parameters to control growth and survival of shrimps. Chen[23] opined that salinity ranges of 15-20 ppt are optimal for culture of *P.monodon.* The brackish water shrimp farming requires saline water for its growth.

Salinity represents the total concentration of dissolved inorganic ions, or salts in water. Mazid[16] the optimum range of salinity for prawn farming is 12-16 ppt and for shrimp farming 5-30 ppt. Azhar[7] found the similar results that the water salinity in the range of 15 to 35 ppt in shrimp farms of Ratnagiri, Maharastra.

Alkalinity of water samples: During the study period, the values of alkalinity were recorded and they ranged from 110 to 180 ppm respectively. On the other hand Rahman[8] found that the alkalinity varied from 154.6 to 167.2 mg/lit in the shrimp farms of the salinity prone areas of Bangladesh. Mazid[16] the suitable range of alkalinity for shrimp farming is 60 -180 and for prawn farming is 20 to 300ppm. The research finding was similar to the recommended level of alkalinity of shrimp farming which might be due to the appropriate management system. Azhar[7] found the similar results that the alkalinity in the range of 110 to 140 mg/lit. in shrimp farms of Ratnagiri, Maharastra.

Total hardness of water samples: During the study period, the values of hardness were recorded and they ranged from 118 to 120 mg/lit. On the other hand Rahman[8] found that the hardness content of water was found to vary from 89.01 to 117.83 mg/lit. in the shrimp farms of the salinity prone areas of Bangladesh. Azhar[7] found the similar results that the hardness in the range of 100 to 115 mg/lit in shrimp farms of Ratnagiri, Maharastra.

Analysis of soil parameters: Physico-chemical parameters of soil from selected culture ponds were analyzed periodically. Physico-chemical properties of soil included temperature, soil pH, soil alkalinity, organic carbon and organic matter. The results are described below.

Soil pH: The soil pH of the selected ponds was recorded ranged 6.18 – 9 (Table-2). Maximum soil pH 9 was recorded from shrimp ponds. The reason is that farmers continuously use lime to maintain the water quality of these ponds. The mean value of total soil pH in the test ponds was 7.57±0.93 and the mean was significantly different (P<0.001) (Table-2).

The soil pH of the selected ponds was recorded ranged 6.18 – 8.9 (Table-2). Maximum soil pH (8.9) was recorded from shrimp ponds. No significant variations in soil pH were found in the present investigation. The reason is that farmers continuously use lime to maintain the water quality of these ponds. Banerjea[20] stated that soil pH could be depended on various factors. When the mud layers are not well aerated and the supply of oxygen falls short then the decomposition rates of the products are reduced or partially oxidized. However, the production of H_2S, CH_4 and short chain fatty acids are undesirable in as much as they make the soil strongly acidic and reduced the rate of bacterial action, ultimately leading to less productivity.

Soil alkalinity: The amount of total alkalinity range was found 28-34 ppm from shrimp farms (Table-2). Soil alkalinity varied from pond to pond. The mean value of total soil alkalinity in the test ponds was 30.93±2.23 and the mean was significantly different (P<0.001) (Table-2).

Table-2: Soil quality parameter levels in *L.vannamei* shrimp ponds at different places of Andhra Pradesh

Parameter	Measured Ranges	Obtained value (mean ± SD)
pH	6.18 – 9	7.57±0.93
Organic carbon %	1.12 - 6.79	3.69±1.49
Available phosporus	30– 79.5	55.94±16.15
Total nitrogen	0.14 – 0.19	0.17±0.014
Alkalinity	28 – 34 ppm	30.93±2.23

The amount of total alkalinity was found 28-34 ppm from shrimp farms (Table-2). Soil alkalinity varied from pond to pond. Ahmed[24] reported that alkalinity range 20-28 ppm is the suitable range for coastal aquaculture in Bangladesh. The amounts of alkalinity obtained from the selected ponds (1-10

years aged ponds) are almost similar to the optimum level (20-35 ppm)[25, 26]. Previous study is suggested that the higher amount of alkalinity is harmful for the proper growth of shrimp and other cultivable species[27].

Organic carbon: The amount of organic carbon range was found 1.12 - 6.79. The concentration of organic carbon in the present study due to using supplementary feeds in the ponds which remain unused and deposited on the soil bottom. The mean value of total soil organic carbon in the test ponds was 3.69±1.49 and the mean was significantly different (P<0.001) (Table-2).

The amount of organic carbon was found 1.12 - 6.79. Boyd and Green[28] recommended that range of organic carbon 1.0-3.0% is the best range for coastal aquaculture. Boyd[25] also reported that organic carbon value 0.60-1.50 % is highly suitable for aquaculture. Ahmed[24] reported that organic carbon range 0.95 to 1.50 % is the suitable range for aquaculture of Bangladesh. The concentration of organic carbon in the present study due to using supplementary feeds in the ponds which remain unused and deposited on the soil bottom.

Conclusion

It is necessary for the environmental and shrimp culture researcher to control the ill effects caused by imbalance in the quality of water and soil of shrimp ponds for survival of aquatic animals. So the present study has helped to formers and researchers for their future studies to improve the growth and productivity of shrimps. The study conclude that the maintenance of optimal water and soil quality parameters in all the vannamei culture systems helps the environmental friendly practices of shrimp aquaculture in India.

References

1. APHA (1990). Standard methods for the examination of water and waste water. *American Public Health Association*. New York. 17th Ed. P-1527.

2. Boyd C.E. (1995). Bottom Soils, Sediment, and Pond Aquaculture. Chapman and Hall, New York, New York.

3. Singh S.P. (1984). Site selection: Soil quality considerations in the selection of sites for aquaculture farms. Aqua-Train. /NACA/84-036, 19.

4. Chiu Y.N. (1988). Water quality management for intensive prawn ponds. Technical Considerations for the Management and Operation of Intensive Prawn Farms. V.P. Aquaculture Society, Iloilo city, 102-129.

5. Arrignon J.V.C., Joner J.V., Lauren P.J., Griessinger J.M., Lacroix D., Gondouin P. and Autrand M. (1994). Warm Water Crustacean. The Macmillan Press. London.

6. Allan G.L. and Maguire G.B. (1992). Effects of pH and salinity on survival, growth, and osmoregulation in Penaeus monodon Fabricius. *Aquaculture,* 107, 33-47.

7. Azhar Mudassir, AS Mohite and Sadawarte Rahul (2016). Soil and water quality parameters of Brackish water shrimp farms of Ratnagiri, Maharashtra. *The Asian journal of animal science,* 11(2), 107-110.

8. Rahman Md. Motiur, Islam Md. Ariful, Islam H.M. Rakibul, Islam Md. Khairul and Khan Kamal Uddin Ahmed (2017). Assessment of Production Performance In Relation To Limnological Properties in Low Depth Shrimp Farms in Bangladesh. *Imperial Journal of Interdisciplinary Research*(IJIR), 3(3), 1279-1288.

9. Boyd C.E. and Tucker C.S. (1998). Pond Aquaculture Water Quality Management. Kluwer Academic Publisher.

10. Tsai S-J and Chen J-C. (2002). Acute toxicity of nitrate on Penaeus monodon juveniles at different salinity levels. *Aquaculture,* 213, 163-170.

11. Chen J.C. and Lei S.C. (1990). Toxicity of ammonia and nitrite to Penaeus monodon juveniles. *J. World of Aquaculture Society,* 21, 300-306.

12. Regnault M. (1987). Nitrogen excretion in marine and fresh-water crustacea. *Biol.Rev*., 62, 1-24.

13. Burford M.A. and Williams K.C. (2001). The fate of nitrogenous waste from shrimp feeding. *Aquaculture* 198, 79-93.

14. Jiang D-H., Lawrence A.L., Neill W.H. and Gong H. (2000). Effects of temperature and salinity on nitrogenous excretion by Litopenaeus vannamei juveniles. *Journal of Experimental Marine Biology and Ecology*, 253, 193-209.

15. Lawson T.B. (1995). Fundamentals of Aquacultural Engineering. Chapman and Hall, an ITP, Company, New York.

16. Mazid M.A. (2009). Training Manual on Water quality Management in Shrimp Farm Bangladesh Quality Support Programm- Fisheries. *UNIDO, DHAKA, Bangladesh,* 1-108.

17. Krishnani K.K., Gupta B.P. and Pillai S.M. (2006). Water quality requirements for shrimp farming. Training Manual on Shrimp Farming, 21-27.

18. Apud F.D., Gonzales K. and Deatras N. (1981). Survival, growth and production of P. monodon Fabricius at different stocking densities in earthen ponds with flow through system and supplemental feeding. *Fish. Res. J. Philipp*, 6(2), 1-9.

19. Rowland S.J. (1986). Site selection, design and operation of aquaculture farms. *Freshwater aquaculture in Australia*, Brisbane, Australia: Rural Press Quessland, 11-22.

20. Banerjea S.M. (1967). Water quality and soil condition of fishponds in some states of India in relation to fish production. *Indian J. Fish.,* 14(1&2), 115-144.

21. McGraw William, Teichert-Coddington David R, Rouse David B. and Boyd Claude E. (2001). Higher minimum

dissolved oxygen concentrations increase penaeid shrimp yields in earthen ponds *Aquaculture,* 199(3), 311-321.

22. Lazur A. (2007). Growout pond and water quality management. JIFSAN (Joint Institute for Safety and applied Nutrition) Good Aquacultural Practices Program, University of Maryland, 17.

23. Chen H.C. (1985). Water quality criteria for farming the grass shrimp, Penaeus monodon. Aquaculture Department, Southeast Asian Fisheries Development Center.

24. Ahmed H. (2004). Soil Quality Analysis and Considerations in the selection of sites for sustainable Aquaculture in the South East Coast of Chittagong Specially Halishahar Area. M.Sc. Thesis (unpublished), Institute of Marine Sciences and Fisheries, University of Chittagong, Chittagong, Bangladesh, 80.

25. Boyd C.E. (1976). Chemical and textural properties of muds from different depths in ponds. *Hydrobiologia*, 48(2), 141-144.

26. Boyd C.E. and Pipoppinyo S. (1994). Factors affecting respiration in dry pond bottom soils. *Aquaculture,* 120, 283-293.

27. Townsend W.N. (1982). An Introduction to the Scientific Study of the Soil. Edward Amold (Publishers) Ltd. U.K, 209.

28. Boyd C.E. and Green B.W. (2002). Coastal Water Quality Monitoring in Shrimp Farming Areas, An Example from Honduras. *Report prepared under the World Bank*, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium, 29.