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DETERIORATION OF SOIL AND WATER QUALITY BY PRACTICING SHRIMP CULTURE IN SATKHIRA, BANGLADESH

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ABSTRACT

Shamim AHM, Sobahan MA, Saha B, Sarkar BK, Tabrig MSU (2015) Deterioration of soil and water quality by practicing shrimp culture in Satkhira, Bangladesh. *J. Soil Nature* 8(3), 7-13.

Successful agriculture depends on healthy soil and water. The present study based on laboratory analysis for soil and water quality like particle size analysis, pH, electrical conductivity (EC), salinity, heavy metal test, turbidity, dissolved oxygen (DO) and total dissolved solids (TDS). Results reveal that pH and EC level of both soil and water of shrimp gher are increasing (8.2 and 18.72 respectively). Moreover, turbidity and DO of soil and water has been found in a very fragile condition. Except TDS and temperature other physico-chemical parameters of shrimp gher water were not suitable for shrimp cultivation and the nutrient (ammonia and phosphate) concentrations were higher than the optimum limit. Different types of heavy and toxic metals such as Pb, Cd, Cr, Ni, Co, Fe, Cu and Mn have been detected in gher soils. The present research suggesting that an immediate step is essential to stop the further degradation of soil and water quality in shrimp gher.

***Key words**: soil and water quality, shrimp gher, Satkhira, Bangladesh*

INTRODUCTION

Shrimp farming in Bangladesh has been recognized as a part of the Blue Revolution. During the last few decades shrimp culture, particularly the black tiger shrimp (*Bagda*) has been a major component in the development of our national economy (Kabir and Eva, 2014). It is the second largest source of earning foreign currency in Bangladesh (Ahasan 2012). Among exported fishes only shrimp contributed 57% during 2010-2011. Bangladesh has a huge coastal tidal area which is considered favorable for shrimp farming and 0.276 million hectares of land are currently under brackish water shrimp cultivation. Bangladesh produces 2.5% of the total production of shrimp in the world. The BFFEA (Bangladesh Frozen Foods Exporters Association) 2012 had been reported that more than 2 million people directly and indirectly are engaged in upstream and downstream activities related to shrimp industry in the country (harvesting, culturing, processing and exporting).

Apart from the overall contribution of shrimp cultivation to the national economy of Bangladesh, it has been causing severe threats to local ecological systems, such as deterioration of soil and water quality, decrease of local variety of fish, saline water intrusion in ground water, local water pollution and so on (Islam 2003 and Eva 2012). Salinization in ground water and saline water intrusion in surrounding areas have caused a serious ecological and socioeconomic damage in the coastal environment. Salinity is being thought to be a silent poison in the coastal regions of Bangladesh due to continuous shrimp cultivation. In this region, the practices of shrimp farming have caused massive loss of crop production, loss of fruit and other indigenous floral species, fresh water crisis for drinking and so on (Wahab 2003 and Karim 2003).

The absence of national policy and strategy on sustainable shrimp aquaculture has been a fundamental problem of this sector (Environmental Justice Foundation 2004). Gradual increase of toxic elements in the soil of this region is contaminating lower level soil. Products of this soil also carry these toxic substances and have the potentiality to create health hazards. Primavera (1998) reported that with the steady rise of biomass and food inputs, water quality in high density ponds decreases over the cropping periods.

Considering the above facts, the present study was an attempt to identify various negative impacts of shrimp farming on the local environment particularly on soil and water quality change. Shrimp farming has taken place mainly on the reclaimed mangrove forest at the Sundarban region at Shyamnagar Upazila of Satkhira District from where lion share of the shrimp production of Bangladesh come.

MATERIALS AND METHODS

Study Location: The study area, Shyamnagar is the largest Upazila (Fig. 1) in Satkhira district in terms of area and second largest in terms of population. The Upazila located between 22º36´ and 22º24´ north latitudes and between 89º00´ and 89º19´ east longitudes. The distance of this place from the divisional headquarters Khulna is about 120 km and from capital city Dhaka about 400 km. It is situated adjacent to the world heritage Sundarban. Main rivers are Ray Manngal, Kalindi, Kobadak, Mother kholpetua, Arpangachia, Malancha Hariabhanga and Chuna. Soil and water samples were collected from different 5 shrimp gher at Shyamnagar Upazila of Satkhira District during May 2011 to assess physico-chemical parameters, nutrients and metal contents.

Sample Collection and Storage: Soil and water samples were collected from selected shrimp gher (gher-1: Horinagar, gher-2: Kadamtala, gher-3: Nildumur, gher-4: Burigoalini and gher-5: Chandipur) at Shyamnagar Upazila of Satkhira District. Three samples were collected from different locations of same shrimp gher and mixed together to represent the particular gher. Soil samples from each study site were collected into pre-cleaned polythene bag and water samples were collected in 1000 ml plastic bottles. All samples were transported to the laboratory as early as possible.

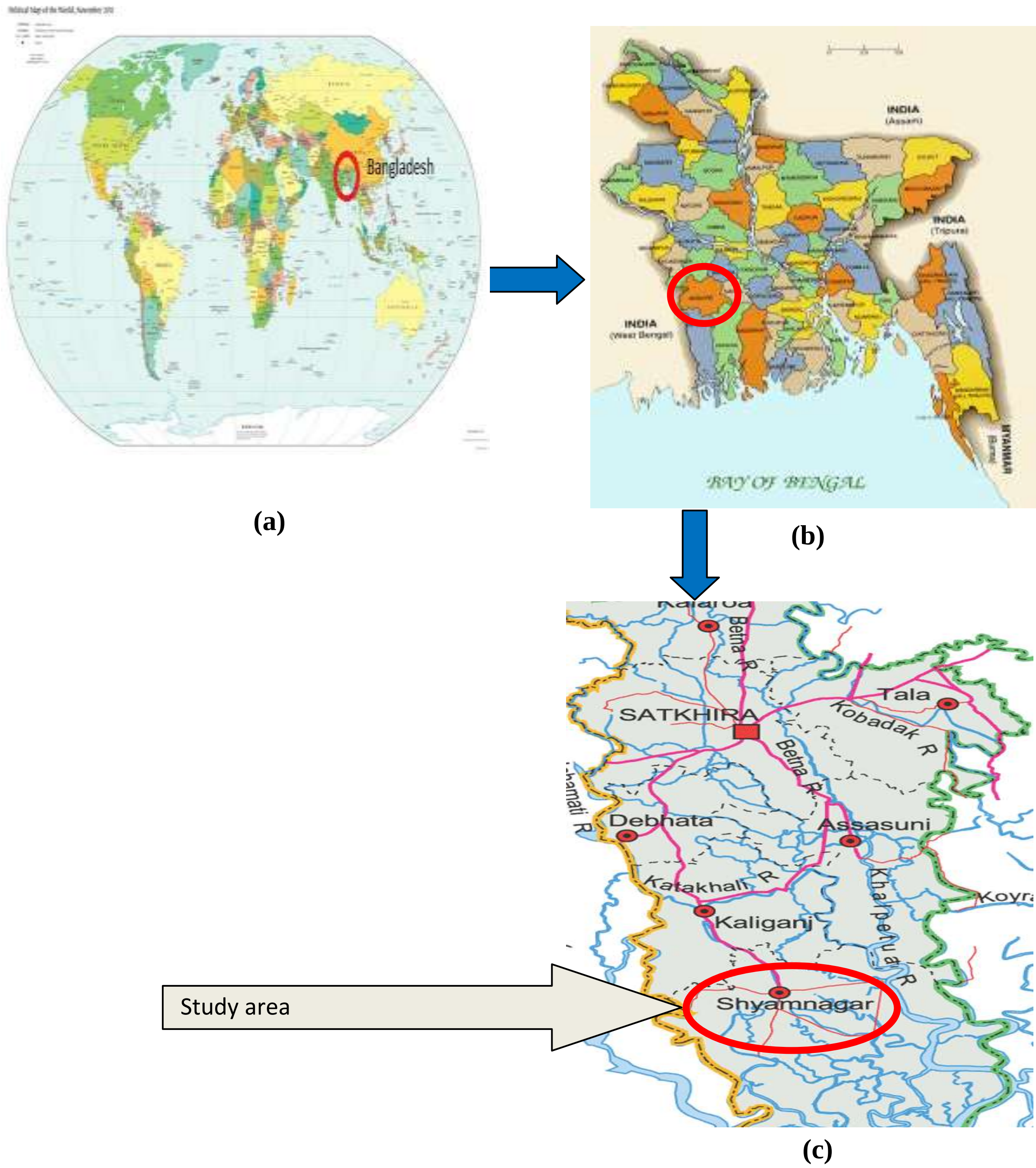

Fig. 1. Pointing Out the Study Area in Context of the World. (a) World Map, (b) Map of Bangladesh, (c) Map of Satkhira (Shyamnagar Upazilla) District

Analytical Procedures: Collected samples were analyzed in laboratory for particle size, hydrogen ion concentration (pH), electrical conductivity (EC), total dissolved solids (TDS), salinity, dissolved oxygen (DO), turbidity, lead (Pb), cadmium (Cd), chromium (Cr), Nicle (Ni), cobalt (Co), iron (Fe), manganese (Mn), ammonia-N and phosphate. After treatment with 1M CH_3COONH_4 (pH 5.0) and with 30% H_2O_2 to remove free salts and organic matter, respectively, particle size distribution was determined by the pipette method (Day 1965). The hydrogen ion concentration (pH), electrical conductivity (EC), total dissolved solids (TDS), Salinity were measured using multimeter analyzer (Sense Ion 156, HACH, USA); dissolved oxygen (DO) was measured using DO meter (HQ 30D, HACH, USA). Turbidity was determined by 2100Q Portable Turbidimeter (Hach, USA). Lead (Pb), cadmium (Cd), chromium (Cr), Nicle (Ni), cobalt (Co), iron (Fe) and manganese (Mn) were analyzed by flame atomic absorption spectrophotometer (AA-7000, Shimadzu, Japan).

Ammonia-N was determined using Nesslerization method described in standard methods for the examination of water and wastewater (APHA 1975) and phosphate was measured using the vanadomolybdophosphoric yellow color method in nitric acid system.

RESULTS AND DISCUSSION

Before practicing shrimp, people were mainly engaged in agricultural activities in coastal area. Different varieties of rice, vegetables and fresh water fishes were cultured in this area. Salinity intrusion due to shrimp cultivation is heavily affecting on the local environment soil and water qualities are degrading day by day (Kabir and Eva, 2014).

Soil Texture: Soil texture is important to identify soil characteristics, their saline holding capacity and also suitability for different crops. Generally sandy soils tend to be less saline because sand particles are less coherence to each other and salts leach easily. But salts tend to attach to clay particles and clay soils tend to be more saline for longer. To identify soil texture of surveyed area, soil samples were taken from different shrimp gher. Table 1a shows the soil composition of surveyed areas. The soil of the sampled area is mainly clay dominating. Every gher of soil was found the highest percentage of clay, then silt and a small amount of sand.

Soil pH: To measure the degree of soil acidity and alkalinity, soil pH is a very important variable and it helps to know about soil properties chemical, biological and indirectly physical environment including both nutrients and toxins. The ideal range of pH in soil is 6.0 to 6.5 because most of the plants' nutrients are available in this stage (Vossen 2012). The Central Institute of Brackish Water Aquaculture (CIBA), 2001 had also been reported that the optimum value for aquaculture in soil is 6.5 -7.5. We found that the pH values ranged from 7.8 to 8.2 in the collected sample (Table 1b) which was more than optimal value. Accordingly, it was not suitable for shrimp cultivation and crop production. Highest pH was found in gher-1 and the pH is decreasing slightly in other ghers. It is noted that the pH below 8.5 indicates saline soil (Brady and Weil, 2004).

Table 1a. Textural analysis of soil collected from different shrimp Gher

Sample ID	Sand (%)	Silt (%)	Clay (%)
*Gher-1	5.28	40.68	54.04
Gher-2	5.35	43.71	50.94
Gher-3	4.12	46.53	49.35
Gher-4	5.25	38.70	56.05
Gher-5	4.79	27.61	63.60

*Gher = Small pond like water body locally known as gher

Table 1b. The pH, EC and salinity of soil samples collected from different shrimp Gher

	Parameter		
Sample ID	pH	EC mS/cm	Salinity (%)
*Gher-1	8.2	10.07	5.1
Gher-2	8.1	11.77	6.7
Gher-3	7.8	11.37	6.5
Gher-4	8.0	11.02	5.5
Gher-5	8.2	10.25	5.2
Optimum value for aquaculture	6.5-7.5 (CIBA 2001)	4.0 (CIBA 2001)	-

*Gher = Small pond like water body locally known as gher

Electrical Conductivity (EC): The EC values of surveyed gher soil were in the range of 10.07 mS/cm to 11.77 mS/cm (Table 1b). An EC values less than 1.0 indicates that soils are highly suitable for cultivation, EC values of 1-3 is injurious to crop growth, EC values between 3 and 4 will definitely cause yield reduction and soil with EC values more than 4 are designated as saline soils and need to reclamation to restore them for cultivation (Umamaheswari *et al.* 2005). Therefore, the result shows that EC of the soils is at injurious level and this situation will be worse in future.

Salinity of Soil: Each soil contains some soluble salts, but when soluble salts contents exceeds rate exists the tolerance level of plants is known as soil salinity. The reason behind the increase of soil salinity is poor drainage system, poor irrigation system, less rainfall, dumping toxic substances and others (Blaylock 1994). Results show the salinity ranged from 5.1 to 6.7 percent in gher-1 and gher-2, respectively.

Physico-Chemical Parameters of Shrimp Gher Water

Water quality is one of the important factors in the determination of shrimp farm culture activity success. The result analysis of the shrimp gher water is presented in the Table 4.

Water pH: For aquaculture a standard value of pH has to be maintained in the range of 7.5 to 8.5 (CIBA 2001) and the optimum pH value for shrimp cultivation was also within this range and this value should not vary more than 0.5 unit. In some cases, the pH value in gher water was less than the optimum value was not favorable for shrimp cultivation. There is no remarkable change was found in the gher water.

Electrical Conductivity (EC): The EC values of shrimp gher water were almost 2 times higher in comparison with shrimp gher soil which was not suitable for shrimp culture.

Salinity: For shrimp cultivation the minimum level of salinity in water is 5 ppt (Alam 2007). To get optimum production salinity level should be 15-25 ppt (Central Institute of Brackish Water Aquaculture, 2001). The salinity level of gher water was ranged from 8.5 to 11.1 percent which is not harmful for aquaculture.

Total Dissolved Solid (TDS): Normally TDS ranges from 5 to 1000 mg L^{-1} (Brady and Weil, 2004). The TDS values ranged from 688 to 936 mg L^{-1} (Table 1c) which was not affected by saline water.

Dissolved Oxygen (DO): Maintenance of an adequate level of DO in pond water is very important for shrimp survival and prolonged exposure to the stress of low concentration of oxygen can inhibit shrimp growth. Poernomo (1992) had been reported that the tolerance DO for shrimp culture is <3 mg L^{-1}(3-10 mg L^{-1}) and the optimum DO ranges from 4-7 mg L^{-1}. Cheng *et al.* (2003) reported that DO values higher than 5 mg L^{-1} have often been recommended for intensive culture practices. In study area, the DO ranged from 7.0 to 7.2 mg L^{-1} (Table 1c).

Table 1c. Physico-chemical parameters of water samples collected from different shrimp Gher

	Parameter						
Sample ID	**pH**	**EC mS/cm**	**TDS g/L**	**Turbidity (NTU)**	**DO (mg/L)**	**Salinity (%)**	**Temperatures (^{0}C)**
*Gher-1	7.1	14.68	7.34	63.4	7.1	8.5	31
Gher-2	7.2	13.75	6.88	69.2	7.0	7.9	32
Gher-3	7.2	16.55	8.27	11.2	7.1	9.7	31
Gher-4	8.1	18.72	9.36	196	6.8	11.1	30
Gher-5	8.0	18.61	9.31	31.7	7.2	11.0	32
Optimum value for aquaculture	7.5-8.5$^¥$	-	15-25$^\#$	0-25$^\#$	4-7$^¥$	15-25$^¥$	28-32$^¥$

*Gher = Small pond like water body locally known as gher, #Hajek and Boyd 1994; ¥ CIBA 2001

Turbidity (NTU): The turbidity values observed in the 5 mixed shrimp gher water samples was ranged from 11.2 to 196 NTU which was deviated from optimal value (0-25) recommended by Hajek and Boyd (1994). They had reported that turbidity range from 0 to 25 NTU is considered as slight, 25 to 100 NTU as moderate and greater than 200 NTU as severe for agriculture.

Waters Temperature: Temperature with range from 20-32^{0}C is recommended tolerance value for shrimp culture and 29-30^{0}C were the optimum temperature for cultured shrimp growth. In aquaculture, high temperatures could also increase intensity and frequency of disease outbreaks of shrimp and adversely impact on water quality in source water bodies (Goggin and Lester, 1995; Vilchis *et al.* 2005).

Nutrient Contents in Shrimp Gher Water

The nutrient (ammonia and phosphate) contents in different shrimp gher water samples are presented in Table 2.

Table 2. Ammonia and phosphate contents of water samples collected from different shrimp Gher

	Nutrient concentrations (mg L^{-1})	
Sample ID	**Ammonia-N**	**Phosphate**
*Gher-1	0.41	0.20
Gher-2	0.40	0.40
Gher-3	0.52	0.15
Gher-4	0.63	0.15
Gher-5	0.75	0.35
Optimum value for aquaculture	#0.1 mg L^{-1}	#0.005 to 0.2 mg L^{-1}

* Gher = Small pond like water body locally known as gher, #Chien 1992

The ammonia concentration ranged from 0.40 to 0.75 mg L^{-1}. The concentration of ammonia of shrimp gher water was higher than optimum value 0.1 mg L^{-1} recommended by Chien (1992). The concentration of phosphate observed in different shrimp gher water ranged from 0.15 to 0.40 mg L^{-1}, which is greater than optimum value (0.005 to 0.2 mg L^{-1}). Since the natural concentrations of phosphorus usually are low, so the high concentration of phosphorus was due to the presence of feed and phosphorus containing fertilizer in high amounts. It is noted that nitrogen and phosphorus are the two most important nutrients which stimulate the growth of plankton and water plants that provide food for fish.

Metal Contents in Shrimp Gher Soil and Water

The concentration of metals in soils and gher waters are presented in Tables 3 and 4, respectively. In the study area, Pb levels ranged from 1.14 to 1.54 mg kg^{-1} in soil sample but in water samples it ranged from 0.012 to 0.022 mg L^{-1}. The concentration of lead in water is higher than optimum value <0.02 mg L^{-1} recommended by Meade (1989). There was significant difference observed between soil and water samples which would be due to the high pH in shrimp gher water. At higher pH, lead hydroxide and carbonate species tend to dominate (Zweig *et al*. 1999). Cadmium (Cd) level was varying from 0.39 to 0.50 mg kg^{-1} in soil and Cd was not detected in water samples where detection limit was 0.10 mg L^{-1}. Chromium (Cr) levels varied 3.69 to 4.56 mg kg^{-1} in soil and between 0.078 to 0.122 mg L^{-1} in water samples. The concentration of Cr in water samples was higher than the critical value (0.03 mg L^{-1}) for brackish water recommended by Meade (1989).

Nickel (Ni) levels ranged from 1.83 to 4.53 mg kg^{-1} in soil sample but in water samples it ranged from 0.011 to 0.054 mg L^{-1}. The concentration of Cu in shrimp gher water was almost similar to the optimum 0.1 mg L^{-1} for black tiger prawn recommended by Chien (1992). The maximum admissible copper concentration in water was in the range of 0.001 to 0.01 mg L^{-1} depending on the species of fish and physico-chemical state of the water (Svobodova and Vykusova, 1993). Copper (Cu) level was varying from 3.53 to 5.16 mg kg^{-1} in soil and ranged between 0.060 to 0.70 mg L^{-1} in water samples. Iron (Fe) levels varied 2.29 to 5.19 mg kg^{-1} in soil and between 0.095 to 0.444 mg L^{-1} in water samples.

The concentration of cobalt (Co) in soil 1.17 to 1.57 mg kg^{-1} and in water samples Co was not detected in water samples where detection limit was 0.02 mg L^{-1}. Manganese is an essential micronutrient for aquatic organism but is neurotoxic in excessive amounts. In the study area, Mn levels varied 1.78 to 8.46 mg kg^{-1} in soil and between 0.002 to 0.005 mg L^{-1} in water samples. DWAF (1996) had been reported that Mn concentrations in the mg L^{-1} range can be found in anaerobic bottom water bodies where Mn has been mobilized from the soil.

Table 3. The content of metals in soils collected from different shrimp Gher

Sample ID	Metal concentration (mg kg^{-1}) dry weight							
	Pb	**Cd**	**Cr**	**Ni**	**Cu**	**Co**	**Fe**	**Mn**
***Gher-1**	1.54	0.40	4.56	2.68	5.16	1.41	2.97	1.78
Gher-2	1.22	0.43	3.89	4.22	4.22	1.41	2.29	8.46
Gher-3	1.34	0.50	4.09	3.05	3.53	1.37	5.19	8.23
Gher-4	1.50	0.48	3.81	4.53	4.62	1.57	4.22	5.78
Gher-5	1.14	0.39	3.69	1.83	3.91	1.17	2.71	2.28

*Small pond like water body locally known as gher.

Table 4. The content of metals concentration of water collected from different shrimp Gher

Sample ID	Metal concentration (mg L^{-1})							
	Pb	**Cd**	**Cr**	**Ni**	**Cu**	**Co**	**Fe**	**Mn**
*Gher-1	0.012	BDL#	0.116	0.019	0.060	BDL	0.240	0.003
Gher-2	0.022	BDL	0.122	0.017	0.067	BDL	0.095	0.005
Gher-3	0.000	BDL	0.116	0.011	0.068	BDL	0.444	0.003
Gher-4	0.022	BDL	0.103	0.022	0.073	BDL	0.178	0.002
Gher-5	BDL	BDL	0.078	0.054	0.069	BDL	0.220	0.002

#**BDL=** below detection limit (Detection limits: Cd = 0.03 ppm, Co = 0.02 ppm)

*Gher = Small pond like water body locally known as gher

CONCLUSIONS AND RECOMMENDATIONS

Results show that except dissolved oxygen (DO: 7.0 to 7.2 mg L^{-1}) and temperature (30 to 32^0C) other physico-chemical parameters of shrimp gher water were not suitable for shrimp cultivation. The nutrient like ammonia (0.40 to 0.75 mg L^{-1}) and phosphate (0.15 to 0.40) concentrations were higher than the optimum limit (0.1 mg L^{-1} for ammonia and 0.005 to 0.2 mg L^{-1} for phosphate). Soils act as a sink for metals because concentration of metal in soil was much higher than the concentration in water.

The present research reveals that an immediate step is essential to stop the further degradation of soil and water quality in gher farms. Saline water being destructive to local fresh water sources, the level of salinity has to be maintained in gher water for better production and environmental sustainability. Proper drainage system needs to be introduced to maintain water quality and discharge effluents from gher. Saline tolerant rice and other crops may be introduced in shrimp cultivated area. Sustainable shrimp cultivation should be maintained to ensure social, economic and ecological stability. Above all, more research initiatives have to be conducted in order to identify better solutions of environmental issues induced by shrimp cultivation.

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REFERENCES

Ahasan DA (2012) Bangladesh's winning maritime boundary, development, conservation and management of fish resources, national fish week 2012 compendium (in Bengali), Narinda Dhaka; Department of Fisheries, Ministry of Fisheries and Livestock, GoB, pp. 23-25.

Alam SMN (2007) Factors affecting penaeus mondon yield in extensive farming system in Southwest Bangladesh, *Journal of Fisheries International* 2(2), 162-170.

APHA (1975) Standard methods for the examination of water and waste water analysis; AE Greenberg, LS Clesceri and AD Eaton (eds), American public health association, American water works association, Water environment federation, Washington DC, USA.

BFFEA (Frozen shrimp and fish exports from Bangladesh) (2012) (1995-1996 to 2009-2010). Online-available at "http:/www.bffea.net/export.htm".

Blaylock AD (1994) Soil salinity, salt tolerance and growth potential of horticultural and landscape plants, Laramie, Wyoming; US Department of Agriculture, University of Wyoming, pp. 2-94.

Brady NC, Weil RR (2004) The Nature and Properties of Soil, (13^{th} ed.) Singapore; Pearson Education.

Cheng W, Liu CH, Kuo CM (2003) Effects of dissolved oxygen on hemolymph parameters of freshwater giant prawn, Macro brachium Rosenberger (de Man), Aquaculture 220, pp. 843-856.

Chien YH (1992) Water quality requirement and management for marine shrimp. World Aquaculture Society, pp. 144-156.

CIBA (Central Institute of Brackish Water Aquaculture) (2001) Soil and water quality management in brackish water aquaculture, special publication 13, pp. 1-99.

Day PR (1965) Particle fractionation and particle size analysis. *In* Methods of Soil Analysis, Part 2 (Ed) CA Black, Agron. Series 9; Am. Soc. Agron., Publ. Madison, WI, USA, pp. 545-566.

DWAF (Department of Water Affairs and Forestry) (1996) South African water quality guidelines, vol. 1: domestic use and vol. 2: agricultural use, Pretoria, South Africa.

Environmental Justice Foundation (2004) Farming the Sea, Costing the Earth: Why We Must Green the Blue Revolution, Series Report, London, UK, pp. 2-11.

Eva IJ (2012) Economic and ecological assessment of shrimp farming; a study in Debhata Upazila, Satkhira district, Bangladesh; an unpublished MSc thesis, Department of Geography and Environment, University of Dhaka, pp. 1-68.

Goggin CL, Lester RJG (1995) Perkinsus; A protistan parasite of abalone in Australia review: Marine and Freshwater Research, 46, pp. 639-646.

Hajek BF, Boyd CE (1994) Rating soil and water information for aquaculture, Aquacult; Eng. 13, pp. 117-128.

Islam MS (2003) Socioeconomic impacts of alternative shrimp-crop farming in Bangladesh; In M Wahab (ed) environmental and socioeconomic impacts of shrimp farming in Bangladesh, Dhaka, pp. 61-78.

Kabir H, Eva IJ (2014) Environmental impacts on shrimp aquaculture: The case of Chandipur village at Debhata upazilla of Satkhira district, Bangladesh, *Journal of Asiat. Soc. Bangladesh Sci*. 40(1), 107-119.

Karim MR (2003) Present Status and Strategied for Future Development of Shrimp Farming in Bangladesh, In M. Wahab, (ed.) Environmental and Socioeconomic Impacts of Shrimp Farming in Bangladesh, Dhaka, pp.1-8.

Meade JW (1989) Aquaculture management, Van Norstand Reinhold, New York, NY.

Poernomo A (1992) The selection of environment friendly shrimp pond, Centre for Research and Development of Fisheries, Jakarta.

Primavera JH (1998) Tropical Shrimp Farming and Its Sustainability, in S. S. D. Silva (ed). Tropical Mariculture, Academic Press, pp. 257-290.

Svobodovà Z, Vykusovà B (1993) Determining the maximum admissible concentrations of substances in water from the point of view of fish culture requirements, Research Institute of Fish Culture and Hydrobiology, Vodńany.

Umamaheswari LK, Ravirajan P, Nasurudeen, Hattab KO (2005) Environmental impact of shrimp farming in India, Puducherry UT., India; Pandit Jawaharlal Nehru College of Agriculture and Research Institute, pp. 1-7.

Vilchis LI, Tegner MJ, Moore JD, Friedman JD, Friedman CS, Riser KL, Robbins TT, Dayton PK (2005) Ocean warming effects on growth reproduction and survivorship of Southern California abalone, Ecological Applications, 15.

Vossen P (2012) Changing pH in soil, Santa Rosa; cooperative extension University of California, pp. 1-2.

Wahab MA (2003) Environmental Impacts of Shrimp Farming in the Coastal Areas of Bangladesh, In M.A. Wahab, (ed.) Environmental & Socioeconomic Impacts of Shrimp Farming in Bangladesh, Dhaka: BRAC Centre, Dhaka, Bangladesh, pp. 19-32.

Zweig DR, Morton JD, Stewart MM (1999) Source water quality for aquaculture, a guide for assessment, environmentally and socially sustainable development; The World Bank, Washington DC.