ON ACID SULFATE SOILS OF THE COASTAL AQUACULTURE PONDS OF BANGLADESH

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ABSTRACT: With the stimulus of the very high international market value of penaeid shrimp, new pond areas for shrimp farming are rapidly being added in Bangladesh. Unfortunately, this expansion is occurring with the loss of some natural mangrove forests and with soils and sediments that are far from ideal for aquaculture. In this study, two representative shrimp farming areas were surveyed and pH, in profile depth, was recorded. It was found that the shrimp farming areas of the Chakaria Sundarban are more acidic than those of the Khulna-Satkhira region due to the acid sulfate soils.

KEY WORDS: Acid sulfate soils - aquaculture ponds - Bangladesh.

INTRODUCTION

A major barrier in the rapidly expanding aquaculture industries in tropical and subtropical countries is the presence of massive quantities of pyrite (FeS₂) in coastal soil and sediment (Simpson and Pedini, 1985). When exposed to air, pyrite in moist soil is oxidized to produce iron oxide and sulfuric acid. Once oxidation of pyrite occurs soils are termed 'acid sulfate soil' (Boyd, 1992). Acid sulfate soils cover an area of 10-15 million ha or about 1% of the total cultivated agricultural area in the world (Brinkman, 1982). They cover a relatively minor fraction of the earth (Fig.1), unfortunately they are generally found in high population density areas having good climatic conditions, thus making them extremely desirable for aquaculture development. About half of the acid sulfate soils are in Asia (7 million ha) and most are centered in low latitude coastal zones (Simpson and Pedini, 1985).

Strong acid sulfate soils have a pH of less than 3.5 (Boyd, 1992) and have tremendous chemical and biological impacts on brackish water aquaculture due to pyrite oxidation (Simpson and Pedini, 1985). The process of formation of pyrite in slowly accreted low land has been described by Boyd (1992). The reactions that accomplish pyrite oxidation are largely mediated by microbial communities and many of which can be summarized by the following chemical reactions involving pyrite and oxygen (Stum and Morgan, 1981):

i. FeS₂ + 7/2 O₂ + H₂O ----> Fe²⁺ + 2SO₄²⁻ + 2H⁺  
ii. Fe²⁺ + 1/4 O₂ + H⁺ ----> Fe³⁺ + 1/2 H₂O  
iii. Fe³⁺ + 3H₂O ----> Fe(OH)₃(S) + 3H⁺  
iv. FeS₂(S) + 15/4 O₂ + 7/2 H₂O ----> Fe(OH)₃(S) + 2SO₄²⁻ + 4H⁺

The first reaction (i) illustrates the conversion of solid mineral pyrite to dissolved iron (+2 oxidation state) and dissolved sulfate. Two hydrogen ions (acid) are generated for each dissolved iron ion. In the presence of oxygen, the relatively soluble form of iron (+2 oxidation state) is converted (ii) to an extremely insoluble form of iron (+3 oxidation state) and in the process removes one of the hydrogen ions generated by reaction (i). When the insoluble form of iron precipitates (iii) as a hydroxide, three additional hydrogen ions are generated for each dissolved iron ion that precipitates. The net result of these three reactions (iv) is to remove pyrite, to
form solid iron hydroxide, and to form dissolved sulfuric acid, generating 4 hydrogen ions (acid) for each iron atoms initially present as pyrite. Sulfuric acid leaches aluminium as well as iron from soil minerals, and the combination of acidic conditions and high concentrations of reactive toxic metals is destructive to most plants and fish, especially shrimp (Simpson and Pedini, 1985). The results are chronically low yields of fish and shrimp, shell softening of shrimp (due to depletion of carbonate in water) and in the worst case, mortality of organisms in culture operation following run-off of acidic water from pond dykes after rainfalls (Simpson and Pedini, 1985).

Rapidly growing, unplanned, uncoordinated and uncontrolled aquaculture industries have recently been developed in areas once covered by mangrove forests in Bangladesh which are rich in pyrite. Conversion of a sizeable area of natural mangrove forest to less productive aquaculture ponds could erode the natural capacity of the coastal zone fisheries leading to economic loss and creating social problems. The present study was conducted on the aquaculture ponds of the Bangladesh coast to gain some knowledge on the occurrence and status of acid sulfate soils.

MATERIALS AND METHODS

The study was carried out in two representative shrimp farming areas of Bangladesh (Fig.2). One in Demoshia, Chakaria Sundarban, Cox’s Bazar and the other in the Kholna-Satkhira region (Polder 31, 32, 33, 5 of the coastal Embankment Project, C.E.P.). Samples from subsurface layers were taken using a Dutch auger for determination of pH between October 1982 and May 1983. Soil pH was determined in both wet and dry conditions (soil and distilled water, 1 : 1.5) by using a hand held, field model pH probe (Takemura Electric Works, Tokyo), and a digitital pH meter.
RESULTS AND DISCUSSION

Of the two sampled areas, the soils from Chakaria Sundarban were found to be more acidic. Once this area was occupied by dense mangroves, one of the oldest natural mangrove forests in the subcontinent (Mahmood, 1990). Consequently it has a rich reserve of pyrite in its soil. In the present investigation, the mean pH in 0-10, 10-20, 20-30, and 30-40 cm wet soil layers were 4.36, 4.58, 4.78, and 4.95, respectively (Fig.3). The pHs declined drastically when the soil samples were dried to 3.16, 3.15, 3.19, and 3.20, respectively (Fig.3).

These results agree well with those of Singh (1980) who made a similar survey on acid sulfate soils in Iloilo, Philippines. He noted that when acid sulfate soils are dried, oxidation takes place upon exposure to air and pH goes down. In an acid sulfate soil, the pH slowly increases vertically with increasing depth. This is because the upper soil layer comes into contact with air and a slow rate of oxidation takes place. But deeper layers are anaerobic and never exposed to air (Singh, 1980). Our study gave similar results.

The shrimp farmers of Chakaria Sundarban, an area very recently converted to shrimp ponds after clearing the mangroves, have many problems due to the acid sulfate soil. In extensive and semi-intensive shrimp farming the pH of the pond waters are lowered as a result of monsoon rain run offs of acidic water from pond dykes. This often causes mortality of the growing stock.
Fig. 3. Soil pH of aquaculture ponds of Chakaria Sundarban region: (a) in 0-10 cm layer, (b) in 10-20 cm layer, (c) in 20-30 cm layer, and (d) in 30-40 cm layer.

Fig. 4. Soil pH of aquaculture ponds of Khulna-Satkhira region: (a) in 0-10 cm layer, (b) in 10-20 cm layer, (c) in 20-30 cm layer, and (d) in 30-40 cm layer.
In the Khulna-Satkhira region, the soils are less acidic than those of Chakaria Sundarban. The mean soil pHs were 5.58, 5.74, 5.93, and 6.15 in 0-10, 10-20, 20-30, and 30-40 cm layers, respectively, when wet and, after drying, the means were 4.09, 4.04, 4.37, and 4.16, respectively (Fig.4). Here also the pH increased slightly with increasing depth and declined after drying. This region was also once a dense mangrove forest and now, due to its acid sulfate soils and the monsoon impacts, the shrimp farmers have problems similar to the Chakaria Sundarban area.

The results of our study reveal that soil acidity of ponds is a great problem in shrimp farming in the coastal zone of Bangladesh. In order to address this problem and to increase production from the coastal aquaculture ponds, the following measures are suggested. (1) Avoid acid sulfate soil areas for pond construction. (2) If not possible drain the soil and wait until natural oxidation and leaching remove the acidity. (3) Apply lime to neutralize the acidity. (4) Compact the upper layer of soil to prevent the oxidation of pyrite through integration of Artemia, salt, and shrimp culture. (5) Frequently renew the pond water. (6) Do not expose the deepest layer of the pond bottom soil.

REFERENCES


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