Threatening of the Severity of Acid Sulfate soils to the Adjacent Environment in the Cox's Bazar Coastal Plains of Bangladesh

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Abstract: A field survey was conducted in the Badarkhali area of Cox's Bazar coastal plains in Bangladesh at different spots (latitude $24^0 2^/$ N and longitude $89^0 8^/$ E) to evaluate the severity of the acid sulfate soils covering an area of about 26,000 hectare. The profile study evaluated taking the samples at every 10 cm towards the depth of 100cm. The impact of acid sulfate soils on the water bodies were also studied by taking the water samples from the nearby ditches and ponds. The high base saturation percentage was found in the studied soil profile. The highest value was recorded 64.18 $cmolkg^{-1}$ which might be due to the high content of Na. The highest amount of Total Sulfuric Acidity (TSA) of the studied soil profile was 48.00 cmol kg^{-1} which indicates that a huge amount of lime ($CaCO_3$) of lime per hectare will be required to neutralize the surface 20 cm of the soil which is very expensive. The Al contents of the studied water samples were very (as compared to the tolerable limit) higher in the Pre-monsoon season (March -May) than the autumn (October) due to the flash flood early in the pre-monsoon season, not only causing the killing of fishes and other aquatic lives but also detrimental effect to the skin of the people. [New York Science Journal 2010;3(9):22-27]. (ISSN: 1554-0200).

Keywords: acid sulfate soils, Base saturation percentage, Total sulfuric acidity

1. Introduction

About 24 M ha of land are reported to consist of acid sulfate soils throughout the world (Van Mansvoort and Dent, 1998). Among the world distribution of about 24 Million hectare of acid sulfate soils, about 7 M ha are found to occur in Asia and Far East (White et al. 1996), about 0.7 M ha acid sulfate soils are located in different pockets of Cox's Bazar and greater Khulna district of Bangladesh (Khan et al. 2000). Recently it has been estimated that it has affected some 100 million hectares (M ha) of land world-wide (Sheeran, 2003). Acid sulfate soils are located in the different pockets of the old mangrove forest areas of the coastal areas of Bangladesh. The nature of the elemental dynamics of these pockets may vary due to the sources and types of mangrove vegetation, litter and sediment depositions in that region. It is well known that different mangrove vegetation have variable capability for sulfur uptake from the sulfur enrich sea-water, so the sulfur accumulation seemed to be varied in these soils from place to place and in different pockets. Accordingly the present inventory was carried out on different pockets of the acid sulfate soils of the south-east of Ganges tidal floodplains in Badarkhali of Cox's Bazar coastal plains of Bangladesh. As long as these sediments remain waterlogged, the presence of sulfidic material is not harmful to the environment but when they are drained, various soil physical and chemical processes are initiated. Once the water table drops below the soil surface, O_2 starts to oxidize pyrite, resulting in the production of a significant amount of H_2SO_4 that leaks into drainage and/or floodwaters, which not only inhibits the growth of crops and aquatic organisms but also pollutes drinking water (Khan and Adachi 1999). Massive fish kill in the water bodies polluted by toxic elements drained from the soils have been widely reported in the world (Lin and Melville 1994). Shamim and Farook (2010) reported that acid sulfate soils should be removed and use it as alternative way. Shamim et al. (2008) reported that these soils can be used as sulfur source.

2. Material and Methods

2.1 Location: The study area is located between Latitude $24^0 2^/$ N and Longitude $89^0 8^/$ E (**Fig-1).** The elevation height of the area is 1m and 4km away from the Bay of Bengal. This area is usually known as "tropical monsoon climate" has three main seasons, namely, the monsoon or rainy season (extends from June to October) which is warm and humid and receives 85% of total annual rainfall, the dry season (extends from November to February) receives very little or no rainfall, lowest temperature and humidity, the pre-monsoon season (extends from March to May) highest temperature and evaporation of the year. Most of the soils have been subjected to tidal flooding with brackish and saline water from the tributes' of Moheskhali River.

Figure 1: Spotted area inside round in the map is the sampling area.

2.2 Distribution: The texture of the soils ranged from silty clay to silty clay loam and the land use of these soils were Rice-Fallow, Fallow and salt Bed. Six spots/profiles of acid sulfate soils were considered for investigation of this observation during 2000 covering the 26000 ha which occur in six soil series. Water samples were collected from 6 different spots in October and May from the nearby the soil sampling spots. Water samples were collected from 6 different spots in October and May from the nearby the soil sampling spots.

Table 1: List of the profile name/spot name along with the soils series and name of the spot of the water sample collection considered for investigation.

Spot Name/Profile name (Soil)	Name of soil series	Name of the spot of water collection
Purbapukuria(Spot 1)	Badarkhali	Purbapukuria Site-1
Omkhali (Spot 2)	Noapara	Purb. Site-2
Napitkhalipara(spot3)	Dhurong	Purb. Cyclone
lishsa (Spot 4)	Chakaria	Lake water near helipad
Chiradia (Spot 5)	Kutubdis	Mathamuhuri River
Amin High School (Spot 6)	Harbang	Fish Pond

2.3 Sampling and Analysis: The soils were sampled and analyzed at every 10 cm towards the depth of 100 cm. The bulk samples obtained from each horizon were stored in the field moist condition (by putting the soil samples into polyethylene bag in air tide box) just prior to laboratory analysis where upon subsamples were air-dried and gently crushed to pass a 2 mm sieve. Water samples were also collected from the nearby ditches and ponds of the above mentioned soil profiles and analyzed. Exchangeable cations were extracted with 1M CH_3COONH_4 at pH 7.0 as described by Jacson (1962) and determined by atomic absorption spectrophotometer. Cation Exchange Capacity (CEC) of the soil was determined by saturation with 1M CH_3COONH_4(pH 7.0), ethanol washing, NH_4^+ displacement with acidified 10% NaCl and subsequent analysis by Kjeldahl distillation for pH> 6.0 and 1N NH_4Cl, ethanol washing, $NH4^+$ displacement with acidified 10% NaCl, and subsequent analysis by Kjeldahl distillation for pH< 6.0 as proposed by AARD and LAWOO(1992). Al was determined by following standard methods. The exchangeable acidity (EA), exchangeable base (EB) and base saturation percentage (BSP) were determined by using the following equation: Exchangeable Base (EB) = Exchangeable Na^++ K^++Ca^{2+}+Mg^{2+}; Exchangeable acidity (EA) = CEC-Exchangeable Bases; Base Saturation Percentage (BSP) = EB/CEC*100. Total actual acidity (TAA) and Total potential acidity (TPA) were determined by titration with sodium hydroxide, of the total acidity in soil samples: TAA in natural samples, TPA in samples that have been forcedly oxidized with hydrogen peroxide (Konsten et al., 1988). The difference between these two values indicates the amount of TSA in the samples (Hendro Prasety et al., 1990)

3. Results and Discussions

3.1 Exchangeable acidity (EA): Exchangeable acidity of the studied soil ranged from 7.12 to 18.80 c $molkg^{-1}$. The average exchangeable acidity of spot 1 was 11.19 c $molkg^{-1}$, spot 2 was 15.06 c $molkg^{-1}$, Spot 3 was 9.00 c $molkg^{-1}$, Spot 4 was 14.21 c $molkg^{-1}$, Spot 5 was 12.30 c $molkg^{-1}$ and Spot 6 was 8.32 c $molkg^{-1}$. The higher value was found near the jarosite layer. The higher value of exchangeable acidity indicates prolonged period of dryness of these soils. Khan et al. (1994) also reported that Prolonged period of dryness increased the exchangeable acidity of the soils.

3.2 Exchangeable bases (EB): Exchangeable bases of the studied soil ranged from 21.01 to 7.01 c $molkg^{-1}$. The highest and lowest values of the studied soil profile in spot 1, 2, 3, 4, 5 and 6 were 11.38 to 7.20 c mol kg^{-1}, 21.01 to 15.95 c mol kg^{-1}, 14.57 to 7.33 c mol kg^{-1}, 12.50 to 7.01 c mol kg^{-1}, 16.43 to 11.99 c mol kg^{-1} and 12.71 to 10.55 c mol kg^{-1} respectively. From the results it was clearly observed that the exchangeable bases were decreasing gradually from the surface to the subsoil throughout the soil profile. Khan et al. (1994) also observed the trend of decreasing of EB from surface to subsoil.

Table 2: Some selected chemical properties of the studied soil profile of the Cox's Bazar.

Depth (cm)	EA (Cmol/kg)	BSP (Cmol/kg)	EB (Cmol/kg)	Al Saturation (Cmol/kg)	TPA (Cmol/kg)	TAA (Cmol/kg)	TSA (Cmol/kg)	CEC (Cmol/kg)
Purbapukuria (Spot 1)								
10	9.28	53.36	10.62	42.66	38.69	3.65	35.04	19.90
20	9.82	53.68	11.38	43.02	39.00	3.00	36.00	21.20
40	13.78	39.56	9.02	40.53	41.87	3.95	37.92	22.80
60	11.64	43.50	8.96	59.85	40.01	2.91	37.10	20.60
80	10.41	53.42	7.99	49.38	42.40	4.00	38.40	18.40
100	12.20	37.12	7.20	34.92	47.05	4.45	42.72	19.40
Mean	11.19	46.77	9.20	45.06	41.50	3.66	37.86	20.38
SD	1.53	6.97	1.43	7.86	2.83	0.55	2.45	1.40
Omkhali (spot 2)								
10	12.49	59.73	21.01	23.99	30.24	2.88	27.36	33.50
20	14.65	58.85	20.95	33.80	37.10	3.50	33.60	35.60
40	14.70	55.72	18.50	17.17	34.45	3.25	31.20	33.20
60	17.25	48.02	15.95	22.68	34.25	3.25	31.20	33.20
80	16.69	49.91	16.62	8.32	33.03	3.00	30.03	33.30
100	14.58	56.08	18.62	2.08	34.25	3.25	19.81	33.20
Mean	15.06	54.72	18.61	18.01	33.89	3.19	28.87	33.67
SD	1.56	4.34	1.93	10.45	2.04	0.20	4.45	0.87
Napitkhalipara (spot 3)								
10	9.23	57.07	12.27	36.28	53.00	5.00	48.00	21.50
20	8.81	55.51	10.99	34.65	18.02	1.70	16.32	19.80
40	10.47	41.18	7.33	57.86	63.60	6.00	57.60	17.80
60	9.03	61.74	14.57	34.36	29.15	2.75	26.40	23.60
80	8.73	60.85	13.57	37.76	25.50	2.50	23.01	22.30
100	7.70	64.18	13.80	26.51	22.26	2.10	20.16	21.50
Mean	9.00	56.76	12.09	37.90	35.26	3.34	31.92	21.08
SD	0.82	7.54	2.42	9.61	16.91	1.59	15.33	1.85
Elisha (Spot 4)								
10	18.80	39.94	12.50	35.32	22.84	3.04	20.80	31.30
20	16.30	43.28	12.40	19.49	25.71	3.51	22.20	28.70
40	12.24	43.95	9.56	31.44	19.88	2.98	16.90	21.80
60	18.62	28.16	7.28	21.33	18.97	2.67	16.30	25.90
80	10.37	40.52	7.03	31.12	19.43	2.53	16.90	17.40
100	8.95	44.82	7.01	35.31	21.32	2.72	18.60	15.60
Mean	14.21	40.11	9.30	29.00	21.36	2.91	18.62	23.45
SD	3.90	5.63	2.39	6.32	2.34	0.32	2.19	5.72
Chiradia (Spot 5)								
10	12.37	57.05	16.43	3.78	32.86	3.10	29.76	28.80
20	14.65	46.34	12.65	1.07	33.39	3.15	30.24	27.30
40	14.21	45.76	11.99	1.61	27.56	2.60	24.96	26.20
60	11.58	55.12	14.22	1.82	22.79	2.15	20.64	25.00
80	10.87	55.41	13.51	1.27	29.68	2.80	26.88	24.00
100	10.10	57.76	13.81	1.29	19.08	1.80	17.28	23.90
Mean	12.30	52.91	13.77	1.64	27.56	2.60	24.96	25.87
SD	1.66	4.93	1.40	1.02	5.18	0.49	4.69	1.77
Amin High School (Spot 6)								
10	7.12	62.72	11.98	6.80	21.73	2.05	19.68	19.10

20	9.46	54.73	11.44	5.09	23.85	2.25	21.60	20.90
40	8.19	60.81	12.71	2.49	23.85	2.25	21.60	20.90
60	8.33	56.61	10.87	2.43	31.27	2.95	28.32	19.20
80	8.74	54.94	10.66	6.65	26.50	2.50	24.00	19.40
100	8.10	55.12	10.55	3.30	24.25	2.30	22.05	19.50
Mean	8.32	57.49	11.37	4.46	25.24	2.38	22.88	19.83
SD	0.70	3.13	0.77	1.83	3.03	0.29	2.74	0.77

Table 3: Some selected properties of the studied water samples.

Sampling spot	pH	EC (mS/cm)	Sulfate (ppm)	Aluminum (ppm)
October Sampling Purbapukuria Site-1	3.9	2.07	1096	1.5
Purbapukuria Site-2	4.1	2.0	1018	10
Purbapukuria Cyclone Centre	6.1	2.80	624	3.5
Lake water near helipad	4.0	1.60	1040	12.0
Mathamuhuri River	6.3	0.42	580	1.3
Fish Pond	4.3	0.95	960	11.0
May Sampling Purbapukuria Site-1	3.7	2.75	1225	17.0
Purbapukuria Site-2	4.1	2.62	1155	11.0
Purbapukuria Cyclone Centre	5.8	6.98	1511	9.0
Lake water near helipad	3.9	2.25	1251	15.0
Mathamuhuri River	7.0	0.25	601	1.8
Fish Pond	4.1	1.12	1086	9.5

3.3. Base saturation percentage (BSP): Base saturation percentage of the studied soil ranged from 64.18 to 28.16 c $molkg^{-1}$. The highest and lowest values of base saturation percentage of the studied profile of spot 1, spot 2, spot 3, spot 4, spot 5 and spot 6 were 53.68 c $molkg^{-1}$ to 37.12 c $molkg^{-1}$, 59.73 c $molkg^{-1}$ to 48.02 c $molkg^{-1}$, 64.18 c $molkg^{-1}$ to 41.18 c $molkg^{-1}$, 44.82 c $molkg^{-1}$ to 28.16 c $molkg^{-1}$, 57.76 c $molkg^{-1}$ to 45.76 c $molkg^{-1}$ and 62.72 c $molkg^{-1}$ to 54.73 c $molkg^{-1}$ respectively. Khan et al. (1994) reported that BSP values of the acid sulfate soils ranged from 13-45 c $molkg^{-1}$. In this study the values in several spots were higher may be due to the high sodium content of the soils.

3.4. Aluminium saturation: The lowest Al saturation in Purbapukuria (spot 1) was detected 34.92 c $molkg^{-1}$ and the highest was 59.85 c $molkg^{-1}$. In Omkhali (spot 2) the value was 2.08 to 33.80 c $molkg^{-1}$. In Napitkhalipara (spot 3) and Elisha (spot 4) lowest and highest values were 26.51 c $molkg^{-1}$ to 57.86 c $molkg^{-1}$ and 35.32 c $molkg^{-1}$to 19.49 c $molkg^{-1}$. In Chiradia (spot 5) and Amin High Schoool (spot 6) the lowest and highest value of Al saturation were 1.07 c $molkg^{-1}$ to 3.78 c $molkg^{-1}$ and 2.43 c $molkg^{-1}$ to 6.80 c $molkg^{-1}$ respectively. The lowest value of the studied profile detected in Chiradia (1.07 c $molkg^{-1}$) and highest value was detected in Purbapukuria (59.85 c $molkg^{-1}$).

3.5. Total potential Acidity (TPA), Total Actual Acidity (TAA) and Total Sulfuric Acidity (TSA): The results of TPA, TAA and TSA of the studied profiles have been presented in **Table 2.** In purbapukuria, Omkhali, Napitkhalipara, Elisha, Chiradia and Amin High School the values of TPA ranged from 47.05 c $molkg^{-1}$ to 38.69 c $molkg^{-1}$, 37.10 c $molkg^{-1}$ to 33.03 c $molkg^{-1}$, 63.60 c $molkg^{-1}$ to 22.26 c $molkg^{-1}$, 22.84 c $molkg^{-1}$ to 18.97 c $molkg^{-1}$, 33.39 c $molkg^{-1}$ to 19.08 c $molkg^{-1}$ and 31.27 c $molkg^{-1}$ to 21.73 c $molkg^{-1}$ respectively. In purbapukuria, Omkhali, Napitkhalipara, Elisha, Chiradia and Amin High School the values of total actual acidity (TAA) ranged from 4.45 c $molkg^{-1}$ to 2.91 c $molkg^{-1}$, 3.50 c $molkg^{-1}$ to 2.88 c $molkg^{-1}$, 6.00 c $molkg^{-1}$1.70 c $molkg^{-1}$, 3.51 c $molkg^{-1}$ to 2.53 c $molkg^{-1}$, 3.15 c $molkg^{-1}$ to 1.80 c $molkg^{-1}$ and 2.95 c $molkg^{-1}$ to 2.05 c $molkg^{-1}$ respectively. The total sulfuric acidity (TSA) in purbapukuria, Omkhali, Napitkhalipara, Elisha, Chiradia and Amin High School were 42.72 c $molkg^{-1}$ to 35.04 c $molkg^{-1}$, 33.60 c $molkg^{-1}$ to 19.81 c $molkg^{-1}$, 57.60 c $molkg^{-1}$ to 16.32 c $molkg^{-1}$, 22.20 c $molkg^{-1}$ to 16.30 c $molkg^{-1}$, 30.24 c $molkg^{-1}$ to 17.28 c $molkg^{-1}$ and 28.32 c $molkg^{-1}$ to 19.68 c $molkg^{-1}$ respectively. The pattern and distribution of TSA is different. The highest value of 57.60 15 c $molkg^{-1}$ was detected which indicate that these soils is really problem for future. And if we want to neutralize these soils a huge amount of lime would be required. Van Breemen (1993) reported that 1% oxidizable sulfur will require 30 ton of lime to neutralize per ha of 10 cm surface of acid sulfate soils. That indicates that this huge total sulfuric acid will require huge amount of lime which may not be economical for poor farmer of Bangladesh.

3.6. Cation Exchange Capacity: The CEC of Purbapukuria ranged from 18.40 c $molkg^{-1}$ to 22.80 c $molkg^{-1}$, in Omkhali from 33.20 c $molkg^{-1}$ to 35.60 c $molkg^{-1}$, in Napitkhalipara from 17.80 c $molkg^{-1}$ to 23.60 c $molkg^{-1}$, in Elisha from 15.60 c $molkg^{-1}$ to 31.30 c $molkg^{-1}$, in Chiradia from 23.90 c $molkg^{-1}$ to 28.80 c $molkg^{-1}$ and in Amin High School from 19.10 to 20.90 c $molkg^{-1}$. The uniform CEC value was observed in the profiles of Omkhali and Amin High School. In Napitkhalipara the higher CEC value was observed at the lower depths of the soil. This probably due to the high content of organic matter at these zones of the soil. Khan et al., (1994) reported that the CEC ranged from 16.7 to 27.9 cmol kg^{-1} in the acid sulfate soils and the contents increase with depth. The values were a little bit higher than that range.

3.7. Water quality Analysis

3.7.1. pH and EC: The pH values ranged from 3.9 to 4.0 in October season **(Table 3)** and in May it varies from 3.7 to 7.0 in the studied water samples. These variations were due to the dilution factor of rainwater. The values of pH the water samples were comparatively low in May indicates that acidity produced during dry season have been drained to the water bodies. The ECs of the studied water samples ranged from 0.42 mS/cm to 2.80(mS/cm in October and from 0.25 mS/cm to 6.98 mS/cm in May. The lower pHs were found in the pond water comparison to river water. These low pH water is not suitable for using for crop production. Due to their corrosive action they are not suitable for domestic use as well as for drinking purposes.

3.7.2. Sulfate: The sulfate content of the studied water samples given in **Table 3.** The values ranged from 580 ppm to 1040 ppm in October and 601 ppm to 1511 ppm in May. It was observed that the SO_4^{2-} content is directly correlated with pH. When pH decreases the sulfate content increases. This is due to the oxidation of pyrite of the acid sulfate soils. The SO_4^{2-} content of the river water was low in comparison to pond water.

3.7.3. Aluminium: The Al content of the studied water bodies are given in **Table 3.** The values in October ranged from 1.3 ppm to 12.0 ppm and the value in May ranged from 1.8 ppm to 17.0 ppm. In Purbapukuria the value was only 1.5 ppm in October which increased to 17 ppm in May. Sitting 1994 reported that portable water Al must be 0.05 to 1.5 ppm. But in the water bodies the concentration is much higher than these values which causing massive fish killing in that area. Lin and Melville 1994 also reported that the acidity of acid sulfate soils brings a lot of poisonous material to the water.

4. Conclusion:

The area was studied covering an area of about 26,000 hectare in the Badarkhali area of Cox's Bazar coastal plains in Bangladesh at different spots to evaluate the severity of the acid sulfate soils. The impact of acid sulfate soils on the water bodies were also studied by taking the water samples from the nearby ditches and ponds. The high base saturation percentage was found in the studied soil profile may be due to the high content of Na. Not only that high Al saturation also found in the studied area which is harmful for crop production. The highest amount of Total potential acidity (TPA) and Total sulfuric acidity (TSA) of the studied soil profile was indicates that a huge amount of lime ($CaCO_3$) of lime per hectare will be required to neutralize the surface soil which is very expensive. The Al and SO_4^{2-} contents of the studied water samples were very (as compared to the tolerable limit) higher in the Pre-monsoon season (March -May) than the autumn (October) due to the flash flood early in the pre-monsoon season, not only causing the killing of fishes and aquatic lives but also has the detrimental effect to human bodies.

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