Quantification of the Nutrient Status of the Acid Sulafte Soils of Chakaria Sundarbans in the Cox's Bazar Coastal Plains of Bangladesh.

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Abstract: A field survey was conducted in the chakaria of Cox's Bazar in Bangladesh in 10 different spots (latitude $24^0 2^/$ N and longitude $89^0 8^/$ E) to evaluate the nutrient status of the acid sulfate soils covering an area of about 26,000 hectare. The profile study of 10 spots of different location was studied taking the sample at every 10 cm towards the depth of 100cm. The decreasing trends of pH from surface to subsurface of these soils were observed. The impaired absorption of Ca, Mg was observed. The P availability was observed very low but the water soluble sulfur was very high in the studied profile. The Cation Exchange Capacity (CEC) of the studied soils ranged from 15.1 to 37.4 c mol kg^{-1}. The highest Total Sulfuric Acidity (TSA) of the studied soil profile was 23.6 cmol kg^{-1} which indicates that a huge amount of lime will be required to neutralize the surface 20 cm of the soil which is very expensive. [New York Science Journal 2010;3(8):87-94]. (ISSN: 1554-0200).

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1. Introduction

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). Recently it has been estimated that it has affected some 100 million hectares (M ha) of land world-wide (Sheeran, 2003). About 0.7 M ha acid sulfate soils are located in coastal areas of Cox's Bazar and greater Khulna district of Bangladesh (Khan et al. 2002). 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). In this soil S must take its rightful place as a major plant nutrient together with N, P and K by all stakeholders in balanced fertilization for higher yield and fertilizer efficiency (Shamim and Farook, 2010).

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.

2.2 Distribution:

The organic matter content of the studied soil varied from 10 g kg^{-1} to 51.5g kg^{-1} which is much higher than the average soils of Bangladesh. 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. Ten profiles of acid sulfate soils were investigated covering about 26000 ha which occur in six soil series (Table 1).

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 soluble nutrients were extracted by distilled water in the ratio of 1:10. Water soluble ions (Na, K) were determined by Flame photometry (Jackson, 1973) and (Ca, Mg) by atomic absorption spectrophotometry (Hesse, 1971). 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). The pH, EC, PO_4, SO_4, were determined by following standard methods. Total sulfuric acidity (TSA) of the soils was obtained from the difference between total potential acidity (TPA) and total actual acidity (TCA) as proposed by Hendro-Prasetyo et al. (1990). The potential acidity (TPA) measures, by means of titration with NaOH, the acidity which may develop in pyrite containing samples upon complete oxidation with H_2O_2. The total actual acidity (TAA) measures the actual acidity of a sample, also by titration with NaOH. The total sulfuric acidity (TSA) represents all reducible sulfur fractions of the soil. TSA is therefore a measure for the acidity that may be generated by the oxidation of sulfur fractions.

Figure 1. Map of Bangladesh (sampling spot, indicating the red spot in Cox's Bazar area)

Table 1: Shows the Spot name along with the soil series name.

Spot/Profile Name:	Series Name:
1. Amin High School,	a) Harbang Series:
2. Koralkhali, 3. Koralkhali Salt Bed, 4. Chiradia	b) Kutubdis Series:
5. Mohorizora, 6. Satdaliapara, 7. Elishsa,	c) Chakaria series:
8. Napitkhalipara	d) Dhurong Series:
9. Omkhali,	e) Noapara Series:
10. Purbapukuria	f) Badarkhali Series:

3. Results and Discussions:

3.1 Soil Reaction: The pH of all the soils were examined in both field conditions **(Table 2).** In Elisa the pH values ranged from 5.1 to 3.4 throughout the soil profile of about 1 meter. There is a decreasing trend of pH from surface to subsurface. In Satdaliapara the pH was 4.4 to 3.0 and the values were almost same throughout the soil profile. In Purbapukuria the range of pH was 4.2 to 3.0 and the values were almost same in all the depths. In Chiradia the variation of the pH was found 6.8 to 5.0. The said pHs in all the depths were high. Most of the areas of Chiradia are under salt beds, which might be the region of high pH values of this soil. In Omkhali pHs ranged from 5.8 to 4.0. The lowest pH value was 4.0 found in 20 cm depth followed by 4.2 in surface soil. The pH value of Napitkhalipara varied from 4.9 to 3.3. In Mohorizora and Koralkhali the pH values ranged from 5.7 to 3.7 and 5.0 to 3.2 respectively. In Mohorizora there is a decreasing trend of pH from surface to deeper depths of the soils. In Koralkhali salt bed the value of pH ranged from 6.2 to 3.7 while Amin High School it was 5.5 to 4.0. The pH values of both of these soils were around 4.5 in most of the depths. Among the ten profiles, the distribution of soil pH (field condition) throughout the soil profiles was below 4 in Purbapukuria (3.3 to 3.5).

3.2 Water soluble Ions:

3.2.1. Sodium:

The sodium content of Amin High School ranged from 0.21 to 0.69 c mol kg^{-1}. The highest value (0.69 c mol kg^{-1}) was detected at the depth of 10 cm followed by 0.36 c mol kg^{-1} at the depth of 20 cm. In Koralkhali the value ranged from 0.34 to 1.65 c mol kg^{-1} and the highest value was detected at the surface soil (10 cm). In Koralkhali Salt Bed the values were high in all parts of the soil profile and the value ranged from 15.98 to 21.15 c mol kg^{-1}. In Mohorizora the value ranged from 0.69 to 1.08 c mol kg^{-1}. In Napitkhalipara the highest value was detected at the 10 cm of the surface soil and the value was 4.57 c mol kg^{-1}. The average of 1.42 c mol kg^{-1} was detected from the surface towards 60 cm in Omkhali soil. The much higher values (10.20 c mol kg^{-1}) were detected at the 100 cm depth. In Chiradia the values ranged from 4.30 to 15.12 c mol kg^{-1} and the highest value was detected at the 10 cm of the surface soil. In Purbapukuria the value ranged from 0.89 to 9.1 c mol kg^{-1}. The highest value was detected in 20 cm depth followed by 4.5 c mol kg^{-1} in 10 cm of the surface soil **(Table 2).** In Elisha the values were very low and it ranged from 0.35 to 0.87 c mol kg^{-1}. The above results it revealed that the values were always higher in the upper parts of the soil than the lower parts of the soils, which might be results of Na deposition from the tidal water of sea.

3.2.2. Potassium:

The potassium content was lower in comparison to the sodium of the studied profile **(Table 2).** In Amin Hgih School the K ranged from 0.03 to 0.07 c mol kg^{-1}. In Koralkhali it was ranged from 0.13 to 0.46 c mol kg^{-1}. The maximum K was detected at 10 cm of the surface soil. Except for the distribution of K was almost similar in the rest of the profiles. In Koralkhali Salt Bed the values ranged from 0.83 to 1.01 c mol kg^{-1}. The highest value was detected at 100 cm followed by 0.99 c mol kg^{-1} in 10 cm. In Mohorizora the K ranged from 0.13 to 0.23 c mol kg^{-1}. In Napitlhalipara the value ranged from 0.02 to 0.60 c mol kg^{-1}. The highest value was detected at the 10 cm of the surface soil followed by 0.50 c mol kg^{-1} and 0.24 c mol kg^{-1} at the depths of 80 and 100 cm depth respectively. In Omkhali K contents were almost same in all parts of the soil profile and the average value was 0.43 c mol kg^{-1}. In Chiradia the values ranged from 0.17 to 0.73 c mol kg^{-1}. The highest values was detected at the 10 cm of the surface soil followed by 0.45 c mol kg^{-1} at the depth of 80 to 100 cm. In Purbapukuria the value of potassium ranged from 0.23 to 0.33 c mol kg^{-1}. The highest value was detected at the 0-20 cm depths followed by 0.29 c mol kg^{-1} at 40 cm depth. In Satdaliapara the value ranged from 0.03 to 0.18 c mol kg^{-1}. In surface 20 cm the K was high and after that value is much lower. In Elisha the value ranged from 0.025 to 0.26 c mol kg^{-1}. The maximum K was detected at the 10 cm of the surface soil followed by 20 cm and 40 cm depth. The above results indicate that the K contents of the soils as compared to Na was very low which might be due to the acidic atmosphere of the soils thus resulting the release of K from the soils. The above results indicate that the K contents of the soil as compared to the Na was very low which might be due to the acidic atmosphere of the soils thus resulting the release of K from the soils.

3.2.3. Calcium:

The calcium content of the studied soil ranged from 0.03 to 0.15 c mol kg^{-1}. In surface 10 cm it was much higher as compared to the lower depth. In Koralkhali the highest value (0.46 c mol kg^{-1}) was detected at 10 cm depth. From 10 to 100 cm the values were almost similar and average value was 0.15 c mol kg^{-1}. In Koralkhali Salt Bed the value ranged from 0.21to 0.43 c mol kg^{-1}. The highest value was detected at 10 cm depth followed by 0.29 and 0.28 c mol kg^{-1} in the depths of 60-80 cm and 100 cm. In Mohorizora the values ranged from 0.09 to 0.17 c mol kg^{-1}. The highest value was detected from 60 to 100 cm depth. In Napitkhalipara the Ca ranged from 0.08 to 0.24 c mol kg^{-1} and the highest value of Ca was at 10 cm of the surface soil. The Ca content of the Omkhali soil was almost similar (0.16 c mol kg^{-1}) in all parts of the soil profile except 1-10 cm depth. The value of the surface 0-10 cm depth was 0.21 c mol kg^{-1}. In Chiradia the highest value (0.31 c mol kg^{-1}) was detected at the surface 10 cm soil. Then there is a decreasing trend of the values in sub-soils. In Purbapukuria there was no definite sequence of the values throughout the soil profiles and it was ranged from 0.03 to 0.12 c mol kg^{-1}. In Satdaliapara the values were very low in comparison to the other profiles. The highest value was 0.06 c mol kg^{-1} followed by 0.05 c mol kg^{-1} in the depths of 20 and 10 cm of the depth respectively. In Elisha the values ranged from 0.02 to 0.07 c mol kg^{-1}**(Table 2).** The values of Ca were higher in the surface soil than those sub-soils.

3.2.4. Magnesium:

The magnesium content of the soil profiles was much higher in comparison to calcium value **(Table 2).** The magnesium content of the Amin High School ranged from 0.77 to 3.83 c mol kg^{-1} where the highest value was observed in the surface 10 cm of the soil. In Koralkhali soils the Mg ranged from 2.30 to 11.11 c mol kg^{-1} where the highest value was detected in the surface soil followed by 6.32 cmolkg^{-1} in the depths of 80 cm. In Koralkhali Salt Bed the value (20.69 c mol kg^{-1}) was detected in 10 cm of the surface soil followed by 11.49 c mol kg^{-1} in the depths of 20 and 60 cm. In Mohorizora it was ranged from 1.23 to 4.21 c mol kg^{-1} and the highest value was determined at the lower depths. In Napitkhalipara the value ranged from 5.5.6 to 9.96 c mol kg^{-1}. The highest Mg was detected at the depth of 10 cm and 100 cm followed by 9.19 c mol kg^{-1} in the depth of 60 cm. The values of Omkhali soil ranged from 3.33 to 6.32 c mol kg^{-1}. The highest value was detected at the depth of 10 cm followed by 4.52 c mol kg^{-1} in 20 cm depth. The highest value of Chiradia (6.59 c mol kg^{-1}) was detected at 10 cm of the surface soil. In Purbapukuria it was ranged from 0.83 to 2.0 c mol kg^{-1} and the values were higher in the surface soil than those of the sub-surface soils. In Satdaliapara the values ranged from 0.11 to 0.43 c mol kg^{-1}. The maximum value (0.46 c mol kg^{-1}) was detected at 20 cm depth followed by 0.43 c mol kg^{-1} in the surface soil (0-10cm). In Elisha the Mg ranged from 0.39 to 0.12 c mol kg^{-1} where the maximum value was detected in the surface soil and then a gradual decreasing trend to the sub-soil. It was observed that in Acid Sulfate Soil the Mg content was much higher than that of Ca which might be due to maximum leach out of Ca as compared to Mg as a result of progressive clay disintegration and maximum deposition of Mg from the sea water (Khan et al., 1994).

3.2.5 Sulfur:

Water soluble sulfur was high in all the studied soil profile **(Table 2).** In Amin High School the highest value was 8.12 followed by 2.83, 2.74 c mol kg-1 in the depths of 10 cm, 60 cm and 40 cm respectively. In Koralkhali the distribution of water-soluble sulfur was uniform in all the depths of the soils except for the 60 cm. In 60 cm the value was 15.72 c mol kg^{-1}. The maximum value of 30.17 c mol kg^{-1} was observed in the Koralkhali Salt Bed at the depth of 20 cm followed by 30.06 c mol kg^{-1} in 10 cm depth and then there is a sharp decreasing trend of the values. The highest (15.56 c mol kg^{-1}) value of water soluble sulfur in Mohorizora was observed in 10 cm depths of the soils and was observed in 80 cm depth. In Napitkhalipara the highest value was observed in 10 cm depths of the soils and the value was 16.16 c mol kg^{-1}. The values decreased gradually from surface to sub-soil. The maxium value of 16.32 c mol kg^{-1} was observed in 40 cm depth of Omkhali followed by 16.01, 15.98 c mol kg^{-1} in the depths of 20 cm and 60 cm respectively. In Chiradia the highest (15.44 c mol kg^{-1}) value was observed in the surface soil. Then there is a decreasing trend up to 60 cm depth. After that there is slight increase the sulfur up to 100 cm. The gradual decrease of sulfur in Purbabapukuria soil was found from 40 cm to 100 cm. The highest value was 14.38 c mol kg^{-1} in 40 cm depth followed by 14.19 c mol kg^{-1} in 20 cm depth. In surface the value was 13.03 c mol kg^{-1}. The maximum sulfur was observed throughout the soil profiles of Satdaliapara. The highest value was 39.53 c mol kg^{-1} followed by 39.06 c mol kg^{-1} in the depth of 60 and 100 cm respectively. In Elisha the highest value was 39.06 followed by 34.38 c mol kg^{-1} in the depths of 10 1nd 20 cm. then there was a sharp decrease of sulfur content and the value was 22.50 c mol kg^{-1}. After that there was gradual increase of sulfur up to 100 cm depth. The above results indicated that the distribution of S in the different profiles were irregular which might be due to the deposition of S from different mangrove forest species as well as strong erosion of the soils.

3.2.6. Phosphorus:

The phosphorus status of the studied soil was very low and ranged from 0.020 to 0.031 c mol kg^{-1}. In Amin High School maximum value was 0.026 c mol kg^{-1} in 10 cm depth followed by 0.024 c mol kg^{-1} in 20 cm depth. In Koralkhali the average water soluble P was 0.021 c mol kg^{-1} in the surface 10 to 80 cm depth except for the 100 cm depth. The P in 100 cm depth was 0.027 c mol kg^{-1}. In Koralkhali Salt Bed the highest value of 0.024 c mol kg^{-1} in the depth of 60 cm followed by 0.023 c mol kg^{-1} in the depth of 60 to 100 cm. In Mohorizora the maximum value was observed in the depth of 40 cm followed by 20 cm depth. The highest value of phosphorus was observed to a depth of 100 cm, 80 cm, 60 cm and 40 cm. In Omkhali the water-soluble P varied from 0.020 to 0.023 c mol kg^{-1}. Phosphorus status of the Chiridia soil was almost same in different depths and the value was around 0.022 c mol kg^{-1}. In Purbapukuria P ranged from 0.020 to 0.024 c mol kg^{-1}. The distribution pattern of P in Satdaliapara was almost similar (0.023 c mol kg^{-1}) throughput the profiles except in the 60 cm depth where the value was 0.021 c mol kg^{-1}**(Table 2)**.

3.3 Cation Exchange Capacity:

The cation exchange capacity of the studied soil ranged from 19.1 to 20.9 c mol kg^{-1} in Amin High School, 18.4 to 21.3 c mol kg^{-1} in Koralkhali, 34.4 to 36.9 c mol kg^{-1} in Koralkhali Salt Bed, 16.8 to 20.2 c mol kg^{-1} in Mohorizora, 17.8 to 23.6 c mol kg^{-1} in Napitkhalipara, 33.2 to 35.6 c mol kg^{-1} in Omkhali, 23.9 to 28.8 c mol kg^{-1} in Chiradia, 18.4 to 22.8 c mol kg^{-1} in purbapukuria, 15.1 to 37.4 c mol kg^{-1} in Satdaliapara and 15.6 to 28.7 c mol kg^{-1} in Elisha respectively. From the distribution pattern of the CEC in Amin High School, Elisha, Satdaliapara, Chiradia, Korkhali Salt Bed and Purbapukuria iot was observed that the CEC value was higher in the surface soil than the lower parts of the soil. The uniform CEC value was observed in the in the profiles of Koralkhali and Omkhali. In Mohorizora and Napitkhalipara the higher CEC value was observed at the lower depths of the soil **(Table 2).** 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 c mol kg^{-1} in the acid sulfate soils and the contents increase with depth. The values were a little bit higher in two spots.

Table 2: Distribution of pH and water soluble ions of the studied 10 soil profiles.

Depth (cm)	pH	CEC C mol/kg	Sodium C mol/kg	Potassium C mol/kg	Calcium C mol/kg	Magnesium C mol/kg	Phosphorus C mol/kg	Sulfur (SO_4) C mol/kg
1. Amin High School								
10	4.5	19.100	0.690	0.070	0.150	3.830	0.026	8.120
20	4.8	20.900	0.360	0.030	0.070	0.770	0.024	2.560
40	5.2	20.900	0.260	0.040	0.050	0.570	0.022	2.740
60	5.1	19.200	0.210	0.040	0.040	0.770	0.022	2.830
80	5.0	19.400	0.210	0.050	0.030	1.150	0.020	2.090
100	4.7	19.500	0.200	0.040	0.040	1.100	0.030	2.030
Mean	4.9	19.833	0.322	0.045	0.063	1.365	0.024	3.395
SD	0.241	0.76522	0.17353	0.01258	0.04069	1.12047	0.00327	2.13453
2. Koralkhali								
10	4.5	21.100	1.650	0.350	0.460	11.110	0.021	14.060
20	4.2	20.800	0.690	0.140	0.140	2.300	0.021	14.130
40	4.0	18.400	0.690	0.140	0.130	2.680	0.022	14.310
60	4.0	20.700	0.750	0.150	0.150	3.220	0.021	15.720
80	4.1	21.300	0.850	0.140	0.150	6.320	0.022	14.600
100	4.1	21.000	0.340	0.130	0.150	4.210	0.027	14.410
Mean	4.2	20.550	0.828	0.175	0.197	4.973	0.022	14.538
SD	0.171	0.98107	0.39968	0.07848	0.11799	3.04234	0.00213	0.55742
3. Koralkhali Salt Bed								
10	6.1	36.900	21.150	0.990	0.430	20.690	0.022	30.060
20	4.6	36.900	16.720	0.830	0.210	11.490	0.021	30.170
40	4.8	35.100	15.980	0.870	0.210	10.150	0.021	16.060
60	3.9	34.400	17.580	0.990	0.290	11.490	0.024	16.190
80	4.1	36.400	16.100	0.990	0.290	9.390	0.023	16.440
100	4.7	36.500	16.600	1.010	0.280	11.110	0.023	15.130
Mean	4.7	36.033	17.355	0.947	0.285	12.387	0.022	20.675
SD	0.705	0.9481	1.77443	0.06968	0.07343	3.78959	0.00111	6.68741
4. Mohorizora								
10	4.8	19.700	0.740	0.130	0.110	1.340	0.021	14.060
20	4.3	16.800	0.690	0.150	0.090	1.230	0.023	14.060
40	4.4	17.700	0.860	0.150	0.150	2.680	0.025	14.380
60	4.3	18.400	0.930	0.180	0.170	3.260	0.022	13.630
80	4.0	20.100	1.010	0.210	0.170	3.830	0.022	15.560
100	4.0	20.200	1.080	0.230	0.170	4.210	0.021	14.250
Mean	4.3	18.817	0.885	0.175	0.143	2.758	0.022	14.323
SD	0.271	1.27987	0.13865	0.03547	0.03197	1.14463	0.00137	0.59963
5. Napitkhalipara								
10	5.0	21.500	4.570	0.600	0.240	9.960	0.023	16.160
20	4.9	19.800	3.020	0.150	0.170	5.560	0.022	15.220
40	3.9	17.800	3.120	0.020	0.080	5.750	0.060	14.880
60	4.0	23.600	3.600	0.050	0.090	9.190	0.026	14.410
80	4.0	22.300	3.730	0.500	0.130	8.620	0.027	14.660
100	3.9	21.500	4.040	0.240	0.190	9.960	0.031	13.500
Mean	4.3	21.083	3.680	0.260	0.150	8.173	0.032	14.805
SD	0.474	1.8524	0.52912	0.21886	0.05627	1.84027	0.01307	0.8056
6. Omkhali								

10	5.1	33.500	1.480	0.430	0.210	6.320	0.020	15.810
20	5.1	35.600	1.390	0.430	0.160	4.520	0.021	16.010
40	5.2	33.200	1.460	0.430	0.160	3.680	0.022	16.310
60	5.1	33.200	1.440	0.420	0.150	3.830	0.024	15.980
80	5.5	33.200	9.220	0.420	0.140	3.450	0.023	14.380
100	5.4	33.300	10.200	0.430	0.160	3.330	0.023	14.310
Mean	5.2	33.667	4.198	0.427	0.163	4.188	0.022	15.467
SD	0.16	0.87114	3.90769	0.00471	0.02211	1.02654	0.00134	0.8069
7. Chiradia								
10	5.4	28.800	15.120	0.730	0.310	6.590	0.022	15.440
20	6.2	27.300	4.300	0.170	0.060	0.570	0.022	13.660
40	6.0	26.200	7.990	0.350	0.120	1.920	0.023	13.130
60	6.1	25.000	8.730	0.400	0.120	2.180	0.022	12.970
80	6.0	24.000	8.610	0.450	0.150	1.990	0.023	13.780
100	6.2	23.900	8.610	0.450	0.180	2.680	0.021	13.910
Mean	6.0	25.867	8.893	0.425	0.157	2.655	0.022	13.815
SD	0.273	1.77357	3.18521	0.16611	0.0776	1.87262	0.00069	0.80189
8. Purbapukuria								
10	3.9	19.900	4.500	0.330	0.120	2.000	0.020	13.030
20	3.7	21.200	9.100	0.330	0.050	2.100	0.021	14.190
40	4.1	22.800	1.000	0.290	0.040	1.000	0.021	14.380
60	4.0	20.600	1.100	0.280	0.040	0.980	0.022	14.020
80	4.0	18.400	0.980	0.240	0.120	0.990	0.024	13.910
100	4.0	19.400	0.890	0.230	0.030	0.830	0.023	13.080
Mean	4.0	20.383	2.928	0.283	0.067	1.317	0.022	13.768
SD	0.126	1.39573	3.04334	0.03902	0.03815	0.52245	0.00134	0.52508
9. Satdaliapara								
10	4.0	37.400	0.830	0.180	0.050	0.430	0.023	23.440
20	4.3	32.300	0.740	0.130	0.060	0.460	0.023	20.000
40	4.3	31.800	0.650	0.050	0.030	0.270	0.023	22.340
60	3.4	32.500	0.600	0.050	0.020	0.110	0.021	39.530
80	3.6	16.800	0.480	0.030	0.020	0.120	0.024	26.090
100	3.6	15.100	0.450	0.030	0.020	0.110	0.022	39.060
Mean	3.9	27.650	0.625	0.078	0.033	0.250	0.023	28.410
SD	0.354	8.49171	0.13426	0.05669	0.01599	0.14888	0.00094	7.90288
10. Elisha								
10	4.9	31.300	0.870	0.260	0.067	0.390	0.027	39.060
20	5.2	28.700	0.650	0.210	0.053	0.370	0.026	34.380
40	5.0	21.800	0.560	0.180	0.047	0.320	0.024	22.500
60	5.0	25.900	0.500	0.088	0.031	0.140	0.025	23.810
80	5.0	17.400	0.390	0.032	0.018	0.130	0.027	27.190
100	4.7	15.600	0.350	0.025	0.017	0.120	0.024	27.340
Mean	5.0	23.450	0.553	0.133	0.039	0.245	0.026	29.047
SD	0.149	5.71744	0.17346	0.08959	0.01841	0.11701	0.00126	5.85025

Table 3: Distribution of total sulfuric acidity (TSA: c mol kg^{-1}) in the 10 profiles of the studied acid sulfate soils.

Depth (cm)	1. Amin High School	2. Koralkhali	3. Koralkhali Salt Bed	4. Chiradia	5. Napitkhalipara	6. Omkhali	7. Purbapukuria	8. Mohorizora	9. Satdaliapara	10. Elisha
0-10	8.06	6.88	14.74	12.21	19.60	11.04	14.36	19.86	8.99	3.57

10-20	8.84	3.72	14.72	12.39	6.67	13.77	19.00	15.14	1.79	2.31
20-40	8.82	14.14	9.30	10.25	23.0	12.78	15.54	17.51	5.05	3.02
40-60	11.62	9.67	17.57	8.47	10.81	12.59	20.61	21.33	6.83	1.17
60-80	9.85	9.85	18.87	11.03	8.84	13.02	15.57	9.40	7.89	2.57
80-100	9.58	11.01	11.60	7.07	8.24	12.60	17.04	6.27	12.65	3.19
Weighted average	9.46	9.21	14.47	10.24	12.96	12.63	17.02	14.92	7.20	2.64
SD	1.23	3.57	3.58	2.11	6.94	0.89	2.37	5.96	3.67	0.85
r (depth/ TSA)	0.56⋆	0.52⋆	0.08 NS	-0.80⋆⋆	-0.47⋆	0.24 NS	0.13 NS	-0.74⋆⋆	0.63⋆⋆	-0.14 NS

⋆Significant at 5 % level and ⋆⋆Significant at 1 % level, NS = Non significant.

3.4. Total Sulfuric Acidity (TSA):

The maximum quantity (17.02 c mol kg^{-1} soil, average of 100 cm) of TSA was determined within 100 cm of the soil profile of Purbapukuria followed by 14.92 c mol kg^{-1} in Mohorizora; 14.47 c mol kg^{-1} in Koralkhali Salt Bed; 12.96 c mol kg^{-1} in Napitkhalipara; 12.63 c mol kg^{-1} in Omkhali; 10.24 c mol kg^{-1} in Chiradia; 9.46 c mol kg^{-1} in Amin High School; 9.21 c mol kg^{-1} in Koralkhali; 7.20 c mol kg^{-1} in Satdaliapara and 2.64 c mol kg^{-1} in Elisha. The distribution of TSA with their corresponding depths showed strong positive correlation for 3 profiles, significant negative relationship with 3 profiles and 4 profiles showed no significant relationship with the depths **(Table 3).** Usually acid sulfate soil contains 1 to 5 % oxidizable sulf. But the distribution pattern is quiet different and it is very difficult to predict any amount to neutralize the acidity of the soil. It is known that one mole of acidity requires 50 g (or 11 ton lime ha^{-1}/cmol in the surface of 10 cm soil) of lime ($CaCO_3$) to neutralize the soil. Van Breemen (1993) reported that 1% oxidizable sulfur require 30 ton of lime per hectare of 10 cm of the acid sulfate soil, which indicate that a huge amount of lime would be required for removing the acidity of the studied soil.

4. Conclusion:

The decreasing trends of pH from surface to subsurface of these soils were observed. The Ca content of the studied soil is very low in relation to Mg. The P availability was observed very low but the water soluble sulfur was very high in the studied profile. The high amount of total sulfuric acidity (TSA) were observed in the studied soil profile which indicates that a huge amount of lime will be required to neutralize the surface 20 cm of the soil which is very expensive. But on the other hand high content of sulfur and other nutrients indicates that these soils can be used as fertilizer/bio-fertilizer in the sulfur deficient soils area of Bangladesh.

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