Reason - *A Technical Journal*
ISSN 2277–1654
Vol - XII • 2013

CHARACTERISTICS OF MANGROVES SUBSTRATE SEDIMENTS OF SUNDERBANS

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Manuscript received on: October 04, 2013, acceped after revision on: December 10, 2013.

Abstract: Sunderbans soil is typically a physiologically dry soil because plants cannot absorb water properly from the soil due to presence of high amount of salt. The coastal tidal forest, Sunderbans has the saline micaceous deltaic alluvium of humid region. Sunderbans has too saline humic and acid sulphate soils of humid tropical region. Acid sulphate soil has highly acidic pH, high EC, presence of humic (organic) horizon, dominance of sulphate and chloride salts. Substrate soils of different geomorphic regions like riverbank, mudflats and natural levees of Sunderbans are poor in aeration and water holding capacity.

Keywords: Saline soils, soil reactions, soil characteristics, acid sulphate soils, micronutrients, metal oxides, NPK, soil distributions

1. INTRODUCTION

The substrate soils of Sunderbans are ideal for the luxuriant growth of mangroves-the tidal forest of coastal region. Soils are usually deposited in the convex margin of rivers, meandering creeks and tidal inlets of the estuarine Sunderbans [1]. Soils help in the progradation of coastal Sunderbans facing the Bay of Bengal. The ideal mangroves soils are found in the low lying alluvial coastal plains, drowned valleys, estuarine and deltas carrying water rich in suspended matter with least disturbed marine waters [2].

Mangroves of Sunderbans are physiologically tolerant of high salt levels and have mechanisms to obtain freshwater despite the strong osmotic potential of sediments [3]. During absorption of water from soil a few mangrove species excludes salts with ultra filters present in their root systems. Some mangrove species store salt in their leaves and excrete them through specialized salt glands during seasonal shedding. These species avoid salts through such salt excretion and allow more salt into the xylem. Rest of the mangrove species store salt in leaf vacuoles and convert into succulent. Sometimes some mangrove accumulates salt in the bark or the wood transferring salts from the leaves.

2. SOIL FORMATION

The muddy substratum of the islands of Sunderbans generally contains about 12% sand, 66% silt and 22% clay while mud flats of the Hugli – Matla – Roymangal estuarine area contain about 15% sand, 80% silt and 5% clay. Ganga alluvium and its salinised part are considered as parent materials of the Sunderbans soils. Ganga alluvium is normally salt free where calcite or magnesite is present as rich divalent in this soil. Major quantity of this alluvium drifted into the Bay of Bengal, get salinised and partially deposited at the river banks, mudflats, river flood plains or natural levees at estuarine region after returning from the sea in suspension through numerous tidal creeks, channel and river water courses. Due to admixture of Sodium Chloride (NaCl) present in seawater, silt and clay of Ganga alluvium undergo partial transformation in their exchange complex for the exchange reaction. There are mainly two soil-forming agencies – i) rain water and ii) sea water. Normal soils are produced due to partial leaching by rainwater in presence of calcite, magnesite or dolomite. Saline alkaline soils are produced due to leaching by seawater in presence of excess NaC1 but lacking dolomite. Saline alkaline soils become non-saline alkaline soil when salts get completely leached away and sodium ion enters the exchange complex. Degraded alkali soils are produced when hydrogen ion from organic acids takes part in formation of these soils [4].

3. SOIL CHARACTERISTICS

Salt affected soils are classified on the basis of salt concentration measured as Electrical conductivity (EC) and on Exchangeable Sodium Percentage (ESP) of soil. Bandyopadhyay et al., 2001 describes EC as the reciprocal of electrical resistance and has a unit reciprocal of Ohoms i.e. mhos or Siemens (S) in S.I. units.100 S is equal to 1 m mhos unit. The electrical resistivity is the resistance in ohms of a conductor, metallic or electrolytic which is 1 cm long and has a cross sectional area of 1 cm^2. Electrical conductivity (EC) is, therefore, expressed in reciprocal ohms per cm or mhos per cm.

The dividing line between a saline and a non-saline soil was established in terms of electrical conductivity of saturation water extract of soil (ECe) of 4 d Sm^{-1} at 25°C [5]. Osmotic potential (Ø) can be estimated from the electrical conductivity of soil solution or saturation extract of soil (ECe in dSm^{-1}) by the formula, Ø =0.36 ECe, where, Ø is the osmotic pressure in atmosphere, ECe is the EC of saturation extract of soil in dSm^{-1}. Ece is also related to total concentration (ppm) of salts by the formula,

Salinity (ppm) = 640×EC (dsm^{-1}) or, Salinity (ppt) = 0.64×EC (dSm^{-1})

In Sunderbans, soils are rich in salts due to saline ground water table present at shallow depth. The estuarine region is generally low lying deltaic plain inundated regularly by brackish waters. Surface soils are salinised due to capillary rise of saline water depending upon the elevation, soil texture, climate, drainage and other reasons [5].

4. SOIL CLASSIFICATIONS

Sunderbans soils are classified into four categories namely i) Saline soil ii) Saline alkali soil iii) Non-saline alkali soil and iv) degraded saline alkali or Saline turf soil.

Types	Characteristics
Saline soil	i) Inundated
	ii) Calcite rich
	iii) Rain water washed
Saline alkali soil	i) sea water washed
	ii) Active delta forming
Non-saline alkali soil	i) tidal deposit deficient in Ca
Degraded saline alkali soil	i) Inundated mangrove forest
	ii) Land above sea level
	iii) Area below sea level

5. SALINE SOILS

Saline soils seen in most of the soils are often identified with the white salt encrust on the soil surface. Saline soils have higher concentration of electrolytes (ECe > 4 dSm^{-1} at 25^0C) than the normal soils. These soils have pH less than 8.5, ESP less than 15, and preponderance of chlorides and sulphates of sodium, calcium and magnesium. Salinity varies from 2 to 18 ppt in saline soils. It has an average to high clay percentage and immobile Sasquioxides. There is no lime in saline soils as carbonate and it has 11 to 12% saturation of monovalents in exchangeable bases.

6. CHARACTERISTICS OF THE SALINE SOILS

Availability of mangrove nutrients in Sunderbans soils is affected by higher concentrations of electrolytes in soils. Presence of excess salts in Sunderbans soils interfere with the uptake of nutrient ions by plants. Chloride and sulphates are the chief salt anions. Nitrate may also sometimes, be present in large quantities. Small amount of bicarbonates may be present but soluble carbonates are absent.

6.1. Saline Alkali Soils

Salinity of saline alkali soils ranges between 3 ppt to 12 ppt. This soil pH is more than 8.5 (ESP e” 15). The ECe is limitless when it is originated from salts capable of alkali hydrolysis, otherwise it should be less than 4 dSm^{-1} at 25^0C. It has high and uniform clay percentage and immobile Sasquioxides. Lime is present in fine form or small concretions. It has 40 to 56% saturations of monovalents in exchangeable bases. This type of soil is quite immature for profile development.

Saline alkali soils are of three types in the Sunderbans as following:

i) Rich in calcite

ii) Rich in dolomite

iii) Formation in the inundated areas

This saline alkali soils have three phases of occurrences as –

i) Rain water washed

ii) Sea water washed

iii) Active delta forming phases

6.2. Non-Saline Alkali Soils

Percentage of soil salinity of non-saline alkali soils ranges between 0.1% and 0.9% and pH varies from 7.1 to 8.2. It has an average to high clay percentage and immobile Sasquioxides. It has no lime as carbonate. This type of soil too is quite immature for the profile development. It has 30 to 45 percent saturation of monovalents to exchangeable bases.

6.3. Degraded Alkali Soils

Non-saline alkali soils of Sunderbans sometimes may have ESP $\geq$ 15, yet pH reading in the surface soil may be as low as 6. These are called degraded alkali soils. Soil reaction of degraded saline soils is low where pH ranges between 6 and 6.9. Salinity varies from 6 ‰ to 12 ‰. It has average to high clay percentage and has slightly mobile Sasquioxides. No lime is present as carbonate. This type of soil is immature in the profile development. This saline turf soil has 10% to 17% saturation of monovalents in exchangeable bases.

Degraded alkali soils occur only in absence of alkaline earth carbonates in soil. The low pH is due to exchangeable hydrogen. The physical properties of soils, however, are dominated by the exchangeable sodium and are typically similar to those observed for alkali soils. This soil has three phases found at – i) inundated forest; ii) cultivated areas above sea level and iii) cultivated area below sea level.

6.4. Acid Sulphate Soils

This type of soil is found in the majority islands of Sunderbans. Acid sulphate soils are extremely acidic (pH < 3.5 – 4.0) due to oxidation of pyrites and other sulphidic materials accumulated in soil due to reduction of sulphate salts. These soils are formed due to brackish water submergence for long time. Acid sulphate soils are saline, rich in clay, organic matter and exchangeable Al. They are frequently rich in exchangeable Fe and Mn. pH is very low in this type of soil having ESP < 15.

6.4.1. Characteristics of Acid Sulphate Soils

Acid sulphate soils are highly acidic in nature with or without jarosite mottles, having toxic content of available Fe and soluble Al. These soils are very poor in available P content. They are very low in pH, have usually jarosite mottles of value less than or equal to 6. The soils have high content of soluble S.

Bandyopadhyay et al, (2001) describes that acid sulphate soils develop as a result of the drainage of soils that are rich in pyrites (FeS_2), leading to the oxidation of the compound to produce H_2SO_4.

$$4Fe_2S_2 + 15O_2 + 14H_2O = 4Fe(OH)_3 + 8SO_4^{-2} + 16H^+$$

Oxidation of pyrites may also lead to jarosite $[KFe_3 (SO_4)_2.(OH)_6]$ or natro-jarosite $[NaFe_3 (SO_4)_2 .(OH)_6]$ depending upon the condition of reaction. Presence of straw yellow coloured jarosite mottles (value $\leq$ 2.5 Y and chroma $\leq$ 6.0) are some typical features of these soils.

Acid sulphate soils develop under the condition where the production of acid due to oxidation of pyrites exceeds the neutralizing capacity of soils and the pH falls below 4.0. Initially, pyrites accumulate in water logged soils that are rich in both organic matter and dissolved sulphates following the reaction:

$$2Fe_2O_3 + 8SO_4^{2-} + 16CH_2O + O_2 \rightarrow 4FeS_2 + 16HCO_3 + 8H_2O$$

7. PHYSICO-CHEMICAL PROPERTIES OF SOIL

Physico-chemical properties of the soils play very important roles as because a large number of elements are required for biological production.

7.1. Soil Reaction (pH)

Soils of the brackish water estuaries of the Sunderbans are generally alkaline in reaction and ranges between7.05 and 7.96 (Table 1). Sometimes it goes down to 3.8 as it found in the anoxic reduced environment. pH of soil is one of the most important factors for maintaining the productivity of any water body since it controls most of the chemical reactions. The availability of nutrient elements through mixing, rate of mineralization of organic matter, fixation of P and other elements and growth and survival of different biotic communities are greatly influenced by pH. Soils are classified into acidic (pH < 7.0), neutral (pH = 7.0) and alkaline (pH > 7.0) according to its pH or H^+ ion concentration.

7.2. Organic Carbon

Formation of organic carbon in the estuaries is slow due to presence of salinity in the river waters of the Sunderbans. Organic carbon acts as a source of energy for the microbes participating in the various biochemical processes resulting release of different nutrients. Soil organic matters or humus influence the physical, chemical and biological activities in soil, improves soil structure, aeration, increase water holding capacity, buffering and exchange capacity of soil including solubility of soil minerals and serves as a store house of various nutrients essential for biotic productions. The observed high organic carbon content is perhaps due to difference in texture, river discharge carrying a large amount of humus and high organic production in the surface waters. Organic carbon and total organic matter can contribute to the variations of the different physico-chemical parameters and have significant positive correlation with several trace metals like iron and copper and their oxides. Organic carbon of sediments varies between 0.04% and 1.20% (Table 2) in the tidal mudflats and river flood plain of Sunderbans.

Table 1 Estimation of salinity of sediment samples collected from different locations from Sunderbans

Sl. No.	Sample Locations	Sample No.	Salinity(ppt)	pH
1	Sajnekhali (River bank)	S_1	5.76	7.05
2	Sudhanyakhali (River bank)	S_2	5.60	7.19
3	Panchamukhani (River bank)	S_3	4.95	7.05
4	Pirkhali (River bank)	S_4	5.79	7.25
5	Neti Dhopani (River bank)	S_5	5.80	7.35
6	Bidya (River bank)	S_6	4.93	7.3
7	Paschim Sripatinagar (Mud flat)	K_5	4.09	7.30
8	,,	K_6	5.36	7.68
9	,,	K_7	5.04	7.27
10	,,	K_8	3.44	7.75
11	,,	K_9	2.86	7.35
12	,,	K_{11}	3.44	7.05
13	,,	K_{12}	2.86	7.69
14	,,	K_{13}	2.86	7.19
15	,,	K_{14}	3.48	7.73
16	,,	K_{15}	3.16	7.75
17	Upendranagar (Mudflat)	L_1	3.69	7.18
18	,,	L_2	4.81	7.31
19	,,	L_3	5.18	7.96
20	,,	L_5	4.78	7.56
21	,,	L_6	3.92	7.37
22	,,	L_8	2.88	7.63
23	Achintyanagar (River bank)	P_1	6.4	7.36
24	,,	P_2	5.12	7.37

Table 1 Contd/-...

Sl. No.	Sample Locations	Sample No.	Salinity(ppt)	pH
25	,,	P_3	3.84	7.83
26	,,	P_4	4.48	7.28
27	Banashyamnagar(river bank)	MB_1	5.12	7.41
28	,,	MB_2	1.60	7.25
29	,,	MB_3	4.48	7.39
30	,,	MB_5	5.44	7.28
31	Maipith(River bank)	$T1_5$	3.84	7.83
32	,,	T_{16}	3.2	7.45
33	,,	T_{17}	2.56	7.87
34	Paschim Sripatinagar(Mud flat)	K_{16}	8.00	7.27
35	,,	K_{17}	5.44	7.09
36	,,	K_{18}	4.80	7.59
37	,,	K_{19}	4.48	7.61
38	,,	K_{20}	9.60	7.65
39	,,	K_{21}	4.16	7.34
40	,,	K_{22}	6.72	7.24

8. SOIL NUTRIENTS

Soil nutrients enrich the flora particularly the world famous mangroves in the ecosystem of the Sunderbans. Among these nitrogen, phosphorus and potassium are termed as primary nutrient elements, calcium, magnesium and sulphur are termed as secondary nutrient elements and boron, copper, manganese, zinc, molybdenum, iron and chlorine are termed as micronutrients on the basis of requirement.

8.1. Nitrogen

In the Sunderbans, soils nitrogen occurs mostly in organic combinations and inorganic nitrogenous compounds (NH_4, NO_3 and NO_2) are released through bacterial decomposition of organic matter. It is easily decomposable form of organic nitrogen known as available nitrogen, which is important in the aquatic productivity. Nitrogen stimulates primary production in the aquatic environments as a basic and primary constituent of the protein and is essential for the formation of living matter.

Most of the saline soils are poor in available and total nitrogen. Efficiency of plant roots to absorb nutrients from saline soils is also poor due to reduced root volume and various physiological reasons. Nitrogen is present in such soil mostly in organic form and all the inorganic forms of N comprise less than 2% of total nitrogen in soil. In saline soil, NO_2^- and NO_3^- are present mostly in diffusible forms, whereas NH_4^+ is present mostly in exchangeable form. The process of diffusion is slow in alkali soil condition. The rate of organic matter mineralization is quite slow in the saline soils due to high pH and salinity. Rate of nitrification is too slow in this soil because of high salinity and alkalinity.

8.2. Phosphorus

In highly acidic acid sulphate soils of Sunderbans, phosphorus deficiency becomes one of the limiting factors for growth of mangroves species and its associated plants. At high soil salinity, the uptake of P by the mangroves may also be severally affected due to competitive inhibition caused by Cl^- since both phosphates and chlorides, being anions, are absorbed by essentially the same absorption sites. Phosphorus is essential for assimilation of nitrogen into cellular matter besides respiration, cell division, metabolism, growth and synthesis of protein. Thus it is considered a key element in biological production in aquatic environment and is very often become a limiting factor in fauna food organisms' production. The in situ phosphorus status of most soils is rather low compared to nitrogen and potassium. Phosphorus is absorbed by the mangroves mainly in ionic forms of $H_2PO_4^-$ and $H_2PO_4^{2-}$. In saline soils, the association of P with other elements depends upon soil pH. So that the chemistry of phosphorus is more complex in saline soils compared to normal soils.

Table 2 Physico-chemical parameters of the mangrove sediments

Sl. No.	Seasons	PH	Salinity (‰)	Organic Carbon (%)	Total organic matter (%)
1	Pre-monsoon	7.30	4.09	0.22	0.38
2		7.68	5.36	0.32	0.55
3		7.27	5.04	0.41	0.73
4		6.75	3.44	0.39	0.66
5		7.35	3.86	1.20	2.06
6	Monsoon	7.05	3.44	0.38	0.67
7		7.69	2.86	0.81	1.38
8		7.19	2.86	0.33	0.57
9		6.73	3.44	0.73	1.26
10		6.75	3.16	0.23	0.40
11	Post-monsoon	7.18	3.69	0.35	0.60
12		7.31	4.81	0.29	0.50
13		6.96	5.18	0.14	0.24
14		7.56	4.78	0.30	0.52
15		7.37	3.92	0.04	0.07

8.3. Potassium

Potassium helps in the formation of protein, chlorophyll and in stimulating the growth of aquatic plants. Compared to nitrogen and phosphorus, the importance of potassium in aquatic production is less recognised due to its low requirement and easy availability in the Sunderbans soils. Predominance of micaceous minerals is one of the reasons for the high content of K in the saline soils of the Sunderbans. Sodium – potassium exchange in biotite and dissolution of muscovite structural units release large amount of K in alkaline sodium environments. The mica and feldspar (orthoclase and microcline) constitute the major K bearing minerals in saline soils. Clay minerals also constitute an important source of soil potassium. In saline soils, the exchangeable cations decrease the K fixation in the order Na > Ca > Mg > H > NH_4. Saline soils undergo less leaching losses of K because of impeded drainage condition. Growth of the mangroves is accelerated by potassium. It helps in the formation of chlorophyll and protein of the coastal vegetations. The importance of potassium in this aquatic environment is comparatively less due to its low requirement and easy availability in the mangrove sediments compared to that of nitrogen and phosphorus.

8.4. NPK of Sunderbans

Chemical analysis of sediment samples reveals that the sediments are enriched with nutrients. Estimation of NPK values revealed that available nitrogen (Av. N) ranges from 880 to 1540 kg/ ha, available phosphorus (Av. P) from 11.4 to 26.0 kg/ha and available potash (Av. k) from 2083 to 2958 kg/ha. The organic carbon shows a range between 0.38 and 0.69% and the total organic matter in sediments 0.066 to 1.19% (Table 3). It is found that available potash is five times richer than that of required amount for the natural growth of mangroves, which supply the nutrients to the ambient environment [6]. Nitrogen to phosphorus ratios indicate that the major portion of phosphorus is of abiogenic origin.

9. MICRONUTRIENTS

Calcium is an integral part of the plant tissues. Sulphur is an essential constituent of protoplasm. The concentration of CO_2 in water is influenced by Ca and Mg. Calcium also acts to increase the availability of other ions in water and in general ameliorates the chemical conditions of water. The most important factors influencing the availability of micronutrients in saline soils are pH, soil texture, type and quality of clay minerals, organic matter, calcareousness and salt content in soil. In almost all types

Table 3 Chemical analysis of collected sediment samples of deltaic Sunde

Samples No.	pH (1:2)	Salinity (ppt)	Av.N (kg/ha)	Av.P (kg/ha)	Av.K (kg/ha)	Organic Carbon (%)	Total organic matter (%)
S_1	8.05	5.67	1100	18.6	2285	0.47	0.81
S_2	8.1	5.6	1540	17.8	2554	0.69	1.19
S_3	8.0	4.95	1540	26.0	2083	0.67	1.16
S_4	8.25	5.79	1320	26.0	2957	0.63	1.09
S_5	8.25	5.8	880	20.5	2419	0.38	0.66
S_6	8.3	4.93	1100	11.4	2688	0.47	0.81

of saline soils, there is a negative correlation between soil pH and available micronutrient cations. A highly significant negative correlation has been reported by Bandyopadhyay et al (2001) between extractable Zn, pH and $CaCO_3$ content of soil.

Calcium is generally present in soil as calcium carbonate. The amount of exchangeable phosphorus in the sediments is inversely related to the calcium carbonate – organic matter ratio so that in highly organic soil with low calcium soluble phosphorus remain adsorbed in exchangeable forms and when sediment is very low in organic matter and high in calcium, phosphorus is fixed as insoluble precipitate. Some micronutrients are essential in the mangrove ecosystems and the brackish waters contain considerable amount of Ca, Mg, S and micronutrient elements.

The deficiency of Fe, Mn and Cu is quite frequent in saline alkaline soils particularly when the soil is calcareous in nature. Many a time boron is accumulated in salt affected soils in toxic concentrations due to poor leaching. The native source of this boron in coastal soils is the primary mineral tourmaline. Saline soils sometimes show deficiency of Mo and it is seen that in saline soils Mo availability increases with pH. Zn has the specific role in improving the alkali tolerance of mangroves.

It is observed that in general, saline soils have better availability of micronutrients than the saline alkaline soils in Sunderbans. Highly acidic saline soils or acid sulphate soils of Sunderbans contain toxic concentration of Fe and Mn, particularly in the inundated condition. Al toxicity is seen in acid sulphate soils.

Table 4 Metal oxides of the sediment samples collected from the Sunderbans

Sample No.	Fe_2O_3%	MgO%	Na_2O%	K_2O%	L.O.I%	ROOM% as ‘C’
S 1	6.27	1.86	0.91	2.84	8.94	0.62
S 2	5.48	1.67	0.82	2.40	7.86	0.59
S 3	5.77	1.84	1.00	2.93	8.64	0.61
S 4	5.80	1.80	1.14	2.52	8.25	0.47
S 5	5.56	1.70	1.02	2.39	8.25	0.61
S 6	5.14	1.57	1.04	2.41	7.15	0.64
S 7	6.12	1.66	0.83	2.45	8.65	0.55
S 8	5.98	1.81	0.95	2.30	8.21	0.61
S 9	5.72	1.63	0.93	2.67	8.72	0.57
S 10	6.24	1.47	1.01	2.59	8.72	0.47
S 11	5.88	1.32	0.91	2.64	8.56	0.51
S 12	5.83	1.53	0.89	2.77	8.82	0.58

10. METAL CONTENT AND METAL OXIDES OF SOILS

Sunderbans river estuaries are unique system as it shelter and support various living and non-living resources. In this system some elements of biologically active materials and a few organic compounds play an important role for the productivity of this environment. Some metals and non metals derived from several sources, are carried by the river water and spend considerable period where they are subjected to the influence of tidal flux and experience various bio-geo-chemical transformations. Nitrogen, phosphorus, potassium, carbon, trace metals and organic matter studied in the estuarine sediments of Sunderbans covering a large undisturbed part of the sanctuary areas, provide the clear picture of their occurrence, distribution with reference to productivity and to identify their probable sources.

Collected soil samples are analysed with respect to their metal oxides and their values are furnished in the Table 4 and Table 5. The oxides are shown in percentages while metal contents are shown in parts per million (ppm). Amongst the heavy metals, copper varies from a minimum of less than 10 ppm to a maximum of 100 ppm, while lead and zinc varies from less than 10 ppm to 40 ppm and from 18 ppm to 30 ppm respectively. Generally the metal content is less in the clayey sediments and the higher values are restricted in the finer fractions like sandy silts and/or silt. Mangroves themselves, however, generally have low concentrations of heavy metals and they are very poor indicators of trace metal concentrations. Among metals, Zn showed low value in almost all species of plants and animals followed by Cu and Pb because the low level of metals in the mangroves themselves may be due to low bio-availability in the mangal sediments (Table 5). Disturbances like changes in the frequency and duration of tidal flooding; changes in salinity or prolonged dry periods cause the mangrove soils to lose their metal binding capacity, resulting in mobilization of the metals. These disruptions are often associated with anthropogenic stresses [7]. The seasonal variations of trace metals and metal oxides are probably due to the difference in existing physico- chemical condition and the adjacent land effect of the estuarine region.

11. SOIL DISTRIBUTION

Saline soils are identified in the region of Sandeshkhali II, Hasnabad, Hingalganj, Gosaba, Kultali, Jaynagar II and Mathurapur II. Soils are saline alkaline at Kakdwip, Kulpi and Sagar blocks. Non-saline alkali soils are found at Mathurapur block and degraded saline alkali soil is found in Ghusighata, Sandeshkhali, Tushkhali and Damakhali regions [8].

11.1. Saline Soils: Entire region of Hingolganj and Hasnabad blocks lying west of Sahebkhali River are saline. The northern part of Joynagar II, Kultali and Mathurapur II are saline. A small area lying south of Bidya river in Gosaba and Sandeshkhali II is also saline.

11.2. Saline – Alkaline Soils: The region of Mathurapur II having Mani river, Saralda khal, Raidighi river, Kaloa K, Jalaberia K, Chuprijhara R, Chatu R and Thakuran river on its south and small streams on the north have saline –alkali soils. In Joynagar II, east and south part of Kulpi block show this type of soils. A considerable area in Sagar Island and Kakdwip blocks is under such soils mainly south of Kalnagini K and Ghugudanga R.

11.3. Non-Saline Alkali Soils: This type of soils is found in a part of Mathurapur II block only in tidal deposits deficient in calcium.

11.4. Degraded Saline Alkali Soils: This soil is found in Sandeshkhali block lying between Hatkhali and Bidya River. They occur in southern portion of Gosaba and Hingalganj.

Table 5 Analysis of metal contents (ppm) in the sediments of Sunderbans

Sample no.	Cu	Pb	Zn	Ni	Co	Cd	Cr	Mn
S 1	70	70	80	40	30	< 5	65	620
S 2	40	60	60	30	30	< 5	65	560
S 3	45	60	65	35	35	< 5	70	620
S 4	40	65	60	45	30	< 5	55	580
S 5	40	65	60	35	30	< 5	55	545
S 6	35	55	55	30	30	< 5	50	520
S 7	60	55	70	40	35	< 5	65	570
S 8	55	60	65	30	30	< 5	70	530
S 9	65	65	60	35	30	< 5	60	610
S 10	45	55	45	40	35	< 5	55	540
S 11	55	45	40	45	30	< 5	60	580
S 12	65	40	75	35	35	< 5	50	555

12. CONCLUSION

The high salt content and/or high pH in different types of saline soils cause changes in solubility, availability and efficiency of nutrients for the growth of mangroves in Sunderbans. Nitrogen uptake by a few mangroves grown in the relatively upper middle portions of the islands is affected by the presence of high concentration of Cl^- ion. Further high sodium can cause calcium and magnesium deficiencies. Most of the mangrove species prefer low saline substratum. The mangrove species inundated by two times daily of tides prefer soils hypersalinity areas whereas species those occur in the central portion of islands prefer their habitat with low salinity. Mangrove species diversity and richness depend upon the preferred salinity of respective mangrove species. Mangrove zonation is happened in response to the salinity of both soil and water. Species diversity of mangroves is controlled not only by the salinity alone but by the several factors like availability of nutrients (N P K), organic carbon, soil texture, water holding capacity of soil etc.Substrate soils have a major impact on mangrove nutrition and growth. High salinity and alkalinity of the soils of Sunderbans delay nitrification rates and urea hydrolysis due to poor bacterial activities in soil. The process of diffusion is slow in alkali soil condition. Both saline and alkali are usually low in available nitrogen and organic matter, and have poor contribution from symbiotic and non-symbiotic nitrogen fixation. High nutrient concentration and low salinity of substrate soils produce rapid growth of mangroves in Sunderbans. Clearing of mangroves forest or formation of canopy gaps can change the physical and chemical characteristics of the underlying soils, leading to the anaerobiosis and increased sulfide in the sediments. Mangroves are gradually becoming dwarf due to scarcity of nutrient supply as islands-tops are not inundated on regular basis. Growth of some mangrove species (those prefer less salinity) is reduced because of physiological water deficit on account of high osmotic potential at the root zone soil solution, although there may be sufficient amount of water in soils. Decreasing osmotic potential of soil solution has the net effect of reducing availability of water to plants, although some tolerant mangrove species has the ability to adjust its internal osmotic potential by various means like through production of organic acids, uptake of salts etc [5]. Mangroves grown in the islands of late show stunted growth, smaller and thicker leaves, and dark green or bluish green in colour due to decreased cell elongation and their leaf surface is layered with waxy materials or scorching of leaf margin.

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