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Extraction of Forms of Aluminium in Relation to Pedogenic Processes in Some Inceptisols

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ABSTRACT: *To study the extraction of forms of aluminium in relation to pedogenic processes in some inceptisols of Assam, twelve soil samples were collected from different horizons of three soil pedons, Jaypur and Demoli series in Dibrugarh district and Chatlang series in Tinsukhia district, all belonging to Typic Dystrudepts and analyzed by different selective extraction procedure using various reagents. The mean content of DTPA extractable aluminium from exchangeable and organically bound forms in the soils was 6217 mg kg^{-1} and increased with depth in Chatlang series but no such observations in Jaypur and Demoli series. KCl extractable with a mean of 365 mg kg^{-1} increased with depth in all soil series except the lowermost horizon of Jaypur and Demoli series where it is decreased. Acetic acid partially extractable Al from imogolite, allophane and simple hydroxyl polymers has a mean 1235 mg kg^{-1} that increased with depth except in the lowermost horizon of Demoli series whereas EDTA extracted for organically complexed Al with a mean of 2837 mg kg^{-1} has no pattern in any series. Moreover, analysis of pyrophosphate, oxalate, and dithionite with a mean of 9587 mg kg^{-1}, 11262 mg kg^{-1} and 13277 mg kg^{-1} extractable Al respectively showed that with increasing age of soil, the crystalline aluminium oxide increases at the expense of the poorly crystalline. This trend is reflected in the ratio of $Al_{oxalate}/Al_{dithionite}$ (Al ratio) that estimates the degree of soil development and found in descending order as: Chatlang>Demoli>Jaypur series. Thus, the mean extractable aluminium by the various extracting reagents as in descending order are: $Al_{dithionite}>Al_{oxalate}>Al_{pyrophosphate}>Al_{DTPA}>Al_{EDTA}>Al_{acetic\ acidc}>Al_{KCl}$. Correlation between the different forms of aluminium and selected soil properties were examined.*

***Key words**: extractable aluminium, horizon, pedon, series*

INTRODUCTION

Aluminium is a major constituent of most soils but only when it moves into soluble (Al^{3+}) or exchangeable form, it can affect plants. Since aluminium toxicity occurs in strongly acid soils, plants may also exhibit deficiency symptoms of cacium, magnesium or other cations. Aluminium containing minerals such as gibbsite and kaolnite can dissolve under acidic conditions, releasing aluminium into solution, thus controlling Al activity. Allophane and imogolite, which are amorphous alumino-silicates can retain large quantities of aluminium. Alunite, basaluminite and jurbanite have been found in soil where oncentration of SO_4^{2-} was high from fertlizaton with gypsum or by acd sulphate natural occurrence. The availability of Al^{3+} is not completey understood, but certain soil factors mainly soil pH, types and amount of clay, total amount of Al in the soil and soil organic matter are known to have a significant effect.

Different forms of aluminium exists in soils such as exchangeable, organically bound, amorphous (imogolite and allophane) and crystalline forms. Fractionation of aluminium by sequential extraction is useful in determining various forms of aluminium in soils. Availability of Al in soils is related to the amount of Al present in the various solid form which is in equilibrium with the soil solution. The amount and distribution of extractable aluminum in soil profiles serve as indicators of the stage and degree of soil development as described by Mahaney and Fahey [1].

The objectives of the present investigation were to determine different forms of aluminium in relation to pedogenic processes and inter-relationship among them as well as with some important soil characteristics in some inceptisols.

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MATERIALS AND METHODS

Soil samples from three soil pedons, Jaypur and Demoli series in Dibrugarh district and Chatlang series in Tinsukhia district of Assam were collected horizon wise based on the information of soil survey conducted by Soil and Land Use Survey of India, Kolkata centre for the present investigation. The pedons were classified according to soil taxonomy. Jaypur and Demoli series both belongs to fine loamy hyperthermic family of Typic Dystrudepts and Chatlang series belongs to mixed loamy hyperthermic family of Typic Dystrudepts (Soil Survey Staff, 1975). The soils were sampled in the field and the samples were returned to the laboratory for analysis and thereafter air-dried, powdered and sieved (< 2 mm).

The physico-chemical properties of the soils as determined by different method are : pH (1:2.5) (Jackson, 1958), specific conductance (1:5) (Jackson, 1958), organic carbon (Jackson, 1958), C.E.C. (Harada and Inoko, 1980) and soil texture (Piper, 1966). The different forms of aluminium were extracted using different extractants and determined colorimetrically as described by Chen and He (1985) as given below:

Extractants	Methods	Reference
1. 1M KCl, pH 7.0	10g soil +100mL solution, shake for1hr	Black 1965
2. DTPA, pH, 7.30±0.05	10g soil+ 20ml solution, shake for 2hrs	Lindsay and Norvell,1978
3. Acetic acid, 0.43M, pH 7.0	1g soil+ 60mL solution,centrifuged and evaporated, oxidized twice with 5mL 16M HNO_3 and 10mL 6M HCl, dissolved in 10mL 0.6M HNO_3	Farmer *et al.* 1980
4. EDTA, 0.05M	1g soil+ 60mL solution, centrifuged and evaporated, dried with10mL 6M HCl and dissolved in 10mL 0.6M HNO_3	Farmer *et al.* 1980
5.Sodium pyrophosphate, 0.1M	1g soil+ 60mL solution, centrifuged and evaporated, oxidized twice with 5mL 16M HNO_3 and 10mL 6M HCl, dissolved in 10mL 0.6M HNO_3	Agriculture Canada 1984
6. Acid ammonium oxalate,0.2M, pH 3.0	1g soil+ 60mL solution, centrifuged and evaporated, dried with10mL 6M HCl and dissolved in 10mL 0.6M HNO_3	Agriculture Canada 1984
7. Dithionite-citrate-bicarbonate	1g soil+ 40mL 0.3M sodiumcitrate+ 5mL 0.1M sodium bicarbonate solution+2g sodium dithionite, shake for 15mins, centrifuged and evaporated, oxidized twice with 5mL 16M HNO_3 and 10mL 6M HCl, dissolved in 10mL 0.6M HNO_3	CSSC subcommittee on methods of analysis, 1978

Figure1: Extraction of forms of aluminium

RESULTS AND DISCUSSION

Physicochemical properties of the soils

The pH (H_20) and pH (KCl) of the soils are all extremely acidic to strongly acidic in reaction ranging below 4.51 on the surface soil (table 1). Specific conductivity is low (highest 0.0084 dSm^{-1}). Organic carbon is also low showing a decline with increasing soil depth in all the series with highest mean in Chatlang series (9.85g kg^{-1}). Cation exchange capacity ranged from 2.5 to 10.0

(highest mean in Demoli series7.0 cmol kg^{-1}) and does bear any relationship with th distribution pattern of clay and organic carbon content of the soils. Soil texture varies from silty clay to clay.

Distribution of different forms of Aluminium

KCl extractable Al with a mean of 365 mg kg^{-1} increased with depth in all soil series except the lowermost horizon of Jaypur and Demoli series where it is decreased (table 2). The mean content of DTPA extractable aluminium from exchangeable and organically bound forms in the soils was 6217 mg kg^{-1} and increased with depth in Chatlang series but no such observations in Jaypur and Demoli series. Acetic acid partially extracting Al from imogolite, allophane and simple hydroxyl polymers has a mean 1235 mg kg^{-1} that increased with depth except in the lowermost horizon of Demoli series whereas EDTA extracted for organically complexed Al with a mean of 2837 mg kg^{-1} has no pattern in any series. Moreover, analysis of pyrophosphate, oxalate, and dithionite with a mean of 9587 mg kg^{-1}, 11262 mg kg^{-1} and 13277 mg kg^{-1} extractable Al respectively showed that with increasing age of soil, the crystalline aluminium oxide increases at the expense of the poorly crystalline. This trend is reflected in the ratio of $Al_{oxalate}/Al_{dithionite}$ (Active Al ratio) (table 3). The $Al_{dithionite}$ values are higher than the $Al_{oxalate}$ values in the soils, indicating that a considerable fraction is present in crystalline form. The mean $Al_{oxalate}/Al_{dithionite}$ ratio values estimated the degree of soil development and were found to be in descending order: Chatlang>Demoli>Jaypur series. According to Mahaney and Fahey [1], soils with higher ratios are younger soils whereas low ratios denote older soils. The low mean active Al ratio value (0.710) in Jaypur series suggest the soil is relatively old. Thus, the mean contents of aluminium extracted by the various extracting reagents in descending order are as follows: $Al_{dithionite} > Al_{oxalate} > Al_{pyrophosphate} > Al_{DTPA} > Al_{EDTA} > Al_{HOAc} > Al_{KCl}$. The soil series can be arranged based on the mean of aluminium as extracted by KCl and DTPA as Chatlang>Jaypur>Demoli, acetic acid as Chatlang>Demoli>Jaypur, EDTA as Jaypur>Demoli >Chatlang, and pyrophosphate, oxalate and dithionite as Demoli>Chatlang> Chatlang series.

Inter-relationship between different forms

KCI extractable Al showed significant relationship with DTPA (0.97***) and acetic acid (0.52**). Acetic acid extractable Al significant and positive correlations pyrophosphate (0.60*), oxalate (0.77**) and dithionite (0.57*) extractable Al. The significant positive correlations indicate that the amount of Al extracted by these extractions had strong association among themselves as described by Dolui *et al.*,[2].

Table 1
Properties of the soils used in study

Depth (m)	*pH(1: :25)*		*Specific conductance (1:5) (d Sm⁻¹)*	*Organic carbon (g kg⁻¹)*	*CEC (cmol kg ⁻¹)*	*Particle size distribution (g Kg ⁻¹)*			*Texture*
	H_2O	*1(M)KCI*				*Sand*	*Silt*	*Clay*	
Pedon A : Jaypur series : Fine Loamy Mixed Hyperthermic Typic Dystrudepts									
0.00 - 0.13	3.89	2.69	0.0083	14.60	5.0	404	150	446	Clay
0.13 - 0.38	4.28	3.11	0.0080	6.67	5.0	411	126	463	Clay
0.38 - 0.58 +	4.51	3.32	0.0076	5.54	2.5	396	110	494	Clay
Mean	4.23	3.04	0.0079	8.94	4.2	404	129	468	Clay
Pedon B : Chatlang series : Fine Mixed Hyperthermic Typic Dystrudepts									
0.00 - 0.16	3.93	2.75	0.0083	22.85	7.5	251	186	563	Clay
0.16 - 0.44	3.97	2.80	0.0083	7.35	5.0	198	103	699	Clay
0.44 - 0.65	4.14	2.92	0.0068	5.35	5.0	277	181	542	Clay
0.65 - 0.91 +	4.29	3.09	0.0078	3.86	2.5	264	101	635	Clay
Mean	4.08	2.89	0.0078	9.85	4.9	248	143	610	Clay
Pedon C : Demoli series : Fine Loamy Mixed Hyperthermic Typic Dystrudepts									
0.00 - 0.16	4.51	3.31	0.0084	22.68	10.0	239	312	449	Silty clay
0.16 - 0.39	4.64	3.44	0.0080	7.22	7.5	117	258	625	Silty clay
0.39 - 0.67	5.09	3.91	0.0082	6.93	7.5	103	254	643	Silty clay
0.67 - 0.90	4.51	3.29	0.0073	5.59	5.0	133	242	625	Clay
0.90 - 1.25 +	4.41	3.21	0.0078	5.38	5.0	185	195	620	Clay
Mean	4.63	3.43	0.0079	9.56	7.0	155	252	592	Silty clay
Grand Mean	4.35	3.15	0.0079	9.50	5.6	248	185	567	Clay

Table 2
Aluminium (mg kg^{-1}) extracted by different extractants of 3 soil profiles

Horizon (m)	Al_{KCl}	Al_{DTPA}	Al_{HOAc}	Al_{EDTA}	Al_{pyr}	Al_{oxn}	Al_{dith}
Pedon A : Jaypur series : Fine Loamy Mixed Hyperthermic Typic Dystrudepts							
0.00 - 0.13	170	4200	1116	2688	3950	5500	11,500
0.13 - 0.38	250	5500	1179	3167	7625	10,625	12,500
0.38 - 0.58 +	210	4400	1241	3083	9500	10,720	13,375
Mean	210	4700	1179	2979	7025	8948	12,458
Pedon B : Chatlang series : Fine Mixed Hyperthermic Typic Dystrudepts							
0.00 - 0.16	570	8000	1205	2521	7375	9875	12,00
0.16 - 0.44	605	9700	1241	2604	10,250	11,125	13,375
0.44 - 0.65	785	12,300	1286	3083	12,870	13,625	14,250
0.65 - 0.91 +	800	15,200	1321	2688	7250	11,875	12,875
Mean	690	13,300	1263	2724	9436	11,625	13,125
Pedon C : Demoli series : Fine Loamy Mixed Hyperthermic Typic Dystrudepts							
0.00 - 0.16	50	1,500	1170	2604	8750	10,250	11,500
0.16 - 0.39	205	3,600	1205	2688	9875	10,750	14,750
0.39 - 0.67	250	3,200	1241	3083	14,125	15,125	15,250
0.67 - 0.90	335	4,300	1321	2666	11,850	13,125	14,625
0.90 - 1.25 +	145	2,700	1286	3167	11,625	12,550	13,325
Mean	197	3,060	1246	2842	11,245	12,360	13,890
Grand Mean	365	6,217	1235	2837	9,587	11,262	13,277

Table 3
Data of some soils for comparision of extractable aluminium by different extractants and their ratio

Horizon (m)	Al_{EDTA} / Al_{pyr}	Al_{oxa} / Al_{dith}	*Amorphous Al (mg kg^{-1})* $Al_{oxa} - Al_{pyr}$	*Crystalline Al (mg kg^{-1})* $Al_{dith} - Al_{oxa}$	*Clay / Al_{dith}*
Pedon A : Jaypur series : Fine Loamy Mixed Hyperthermic Typic Dystrudepts					
0.00 - 0.13	0.681	0.478	1550	6000	38.8
0.13 - 0.38	0.415	0.850	3000	1875	37.04
0.38 - 0.58 +	0.325	0.801	1220	2655	36.9
Mean	0.474	0.710	1923	3510	37.6
Pedon B : Chatlang series : Fine Mixed Hyperthermic Typic Dystrudepts					
0.00 - 0.16	0.342	0.823	2500	2125	46.9
0.16 - 0.44	0.254	0.832	875	2,250	52.3
0.44 - 0.65	0.239	0.956	755	625	38.0
0.65 - 0.91	0.371	0.922	4625	1000	49.3
Mean	0.278	0.883	2189	1500	46.6
Pedon C : Demoli series : Fine Loamy Mixed Hyperthermic Typic Dystrudepts					
0.00 - 0.16	0.298	0.891	1500	1250	39.0
0.16 - 0.39	0.272	0.729	875	4000	42.4
0.39 - 0.67	0.218	0.992	1000	125	42.2
0.67 - 0.90	0.225	0.897	1275	1500	42.7
0.90 - 1.25 +	0.272	0.942	925	775	46.5
Mean	0.257	0.890	1115	1530	42.6
Grand Mean	0.326	0.843	1675	2015	42.7

Relationship with soil characteristics

pH(KCl) and pH (H_2O) had significant correlation with pyrophosphate (0.62** and 0.62**), oxalate (0.62** and 0.62**) and dithionite (0.63** and 0.62**) extractable Al. These relationships might be due to the precipitation of Al as aluminium hydroxide at higher pH. Organic carbon showed significant relationship with pyrophosphate, oxalate and dithionite extractable Al. Clay content gave significant correlation with acetic acid, pyrophosphate, oxalate and dithionite extractable Al indicating that these fractions might have been either incorporated within the crystal lattice or sorbed on the surface and interlayer of clay and iron oxides as described by Howkes and Webb [3].

CONCLUSION

Aluminium and silicon ions form soluble complexes that are moblised by various reactions and subsequently reprecipitated as hydroxyl polymers. A fraction of the polymers is chelated by ligand group of organic matter and others tend to be crystalline on ageing. A dynamic equillibrium exists amongst the different forms of aluminium in relation to pedochemical reactions. Various extractants have been used to extract different forms of aluminium. The amount and distribution of extractable aluminum in soil profiles serve as indicators of the stage and degree of soil development.

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