

Charge properties of kaolinite in acidic soils from Thailand

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Abstract

Oxisols and Ultisols of Thailand, generally have kaolinite as the dominant clay mineral. Surface charge properties of kaolinite in these soils have a major influence on chemical and physical properties of the soils yet a limited research has been done to determine the nature of the charge on soil kaolinites, especially in Thai soils. The objective of this study was to evaluate charge properties of kaolinite from highly weathered soils of Thailand. All soils exhibited an acid reaction and clay mineralogy was dominated by kaolinite. The pH in 1:1 H₂O, organic matter and cation exchangeable capacity (CEC) of Ultisols and Oxisols ranged from 4.3-5.1 and 4.4-5.6, 2.5-19.2 and 3.6-26.5 g/kg, 1.94-4.81 and 2.61-19.89 cmol_c/kg, respectively.

The width at half height (WHH) of kaolinite in Ultisols and Oxisols ranged from 0.22-0.66 and 0.5-1.22 °2θ respectively. There was an increase in the CEC of soil with increasing WHH of kaolinite suggesting that surface charge increase with decreasing crystallinity of kaolinite. Charge properties of kaolinite will be investigated by measuring the extent of permanent structural charge by cesium adsorption, and variable charge will be quantified by simultaneous proton titration and background electrolyte (LiCl) adsorption measurements. The research should provide a better understanding of kaolinite properties in soils and help in improving the productivity of kaolinite dominated soils in Thailand.

Key Words

Permanent charge, Variable charge, Acidic soils, Highly weathered soils

Introduction

Oxisols and Ultisols are highly weathered soils of the Tropics (Beinroth *et al.* 2000; West and Beinroth 2000). A large majority of Thai soils are highly weathered and clay fraction is often dominated by kaolinite (Wongvisittrangsri 1986; Yoothong *et al.* 1997). Surface charge properties of kaolinite are not only important for adsorption reactions but they also affect the dissolution behaviour of kaolinites (Chorover and Sposito 1995a). Limited research on the charge properties of soil kaolin from Thailand shows that the surface charge density of the Thai kaolins range from 0.16 to 0.99 C m⁻² in comparison to 0.18 C m⁻² for the Georgia kaolinite (Kanket *et al.* 2005). However, a little is known about the exact nature of the charge in kaolinite of Thai soils. This study aims to contribute towards an understanding of the surface charge properties of kaolinites in highly weathered soils of Thailand by measuring permanent and variable charges of kaolinite.

Methods

Five Ultisols and five Oxisols soil profiles were chosen for the study, and samples from three horizons of each of these profiles were taken for this study. Soils were air-dried, ground and passed through 2 mm sieve for various laboratory analyses. Soil pH was determined in 1:1 soil:solution ratio with distilled water. Organic carbon (OC) was determined by the Walkley-Black method (Nelson and Sommers 1996). Cation exchangeable cations were determined by displacing these with 1 M NH₄OAc at pH 7 solution and cation exchange capacity (CEC) was taken to be equivalent to the sum of exchangeable cations present in the leachate. Extractable acidity (EA) was determined by barium chloridetriethanolamine solution buffer at pH 8.2 (Thomas 1982). Particle size analysis was determined by the International pipette method (Gee and Bauder 1986).

Kaolinite in the clay fraction of soils was concentrated by dissolving iron oxides. CEC will be measured using 0.01 M silver thiourea (AgTU) solution at pH 4.7 to displace exchangeable cations (Rayment and Higginson 1992). Surface area of kaolinite will be measured using the N₂-BET method (Aylmore *et al.* 1970). Permanent and variable charges, and point of zero charge of soil kaolinites will be determined using the procedures described by Chorover and Sposito (1995b) and Phillips and Sheehan (2005).

Results and discussion

Important soil chemical and physical properties of the soils used in the study are given in Table 1. Soil pH of both Oxisols and Ultisols is highly acidic, with mean values of 4.7 and 4.9, respectively. Clay content in the Oxisols was significantly higher (709 g/kg) than the Ultisols (285 g/kg), and this is reflected in the corresponding CEC values of these soils with relatively higher CEC for Oxisols (mean = 10.7 cmol_c/kg) than the Ultisols (mean = 2.92 cmol_c/kg). These values are similar to those for the red Oxisols (mean 9.50 cmol_c/kg) and the red Ultisols (mean = 3.00 cmol_c/kg) in Thai soils (Trakoonyingcharoen *et al.* 2006). In general lower CEC values for both Oxisols and Ultisols indicated the dominance of kaolinite mineral in the clay fraction of these soils.

The clay fraction of the studied soils was dominated by kaolinite in both Oxisols and Ultisols (Figure 1). The WHH of soil kaolinite varied considerably and were generally higher of the Oxisols (mean = 0.73 °2θ) than the Ultisols (mean = 0.49 °2θ) (Table 1; Figure 1) suggesting that an increase in the CEC of soil with increasing WHH of kaolinite similar to Singh and Gilkes (1992) found that a general trend for CEC to increase with decreasing crystal size of soil kaolins. Permanent and variable charges, and point of zero charge are currently being determined using the procedures outlined by Chorover and Sposito (1995b) and Phillips and Sheehan (2005), and this data will be presented at the conference.

Table 1. Chemical and physical properties of highly weathered soils from Thailand.

Soil type	Soil Properties										WHH * 001 (°2θ)	
	pH (H ₂ O)	OC (g/kg)	Sand (-----g/kg-----)	Silt	Clay	Extractable bases						CEC
						Ca	Mg	Na	K	EA*		
Ultisols												
Minimum	4.3	1.45	498	66	176	0.09	0.04	0.07	0.02	1.7	1.94	0.22
Maximum	5.1	11.14	758	173	415	0.38	0.16	0.66	0.07	11.5	4.81	0.66
Mean	4.7	3.42	613	102	285	0.27	0.08	0.31	0.03	4.8	2.92	0.49
Median	4.7	2.78	604	98	259	0.25	0.08	0.29	0.03	3.6	2.69	0.54
SD	0.3	2.45	66	29	65	0.10	0.04	0.17	0.01	3.4	0.79	0.15
Oxisols												
Minimum	4.4	2.09	33	50	512	0.03	0.03	0.06	0.02	7.4	2.61	0.50
Maximum	5.6	15.37	333	422	868	3.77	1.26	3.20	0.25	22.4	19.89	1.22
Mean	4.9	5.58	112	179	709	0.95	0.38	0.41	0.07	13.4	10.70	0.73
Median	4.8	4.18	82	149	737	0.43	0.17	0.19	0.04	13.3	9.75	0.58
SD	0.4	3.80	92	118	123	1.30	0.43	0.71	0.06	4.1	4.39	0.26

* EA = Extractable acidity; WHH = Width at half height

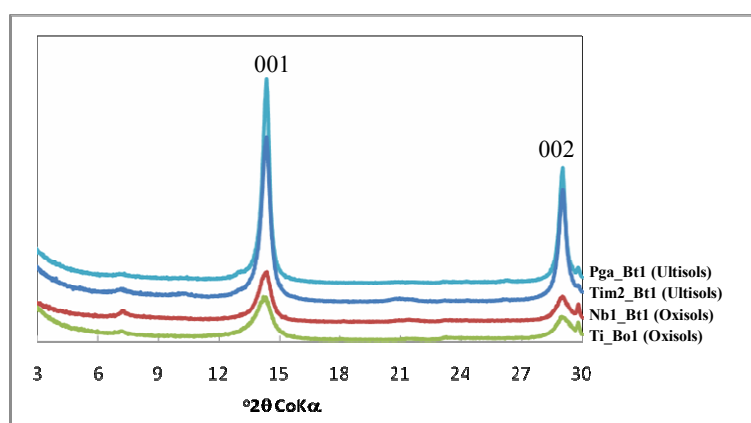


Figure 1. XRD patterns of the oriented specimens of some Oxisols and Ultisols from Thailand showing varying width at half height for the basal reflection of kaolinite.

Conclusions

Mineralogical and surface charge properties of kaolinite in Oxisols and Ultisols from Thailand were investigated to understand their influence on chemical and physical properties of these soils. The preliminary results indicate that the negative surface charge on kaolinite in these soils increases with decreasing crystallinity of kaolinite.

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