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Characterisation of Clay Separates in Major Soil Groups of Tamil Nadu

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ABSTRACT

Characterisation of clay minerals was attempted by fusion analysis with Na_2CO_3 and determination of CEC of the clay separates. Sixteen clay samples were chosen, four representing each soil group. The data revealed two extremes: the black soils were highly siliceous and laterite soil clay highly sesquioxidic. The soils could be arranged in a sequence, black, alluvial, red and laterite in the increasing order of kaolinite and decreasing order of montmorillonite. 1 : 1 clay minerals were dominant in alluvial soils with admixture of 2 : 1 clay minerals and kaolinite was found to be dominant in the red soil clays. The laterite soils were mainly kaolinitic. CEC and silica-sesquioxide ratio bore a close relationship between themselves and either of these could be used as a reliable indicator of clay minerals.

INTRODUCTION

The individual characteristic behaviour of the soil is to a large extent governed by the nature and distribution of clay minerals in the colloidal fraction. The chemical analysis of the clay separates from soils is one of the approaches to determine the nature of clay mineral. Besides the contents of the individual constituents, the molar ratios such as silica-sesquioxides ratio, silica-alumina ratio etc., are found to be within certain definite ranges of values, the magnitude of which depends on the nature of the clay mineral and is found to be characteristic of the clay material. The cation exchange capacity of soil clays is also often used as a parameter to represent the quality index of the clay mineral. The pattern of clay mineral distribution in the four major soil groups of Tamil Nadu is sought to be determined from the data on the chemical composition of the clay separates through fusion analysis and the relationships between the molar ratios and CEC, the parameters often used as quality indices of the soil clays, are deduced in the present study, taking the four heterogenous major soil groups of Tamil Nadu for arriving at this relationship.

MATERIALS AND METHODS

The sixteen soil samples selected for the present study consisted of four major soil groups of Tamil Nadu, namely, the black, red, alluvial and laterite soils, four from each group and collected from different locations in the State of Tamil Nadu (Table I). Clay separation was made by the method

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of Dewis and Freitas (1970) with necessary modification for removal of soluble salts, carbonates and organic matter. Fusion analysis and CEC were carried out according to the method given by Dewis and Freitas (1970).

RESULTS AND DISCUSSION

The data on the chemical composition of the clay separates are presented in Table I.

Black soil clays: Fairly high amounts of silica were associated with black soil clays followed by alluvial, although the silica content was not observed to vary within wide limits. The high silica content by itself was an indication of the siliceous nature and the presence of 2:1 mineral in black soil clays in cosiderable proportions. In addition, higher amounts of lime and magnesia were also observed to be present in those clays by Manickam (1961) and Chinnadurai (1967) by analysis of separated clays through acid digestion. Black soil clays also recorded high values of cation exchange capacity (70-90 me/100 g clay) and the values were considerably higher than in other soil clays. Similar high values of CEC were reported for black soil clays of India by a

TABLE I. Results of fusion analysis of clays (Percentages, on the ignited basis)

Location	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	Cao	Mgo	K_2O	CEC me/100g of clay
BLACK SOIL CLAYS								
1. Saravanampatti (Coimbatore)	58.61	31.17	9.20	21.97	5.63	3.55	1.65	84.0
2. Kallakurichi (South Arcot)	60 94	35.45	9.60	25.85	3.50	3.25	0.45	86.0
3. Kovilpatti (Tirunelveli)	61.94	29.34	9.70	19.64	1.54	5.30	1 28	93.0
4. Kulathur (Tirunelveli)	62.78	32.45	9.20	23.25	1.96	1.00	4.49	70.0
RED SOIL CLAYS								
5. Kallakadu (Tirunelveli)	58.12	40.09	8.00	32.09	1.33	0.10	1.13	18.5
6. Pollachi (Coimbatore)	55.90	40.96	12.00	28.96	1.54	1.45	5.09	35.0
7. Sulur (Coimbatore)	52.56	44.28	13.20	31.78	1.75	0.60	2.87	30.0
8. Salem (Salem)	57.01	41.99	13.20	28.79	0.98	1.05	1.28	26.0
ALLUVIAL SOIL CLAYS								
9. Aduthurai (Thanjavur)	62.46	34.78	11.20	23.58	1.33	0.70	1.70	52.0
10. Agastheeswaram (Kanyakumari)	57.91	39.78	10.40	29.38	3.01	2.20	3.24	46 5
11. Kalathur series (Thanjavur)	57.38	39.33	12.40	26.93	1.89	1.35	1.85	55 5
12. Adanur series (Thanjavur)	59.82	35.76	13.20	22.56	2.03	1.75	1.51	52.0
LATERITE SOIL CLAYS								
13. Ooty (Nilgiris)	41.92	57.83	16.40	41.43	0.77	0.80	2.19	31.0
14. Coonoor (Nilgiris)	53.97	47.19	10.80	36 39	0.63	0.10	0.83	33.0
15 Vallam (Thanjavur)	67.01	46.63	11.20	35.43	1.12	0 05	0.83	16.0
16. Red Hills (Chingleput)	43.63	56.84	14.40	42.44	0.84	0.55	1.70	18.5

number of investigators (Kulkarni and Deshpande, 1970.) The silica sesquioxides and the silica-alumina ratio were also found to indicate the montmorillonitic nature of black soil clays. Silica-sesquioxide ratios had values greater than 3 and those for silica-alumina ratios greater than 4. Roy *et al.* (1962) working on black soils reported that higher values of silica-sesquioxide ratios (2.70-3.51) and silica-alumina ratios (3.68-5.54) together with appreciable amounts of non-exchangeable magnesium indicated the presence of montmorillonite.

Red soil clays : The chemical composition of red soil clays revealed that silica content, in general, was lower than black soil clays but the sesquioxide content was distinctly greater than black soils and distinctly lower than laterite soil clays. Similarly lime and magnesia content were lower for red soil clays in comparison to black soil clays. The potash content was comparatively higher in red soil clays. The data on chemical composition closely agreed with the features described for 1 : 1 clay mineral. In addition, the presence of illite could also be inferred from the comparatively high amounts of potash content. Ghosh and Das (1963) observed that high amounts of potash in red soils of India were indicative of the presence of illite.

The CEC values for the red soil clays ranged from 18.5 to 35.0 me/100g of clay and as compared to black soil clays, the values were much lower. Chinnadurai (1967) obtained values of about 24.3 me/100 g of clay and attributed this to the presence of a mixture of minerals. Higher values observed in the present study could be explained due to the mixture of minerals, kaolinite being dominant.

The silica-sesquioxide ratios ranged from 2.22 to 2.66 and the silica-alumina ratios from 2.81 to 3.46 which indicated the dominance of kaolinite.

Alluvial soil clays : Silica was fairly high with the range lying intermediate between black and red soil clays. Sesquioxides, iron oxide and alumina were in higher proportions as compared to black soil clays and appeared to take intermediate position between black and red soil clays.

The lime and magnesia contents too were found to be higher than red soil clays but were lesser than black soil clays. It was clear that a certain regular pattern of distribution of these constitutents existed and alluvial soil clays could be placed in between black soils and red soils in respect of many of the chemical constituents (Table II). The CEC values of the alluvial soil clays fell in line with the general pattern of distribution of chemical constituents observed above, the values of CEC being intermediate between black and red soil clays- This trend continued even in respect of silica-alumina and silica-sesquioxide ratios (Table III). Thus in the clay mineral assemblage of alluvial soil clays, there was a regular pattern of distribution of 1:1 and 2:1 clay minerals, the latter occuring probably in slightly larger proportion as compared to the former.

TABLE II. Mean values for chemical constituents and cation exchange capacity (Fusion analysis of clays) (Percentages, on the ignited basis)

Clay	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	CEC me/100 g of clay
Black	61.06	32.10	9.42	22.67	3.13	2.27	2.01	83.25
Red soil	55.89	41.83	11.60	30.40	1.40	0.80	2.59	27.37
Alluvial soil	59.39	37.41	11.80	25.61	2.06	1.50	2.07	51.50
Laterite soil	51.63	52.12	13.20	38.92	0.84	0.37	1.38	24.62

There were varying reports of differing pattern of clay mineral distribution in alluvial soils. Chatterjee and Dhar (1968) reported that montmorillonite was present in dominant quantity. Chatterjee and Gupta (1970) noted that alluvial soils of Uttar Pradesh were mainly illitic. Rao and Chatterjee (1972), working on Tamil Nadu alluvial soils reported the presence of montmorillonite with low quantities of kaolinite and traces of illite. The variable composition of alluvial soil clays could be traced to the nature of the soil material transported. Krishnamoorthy (1966) and later Chinnadurai (1967) obtained evidence of the presence of kaolinite in dominant proportion The chemical composition, CEC values and molar ratios of alluvial soil clays, in the present study too indicated the dominance of 1:1 minerals with admixture of 2:1 minerals, the proportion of which was considered to be higher than the red soil.

TABLE III. Molar ratios of clay (Fusion analysis.

Clay	SiO_2 : Al_2O_3	SiO_2 : R_2O_3	SiO_2 : Fe_2O_3	Al_2O_3 : Fe_2O_3
BLACK SOIL				
1.	4.54	3.58	16.84	3.71
2.	4.01	3.25	16.91	4.22
3.	5.37	4.07	16.91	3.16
4.	4.59	3.66	18.03	3.93
Mean	4.62	3.64	17.17	3.75
RED SOIL				
5.	3.08	2.66	19.38	6.30
6.	3.46	2.74	13.09	3.79
7.	2.81	2.22	10.55	3.76
8.	3.37	2.60	11.45	3.40
Mean	3.18	2.55	13.61	4.31
ALLUVIAL SOIL				
9.	4.51	3.46	14.87	3.30
10.	3.35	2.73	14.85	3.43
11.	3.66	2.80	12.26	3.38
12.	4.51	3.28	12.01	2.66
Mean	4.00	3.06	13.49	3.19
LATERITE SOIL				
13.	1.72	1.37	6.79	3.94
14.	2.52	2.12	13.22	5.25
15.	3.22	2.21	15.95	4.96
16.	1.75	1.44	8.07	4.62
Mean	2.30	1.78	11.00	4.69

Laterite soil clays: The laterite soil clays invariably contained a higher proportion of sesquioxides indicating the sesquioxidic nature of the clays. In sharp contrast, the lime and magnesia status appeared to be the lowest.

This was in conformity with the generally observed low base status of the laterite soils reported by numerous investigators.

The CEC values were lower for laterite soil clays but the two clays from the hill district of Nilgiris registered slight higher values, attributable to the presence of other types of 1 : 1 mineral like halloysite and in fact shown to be present with electron micrographs in the present study. Narasinga Rao *et al.* (1961), working on latosols of Mysore State, India reported the presence of halloysite in addition to kaolinite. The silica - sesquioxide ratios too were lower (1.37 to 2.21) for the laterite clays, indicating the dominance of 1 : 1 type of clay mineral. The silica-sesquioxides ratios too were lower (1.37 to 2.21) indicating the dominance of 1 :1 type of clay mineral.

Relationships: Certain other interesting observations were also made known from the study. The CEC values and the molar ratios such as silica-alumina and silica-sesquioxide are largely used to characterize the pattern of clay mineral distribution. It was then thought whether any relationship could be established between CEC and molar ratios, these being the two parameters so frequently used to give an indication of the quality aspect of the soil clay. As surmised, hihly significant correlation was observed between the CEC values of the sixteen clays and the silica-alumina ratio ($r = 0.79^{***}$) and silica-sesquioxide ratio($r = 0.82^{***}$)(Table IV). This established that the two

TABLE IV. Results of statistical analysis for correlation (Fusion analysis of clays).

Independent variable x	Dependent variable y	Correlation coefficient r	Regression equation	No. of pairs of values N
Cation exchange capacity	Silica/Sesquioxide ratio	0.82***	Y= 1.5987+0.249x	16
Cation exchange capacity	Silica/Alumina ratio	0.79***	Y= 2.021 +0.0323x	16
Silica/Alumina ratio	Silica/Sesquioxide ratio	0.99***	Y= 0.1707+0.7342x	16
Silica/Alumina ratio	Silica/Iron oxide ratio	0.67**	Y= 5.1415+2.2900x	16
Silica/Alumina ratio	Alumina/Iron oxide ratio	-0.50*	Y=15.3838−0.4420x	16
Silica/Sesquioxide ratio	Silica/Iron oxide ratio	0.72***	Y= 8.7093+1.8518x	16
Silica/Sesquioxide ratio	Alumina/Iron oxide ratio	-0.43NS	—	16
Silica Iron oxide ratio	Alumina/Iron oxide ratio	0.25NS	—	16
Silica molar percentage	Sesquioxide molar percentage	-0.77***	Y= 0.8633−0.5276x	16
Silica molar percentage	Iron oxide molar percentage	-0.70*	Y= 0.1568−0.0859x	16
Silica molar percentage	Alumina molar percentage	0.72***	Y= 0.7066−0.4388x	16
Sesquioxide molar percentage	Iron oxide molar percentage	0.67**	Y= 0.0274+0.1239x	16
Sesquioxide molar percentage	Alumina molar percentage	0.99***	Y= 0.0274+0.8761x	16
Iron oxide molar percentage	Alumina molar percentage	0.55*	Y= 0.0968+2.6553x	16

*** =Significant at 0.1 per cent level   * =Significant at 5 per cent level
** =Significant at 1 per cent level   NS =Not significant

parameters CEC and molar ratios, ordinarily used for characterizing the clay bore a very close relationship between themselves, despite the divergent nature of the clay minerals from the four major soil groups of Tamil Nadu. The establishment of this relationship could further be exploited.

The use of easily determined CEC as a fairly reliable indicator of the nature of the clay mineral was therefore justified. That the relationships between CEC and molar ratios were of high order, also indicated that CEC values could be successfully used as quality index of clays in regression equations for prediction of soil properties from a knowledge of quantity and quality of soil clays. Interrelationships between the molar ratios themselves could be observed (Table IV). These could be understandably so as there was a certain amount of interdependence between some of the constituents, but nevertheless useful for prediction of one from another constitutent.

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