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Evaluation of Sensitivity to Slaking by Bulk Density Measurements of Disrupted Fragments (Aggregates)

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Key words: **slaking; bulk density measurements; aggregates.**

RINGKASAN

Kajian ini menunjukkan selain dari keempat-empat faktor iaitu: pemeraian, penyerakan, kandungan karbonat atau gipsum dan flokulasi, saiz dan ketumpatan pukal agregat-agregat yang terperai adalah juga mustahak dalam mengkelaskan tanah-tanah mengikut kelas keperaian air. Bagi tanah Ultisols dan Oksisols, didapati agregat-agregat tanah-tanah itu tidak akan terperai jika mempunyai saiz > 1 mm dan ketumpatan pukal yang sekurang-kuranganya 1.7 g cm^{-3}.

SUMMARY

The study shows that other than the four factors viz: slaking, dispersion, carbonate or gypsum content and flocculation, the size and bulk density of disrupted aggregates are also important when classifying the soils into their corresponding water coherence classes. It was found that for the Ultisols and the Oxisols, the aggregates will not slake further if they have a size of > 1 mm and a bulk density of at least 1.7 g cm^{-3}.

INTRODUCTION

In many tropical areas, slaking together with the detachment of soil particles by raindrop impact are the two main causes of serious soil erosion. Slaking here is defined as the macroscopic breakup of dry aggregates on wetting. Emerson (1967) classified the soils into their water coherence classes based on their response to slaking and dispersion. The criteria use in this classification are: slaking, dispersion, carbonate or gypsum content and flocculation. The procedure is given in *Figure 1.*

De Boodt and Carera (1980) found that the size and the bulk density of the disrupted aggregates can be useful in assessing the sensitivity to slaking of saline soils. This paper, examines how the two properties can be related to the degree of slaking of acid tropical soils rich in kaolinitic minerals with hydrous oxides of iron and aluminium.

MATERIALS AND METHODS

Four soil series namely Bungor, Durian, Serdang and Malacca were used in this study. Samples were collected from the topsoil (0–15 cm) and the subsoil (15-30 cm) of each profile. Some of the important properties of these soils are given in Table 1. Based on Emerson's method, the soils were classified into their corresponding water coherence classes (Fig. 1).

3–5 mm air dry aggregates were submerged in distilled water in a flat-bottomed disc for a week care being taken to avoid any disturbance. After complete slaking of the aggregates, the excess water was slowly siphoned out. The disrupted aggregates were dried by the replacement of the soil moisture with organic liquids as described by Jongerius and Heintzberger (1975). To allow for a gradual replacement of the soil moisture, increasing concentrations of the aqueous solution of the organic liquid (methanol) were added. For each addition, an equilibrium period of 24 hours was allowed after which the organic solution was slowly siphoned out. The dry disrupted aggregates were then sieved into various sized fractions of 0.3–0.5, 0.5–1, 1–2, 2–3 and 3–5 mm in diameter.

Two methods were employed for the measurement of the bulk density of the disrupted aggregates:

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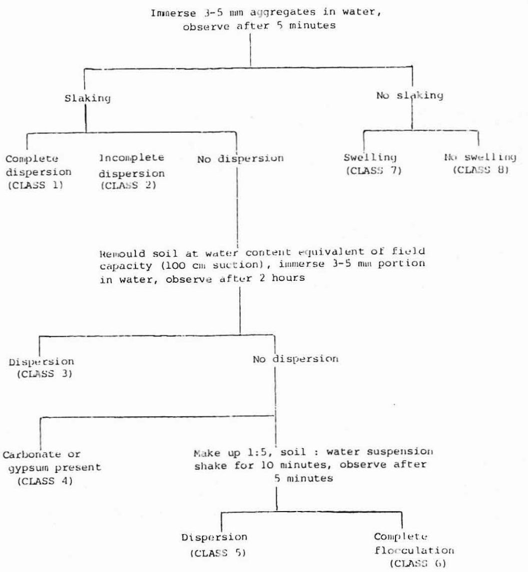

Fig. 1. A classification of soil aggregates according to their slaking and dispersion in water.

a) For aggregate size of 3–0.2 mm diameter, the packing method recommended by Chepil (1960) and later improved by Bisal and Hinman (1972) was used, and

b) For aggregates of 2–5 mm diameter, the floatation method (Campbell, 1973) using zinc chloride solution was employed.

RESULTS AND DISCUSSION

Table 2 gives the results of the slaking and swelling tests. It was observed that within the soils, the susceptibility to slaking was always higher in the subsoil than in the topsoil and was probably associated with the decline of the organic matter content with depth.

During the slaking step, it was observed that the aggregates of the more stable Bungor topsoil retained their identity even after a week of immersion in water. No aggregates < 2 mm were collected (Table 3). On the other hand, the aggregates of the less stable Durian and Serdang subsoils crumbled into pieces almost immediately on wetting and very little or no aggregates > 1 mm were collected. These observations conform with the aggregate stability data given in Table 1.

The examination of the data on the bulk density of disrupted aggregates of the less stable aggregates as indicated by instability index (Table 3) suggests that proper slaking will not occur when the natural water-stable aggregates satisfy the following two conditions simultaneously: 1) the diameter of the disrupted aggregates should be larger than 1 mm; and b) the bulk density of these aggregates should at least be 1.7 g cm^{-3}. This means that aggregates with a diameter of 1 mm or less, having a density lower than 1.7 g cm^{-3} will slake further into finer fragments. This suggests that when assessing the sensitivity of the soils to slaking, besides the four factors used by Emerson,

TABLE 1
Some of the properties of the soils

Series	Horizon	% organic matter	% $CaCO_3$	pH	% <2μm	% 2–50μm	Water coherence class	Instability index (mm)[1]
Bungor	topsoil	1.5	0.5	5.6	39	9	8	0.26
	subsoil	0.5	0.1	5.0	51	13	6	2.30
Durian	topsoil	1.0	0	4.5	23	35	7	1.59
	subsoil	0.4	0	4.4	38	26	5	3.82
Serdang	topsoil	1.0	0	4.4	24	9	7	1.59
	subsoil	0.5	0	5.1	34	9	5	4.02
Malacca	topsoil	0.6	0	4.8	45	25	5	0.95
	subsoil	0.6	0	4.9	46	23	5	1.30

[1] As measured by the dry and wet sieving method of De Leenheer and De Boodt (1959). The smaller the value the more stable the aggregates.

TABLE 2
Slaking and swelling tests and water coherence class of the soils

Series	Horizon	a. Slaking test			b. Swelling test		
		Total aggs.	Slaked	Not-slaked	Total aggs.	Swollen	Not-swollen
Bungor	topsoil	50	8	42	42	8	34
	subsoil	50	50	–	–	–	–
Durian	topsoil	50	10	40	40	30	10
	subsoil	30	–	–	–	–	–
Serdang	topsoil	50	14	36	36	32	4
	subsoil	50	49	1	1	1	–
Malacca	topsoil	50	42	8	8	7	1
	subsoil	50	50	–	–	–	–

TABLE 3
Mean values of bulk density (g. cm^{-3}) of the disrupted fragments (aggregates) obtained from the slaking test

Series	Horizon	Bulk density of water stable agg. of sizes (mm)					Bulk density of air dry clod (>8 mm)	Instability index
		0.3-0.5	0.5-1.0	1-2	2-3	3-5		
Bungor	topsoil	–	–	–	1.70	1.60	1.53	0.26
	subsoil	1.60	1.75	1.70	1.70	1.60	1.63	2.30
Durian	topsoil	2.00	1.75	1.70	1.70	1.70	1.61	1.59
	subsoil	1.92	1.80	–	–	–	1.67	3.82
Serdang	topsoil	2.11	1.92	1.70	1.70	1.70	1.60	1.59
	subsoil	2.11	1.98	–	–	–	1.58	4.02
Malacca	topsoil	1.90	1.75	1.70	1.70	1.60	1.59	0.95
	subsoil	1.82	1.70	1.70	1.70	1.60	1.55	1.30

the size and bulk density of the disrupted aggregates should also be considered. This aspect is important particularly in the case of Ultisols and Oxisols because of the predominance of iron and aluminium oxides in the clay fractions. These oxides which are positively charged at pH of the soils (Gallez *et al.*, 1976; Van Raij and Peech, 1972) bind the negatively charged clay domains and these domains and the silt-size particles (quartz) (Fig. 2) very strongly forming rather compact and heavy aggregates which are resistant to slaking.

It is a general rule that a good agricultural soil must have a bulk density in the order of 1.2–1.3 g cm^{-3}. While this is necessary for good water and air transmission, the occurrence of relatively heavy aggregates is also desirable because they are not readily transported by run-off water and hence, reduce the susceptibi-

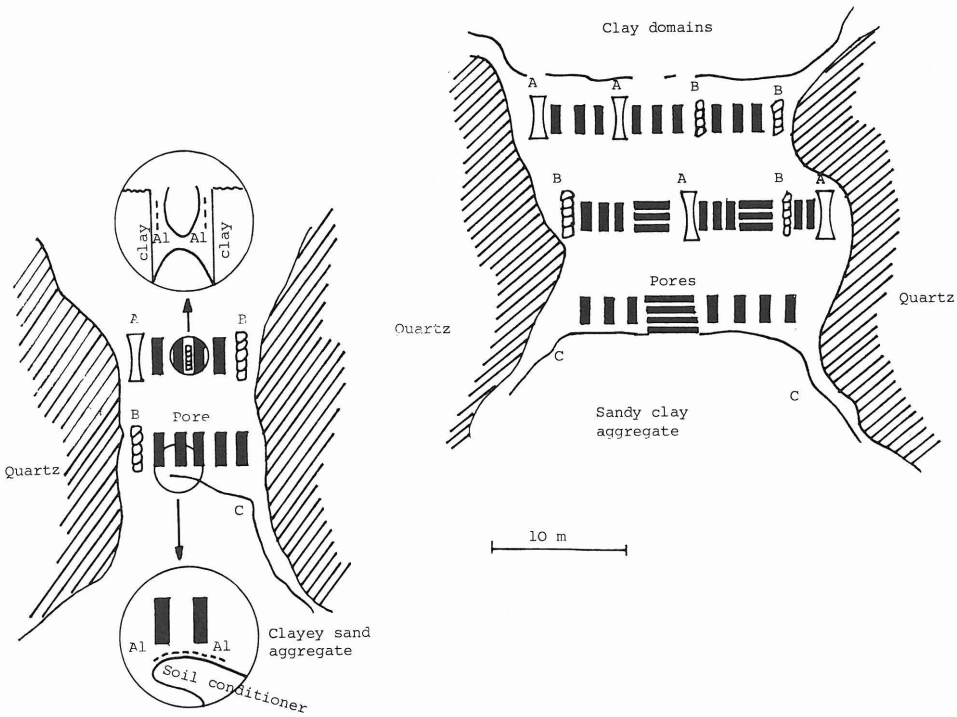

Fig. 2. Model of a soil aggregate stabilized by organic matter or by soil conditioners showing clay domains, organic matter and quartz.

A = weak linkage due to water meniscus
B = very strong linkage due to humus or sesquoixides
C = linkage due to miscelles or polymers (soil conditioners)
dotted lines indicate H-bonding
Notice also the role of aluminium ions. Magnified inserts: organic matter-clay interaction or polymer-clay interaction (after Emerson, 1977).

lity of the soil to erosion by water i.e. its erodibility.

CONCLUSION

In addition to the slaking, dispersion, gypsum or carbonate content and flocculation status of the soils, the size and the bulk density of the natural water-stable aggregates can be very useful criteria when assessing the sensitivity of soils to slaking and dispersion. Proper slaking of the aggregates will not occur when the natural water-stable aggregates have a diameter of larger than 1 mm and a density of at least 1.7 g cm^{-3}.

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