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Modification of Soil Structure of Sand Tailings: I. Preliminary Study on the Effect of Organic Amendment and Iron on Soil Aggregation

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ABSTRAK

Keberkesanan efluen kilang kelapa sawit kering yang mengandungi 14% karbon organik dan larutan besi dalam menggalakkan pengaggregatan di tanah pasir bekas lombong dikaji. Penambahan besi atau efluen kilang kelapa sawit kering pada kadar 20 dan 60 t ha^{-1} tidak memberikan kesan bererti ke atas pengaggregatan dan kestabilan tanah pasir. Pada kadar 100 t ha^{-1}, efluen kilang kelapa sawit memberikan kesan bererti ke atas kestabilan aggregat. Dengan penambahan 0.1% Fe, kadar efluen kilang kelapa sawit kering yang diperlukan untuk pengstabilan dapat diturunkan hampir separuh. Walau bagaimanapun darjah pengaggregatan masih rendah (% pengaggregatan > 2 mm = 5.6%). Ini mungkin disebabkan kandungan pasir sangat halus dan kelodak adalah rendah iaitu hanya 5.8% dan ketiadaan lempung dalam tanah pasir bekas lombong itu. Hasil kajian ini mencadangkan untuk pembaikan struktur tanah pasir bekas lombong dengan menggunakan pembaik tanah, kehadiran juzuk-juzuk tanah halus iaitu lempung dan kelodak dan/atau pasir halus dalam kadar yang mencukupi adalah sangat perlu. Kehadirannya akan menyebabkan pembentukan struktur yang lebih baik bagi tanah pasir oleh pembaik tanah dan seterusnya menyebabkan pembaikan ekonomi air dan nutrien tanah itu.

ABSTRACT

The effectiveness of dried palm oil mill effluent (decanter cake), which contains 14% organic carbon, and iron solution in promoting aggregation in sand tailing soil was determined. The addition of iron or decanter cake at rates of 20 and 60 t ha^{-1} had no significant effect on the aggregation and stability of the sand. At a higher rate of 100 t ha^{-1}, decanter cake gave a significant effect on aggregate stability. With the addition of 0.1% Fe, the rate of decanter cake application for effective stabilization was reduced to almost half. However, generally the extent of aggregation was low (% aggregation>2mm was only 5.6%). This could be due to the low amount of very fine sand and silt, amounting to only 5.8%, and the absence of clay in the sand tailings. It is postulated that an improvement in the soil structure of sandy tailings using amendments essentially requires the presence of fine soil fractions viz. clay and silt and/or very fine sand in sufficient amounts. Their presence will lead to better soil structure formation in the sand tailings by the amendments and hence to better water and nutrient economy of the soil.

INTRODUCTION

Large tracts of land are laid waste after tin mining operations. In 1984, the total hectareage of tin mining lands in Peninsular Malaysia was approximately 113,700 ha (Chan, 1990). Eighty percent of this is sand tailings on which it is difficult to establish vegetation because of the absence of organic matter and the predominance of coarse materials leads to excessive drainage, low water and nutrient retention capacities and high surface temperatures (Lim *et al.*, 1981; Shamshuddin *et al.*, 1986; Mokhtaruddin and Wan Sulaiman, 1990).

Rehabilitation of sand tailings for agriculture can be based on three approaches. These are: improvement in soil water economy by soil structurization; raising the fertility status and reducing leaching losses by organic amendments;

and lowering surface temperatures by mulching. Structurization can be achieved by adding organic matter. In Malaysia, palm oil mill effluent (POME), of which Malaysia produced about 18 million tonnes in 1990, can be a potential source of organic matter. POME, if not utilized, can cause environmental pollution. The use of POME to improve the physical conditions of mineral soils has been reported by many authors (Lim *et al.*, 1983; Wan Sulaiman *et al.*, 1981) but its use to improve the structure of sandy soil is little studied. Besides organic matter, polyvalent metals such as iron (Fe) are known to promote aggregation and stability of soils (Deshpande *et al.*, 1968; Krishna Murti and Rengasamy, 1976). Further Mokhtaruddin (1983) showed that interaction of organic matter and Fe has a synergistic effect in improving aggregate stability.

The objective of this paper is to evaluate the effectiveness of POME, alone or in combination with Fe, as a soil conditioner to promote soil aggregate formation in sand tailings.

MATERIALS AND METHODS

Soil

Sand tailings used were collected from the Universiti Pertanian Malaysia tin-tailing research area. Particle size distribution was determined using the pipette method of Day (1965). Organic carbon content was determined by the wet digestion method of Walkley and Black (Allison, 1965). Free iron oxide was determined by the dithionite-citric-bicarbonate (DCB) method of Mehra and Jackson (1960). Soil pH was measured from 1:2.5 soil/water suspensions. The results are presented in Table 1.

Palm Oil Mill Effluent

The type of POME used was the decanter-dried raw POME (decanter cake). The decanter cake was analysed for its nutrient and carbon contents. Nitrogen was determined by the normal Kjeldahl method and P, K, Ca, Mg and Fe by the dry ashing method (Sharifuddin and Dynoodt, 1981). The amount of N, P and K was measured using an autoanalyser, and Ca, Mg and Fe with an atomic absorption spectrophotometer. Organic carbon was determined by the wet digestion method of Walkley and Black (Allison, 1965). The results are presented in Table 2. Ferrous sulphate was used as a source of Fe.

Experimentation

Air-dried sand (<2mm, 1020 g) in three replicates were treated with 0, 10.5, 31.4 and 52.3 g of decanter cake which corresponded to an application rate of 0, 20, 60 and 100 t ha^{-1}. The sand-decanter cake mixtures were thoroughly mixed and then sprayed with a 0.1% iron solution (ferrous sulphate) or distilled water (0% Fe) until field capacity. Samples were placed in a plastic bag and incubated for 48 hours at ambient temperatures. After incubation they were air-dried. The extent of aggregation was evaluated by the dry sieving technique. In the dry sieving, 100 g of air-dried sample was placed on a nest of sieves with 8.00, 4.75, 2.80, 2.00, 1.00, 0.50 and 0.30 mm openings. The sieves were shaken manually in circular motion ten times. Aggregates remaining on each sieve were weighed. The extent of aggregation was expressed as the fraction of air-dried aggregates >2mm (% aggregation > 2mm). The aggregate stability was determined by the wet sieving technique of Yoder (1936). A 100 g of air-dried sample (<2mm) was placed on a 0.5 mm size sieve. The sieve was shaken up and down in water at a frequency of 40 oscillations per minute for 30 minutes. The height of oscillations was 4 cm. The aggregates remaining on the sieve were dried and weighed. The aggregate stability was expressed as percent water-stable aggregates >0.5mm (%WSA>0.5mm) (Bryan, 1969).

RESULTS AND DISCUSSION

Extent of Aggregation

The sand tailings contain more than 99% sand and trace amounts of clay with negligible very fine sand and silt fractions (Table 1), which are known to act as the skeleton in aggregate formation (Emerson, 1959). This together with the very low contents of organic matter and free iron oxides made the sand tailings structureless.

Percent Aggregation >2mm

Percent aggregation of the sand tailings was not affected by the addition of iron or decanter cake (Table 3). Possible causes were (a) the lack of very fine sand and silt fractions which hinder the formation of aggregates, and (b) the inert

TABLE 1
Particle size distribution and some of the chemical properties of the sand tailings

Fraction	Size (mm)	%
Coarse sand	> 0.50	17.4
Medium sand	0.25 - 0.50	36.5
Fine sand	0.10 - 0.25	40.9
Very fine sand	0.05 - 0.002	0.2
Clay	< 0.002	Tr
pH	-	5.42
Carbon	-	0.15
Free iron oxides	-	Tr

Tr = Trace

TABLE 2
Carbon and nutrient contents of decanter cake

Element	N	P	K	Ca	Mg	Fe	C
Content %	1.14	0.17	0.99	1.19	0.24	0.139	14.4

nature of the sand tailings, which contained more than 99% sand, making the iron or decanter cake ineffective in promoting aggregation. Figure 1 indicates that although the binding of quartz particles by organic matter (Q-OM-Q) might have taken place, the binding seemed weak and could not resist the dry sieving process.

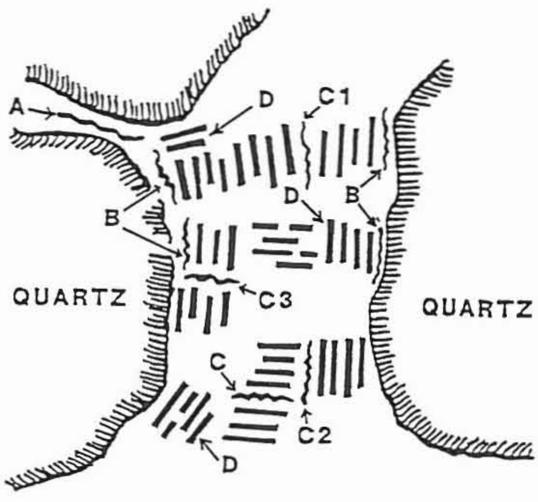

Fig. 1: Possible bonds between clay domains, organic matter and sand particles in an aggregate. Quartz–Organic Matter–Quartz [Q–OM–Q]. [After Emerson, 1977]

A : Quartz–Organic Matter–Quartz [Q–OM–Q]
B : Quartz–Organic Matter–Clay Domain [Q–OM–C]
C : Clay Domain–Organic Matter–Polivalent Metal–Clay Domain [C–OM–P–C]
D : Clay Domain Edge–Clay Domain Face [C–C]

In combination with iron, only the highest rate of decanter cake application (100 t ha^{-1}) showed a significant effect on the percent aggregation (Table 3).

Percent Water-stable Aggregates >0.5mm (%WSA>0.5mm)

Table 4 shows the effect of iron, decanter cake and their combination on aggregate stabilty. As

TABLE 3
Comparison between mean percent aggregation of control and treatments using LSD test

Treatment	Mean % aggregation[a]	Difference from control[b]
Control	4.3	-
0.1% Fe	4.0	-0.3[ns]
20 t ha^{-1} decanter cake	4.0	-0.3[ns]
60 t ha^{-1} decanter cake	4.3	0.3[ns]
100 t ha^{-1} decanter cake	6.0	1.7[ns]
20 t ha^{-1} decanter cake + 0.1% Fe	5.7	1.4[ns]
60 t ha^{-1} decanter cake + 0.1% Fe	5.3	1.0[ns]
100 t ha^{-1} decanter cake + 0.1% Fe	11.3	7.0[**]
LSD (5%)		4.36
LSD (1%)		6.05

[a] Average of 3 replications
[b] ** = Significant at 1% level, * = Significant at 5% level, ns = Not significant

TABLE 4
Comparison between mean percent WSA > 0.5 mm of control and each of the treatments using LSD test

Treatment	Mean % aggregation > 2 mm[a]	Difference from control[b]
Control	23.3	-
0.1% Fe	21.7	1.6[ns]
20 t ha^{-1} decanter cake	23.0	-0.3[ns]
60 t ha^{-1} decanter cake	24.7	1.4[ns]
100 t ha^{-1} decanter cake	33.0	9.7**
20 t ha^{-1} decanter cake + 0.1% Fe	27.3	4.0[ns]
60 t ha^{-1} decanter cake + 0.1% Fe	33.3	10.0**
100 t ha^{-1} decanter cake + 0.1% Fe	33.7	10.4**
LSD (5%)		6.55
LSD (1%)		9.09

[a] Average of 3 replications
[b] ** = Significant at 1% level, * = Significant at 5% level, ns = Not significant

with percent aggregation, aggregate stability was not significantly affected by the addition of Fe. The addition of decanter cake at the rate of 20 and 60 t ha^{-1} slightly increased the stability of the aggregates but the increase was not significant. At the highest rate of 100 t ha^{-1}, decanter cake gave a significant increase in aggregate stability. This is in accordance with the known fact that organic matter in adequate amounts is needed for the formation of water-stable aggregates. In combination with iron, the higher rates of decanter cake application (60 and 100 t ha^{-1}) gave a significant increase in the aggregate stability but the lowest rate of 20 t ha^{-1} did not. It appears that the addition of 0.1% Fe was able to reduce the amount of decanter cake required for effective stabilization implying that the interaction of iron and organic matter was partly responsible in aggregate stabilization in sandy soils. Giovannini and Sequi (1976) suggested that iron forms bridging between organic polymers (-OM-P-OM-), which binds the sand particles more strongly.

The above findings suggest that the combination of decanter cake and iron has a greater effect than the decanter cake or iron alone on the stability of aggregates in sandy tailings. However, the overall extent of aggregation resulting from this treatment was still low (average % aggregation > 2mm is 5.6%, Table 2). Previous work has demonstrated a similar effect in that the addition of organic amendments to sandy soils failed to give positive response to the aggregation and stability of these soils (Lim *et al.*, 1983; Othman *et al.*, 1990). On the other hand, when similar experiments were carried out on mineral soils, a significant increase in aggregation and stability was noticed (Mokhtaruddin, 1983; Mokhtaruddin and Wan Sulaiman, 1987).

Figure 1 clearly shows that for good aggregation in the sand tailings, the presence of clay, silt and very fine sand fractions is indispensible. Clay particles is a well known cementing material binding the skeletal materials, such as very fine sand, together into aggregates (Peterson, 1946; Kemper and Koch, 1966; Dixon, 1991).

CONCLUSION

Iron and organic matter are known as excellent aggregating and stabilizing agents in soils. Nevertheless,this study shows that the addition of iron or decantered dried raw POME (decanter cake) at 20 and 60 t ha^{-1} to the sand tailings (which comprised more than 99% sand) had no effect on aggregation and stability. At higher rates (100 t ha^{-1}), decanter cake had a positive effect on aggregate stability. In combination with iron, the rate of decanter cake application can be reduced to 60 t ha^{-1} for effective stabilization. However, the overall extent of aggregation resulting from the latter treatment was low (% aggregation > 2mm = 5.6%). The most probable explanation was the lack of very fine sand and silt fractions, which act as skeleton in the formation of aggregates, and the absence of clay, which interacts with organic polymer and polyvalent metal to form a strong bond. It is therefore postulated that the presence of fine fractions in sufficient quantity is a prerequisite for soil structure improvement or development in sand tailings using amendments.

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