Pertanika 9(1), 89 – 97 (1986)

Morphology, Mineralogy and Chemistry of an Ex-Mining Land in Ipoh, Perak

J. SHAMSHUDDIN, NIK MOKHTAR and S. PARAMANANTHAN
Department of Soil Science,
Faculty of Agriculture,
Universiti Pertanian Malaysia,
43400 Serdang, Selangor, Malaysia.

Key words: Sandy deposits; slime; organic matter; morphology; mineralogy.

ABSTRAK

Satu kajian telah dijalankan untuk mencirikan 20.3 ha tanah bekas lombong di Kg. Kepayang Baru, Ipoh. Keputusan kajian menunjukkan tanah bekas lombong itu boleh dikelaskan kepada tiga kumpulan iaitu endapan berpasir, endapan berlempung dan campuran berpasir dan berlempung. Kandungan bes, karbon organik, fosforus and nitrogen didapati sangat rendah. KPK juga rendah, tetapi pH tanah sangat tinggi. Mineral dominan di dalam bahagian lempung ialah kaolinit, mika dan klorit.

ABSTRACT

A study was carried out to characterize the 20.3 ha of ex-mining land at Kg. Kepayang Baru, Ipoh. The study shows that the ex-mining land can be classified into three groups i.e., sandy, clayey and a mixture of sandy and clayey deposits. The bases, organic carbon, phosphorus and nitrogen contents are very low. The cation exchange capacity is low, but pH is very high. The dominant minerals in the clay fraction are kaolinite, mica and chlorite.

INTRODUCTION

Active tin mining in Malaysia took place in the late nineteenth century, immediately after the British colonization of the Malay Peninsula had begun. As a result of about 100 years of mining, the country is now left with over 200,000 ha of ex-mining land. The largest concentration of these abandoned mines occur in the vicinity of Ipoh and Kuala Lumpur. The lands often have sandy deposits, clayey deposits and areas with mixtures of the two often with mining pools interpersed throughout the area.

Mining activities have been cited to cause destruction of plants and animals, shallowing of river bed, siltation of drainage system and destruction of agricultural land. The ex-mining land, usually referred to as tin-tailing areas, are known to have low water holding capacity, high hydraulic conductivity, low nutrient status and poor structural stability (Lim *et al.*, 1981). In some areas, in particular in the vicinity of Dengkil, Selangor, the pH is very low with values of 2.8 – 3.0 (Maesschalck and Lim, 1978). If the mining areas are underlain by limestone, the pH could rise to 7 or more. The soils are also limited by high soil surface temperatures, which can go up to as high as 45°C on a hot sunny day (Maene *et al.*, 1978).

A typical ex-mining land consists of pond (sometime very deep) surrounded by sand and a mixture of silt and clay deposits usually referred to as slime *(Fig. 1)*. There can also be areas where slime and sand occur together. It is this separation of sand and slime that limits the soils for crop production because they are either too

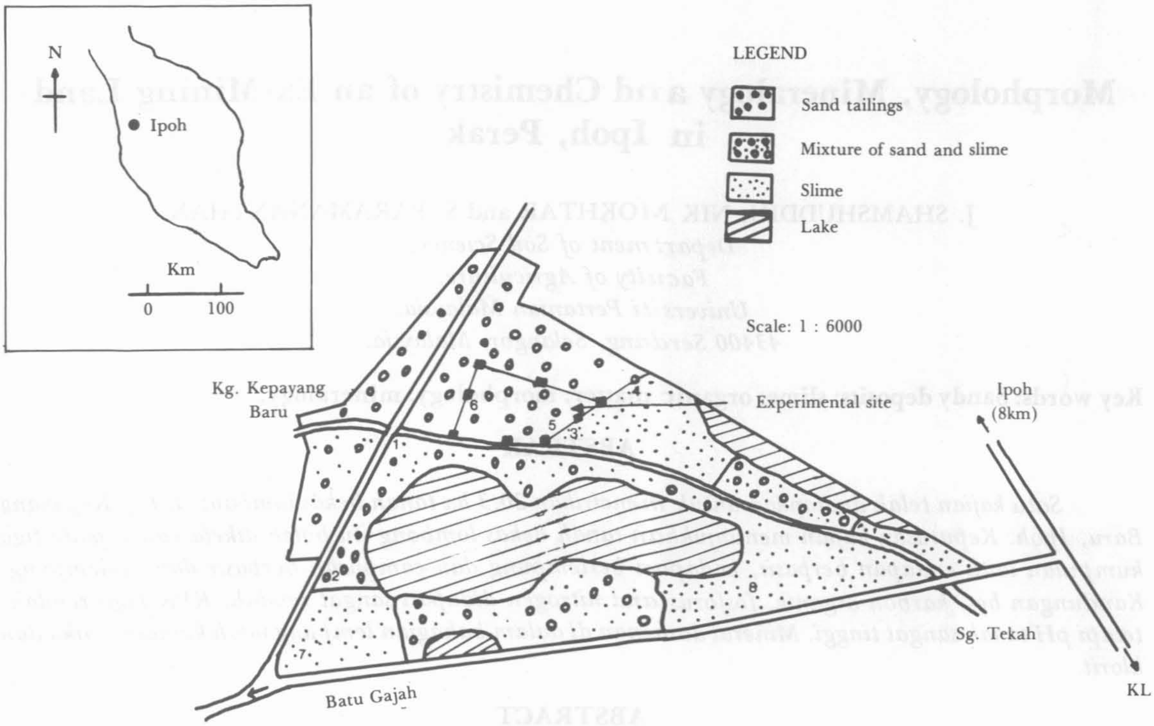

Fig. 1: A soil map of ex-mining land at Kg. Kepayang Baru, Ipoh

sandy or too clayey. In either case, soil structural development is very slow or none.

Research into the application of various types of organic materials to ameliorate tin-tailings and trials on the suitability of various types of legumes have been carried out (Lim *et al.*, 1981). It is reported that these soils have potential for crop production if properly managed. As such some of the tin tailings in the vicinity of Kuala Lumpur and Ipoh are intensively cultivated for vegetable and fruit production (Tan and Khoo, 1981). The farmers in the areas use organic manures and sprinkler irrigation to grow their crops.

The objective of this paper is to characterize the ex-mining land at Kg. Kepayang Baru, Ipoh morphologically, mineralogically and chemically and to relate these properties to management practices for crop production. Some of the data available in this paper might be useful to soil scientist, agronomists, agricultural planners and geologists, as very little work to characterize these deposits have been reported.

MATERIALS AND METHODS

The area under consideration is situated about 8 km south of Ipoh, roughly at longitude 101° 10′ E and latitude 4° 32′ N, in an area known as Kinta Valley. Kinta Valley is well known throughout the world for her rich placer tin deposits. The valley is surrounded by acid pluton of Carboniferrous age (Gobbett, 1972) to the east and west. The alluvial deposits, which are mainly derived from the granitic mountains, are underlain by limestone of Upper Paleozoic age. Tin deposits are found in the alluvial materials overlying the limestone.

About 20.3 ha (50 acres) of ex-mining land at Kg. Kepayang Baru, 8 km from Ipoh have been set aside by the Department of Agriculture, Perak for agricultural research by the staff of Soil Science Department, Universiti Pertanian Malaysia. The area was identified and subsequently surveyed in detail, and a soil map was prepared *(Fig. 1)*. The four mapping units shown in *Fig. 1* describe the textural properties of the tin-tailings and their geographical distribution. The Arabic numerals (1, 2, 3 ... 8)in the map indicate the observation points where samples were examined and collected.

At the observation points of interest, a set of data were compiled and these are given in Table 1. The data in Table 1 are presented in the form of a formula: —

$$\frac{1.2 - 3.4}{5.6}$$

where,

1 = texture at 25 – 50 cm depth
2 = profile development
3 = colour at 25 – 50 cm depth
4 = drainage
5 = surface texture
6 = soil depth

This is actually a modified version of the Field Legend (Paramananthan, 1978) in which parent material and terrain class are not taken into account.

Samples were collected by an auger at three depths, namely 0 – 15, 15 – 30 and 30 – 45 cm. These samples were air-dried, ground and sieved to pass through a 2 mm sieve. Analysis for texture, pH (H_2O), bases, CEC (NH_4OAc), P, C, N, Fe_2O_3 and micronutrients (Zn, Mn, Cu) by aqua regia were subsequently carried out. pH_0, which is an important soil chemical parameter, was determined by the method of Gillman and Uehara (1980). Total Na, K, Mg, Al, Mn, Fe and heavy metals (As, Dy, V, Co, Sb, Cr, U) were determined by nuclear activation analysis (NAA) using facilities available at Unit Tenaga Nuklear (Puspati), Bangi. The pH of water in the ponds was also determined.

The type of minerals present in the clay fraction was identified by X-ray diffraction (XRD) analysis. A complementary study by transmission electron microscopy (TEM) to identify clay minerals was also carried out.

TABLE 1
Morphological properties of ex-mining land at Kg. Kepayang Baru, Ipoh

SITE (Sample No.)	SOIL PROPERTIES (January 1985)
1	*Sandy loam ● Entisol — 10 YR 5/6 ● Poorly drained* Sand ● Deep
2	*Clay loam ● Entisol — 5 YR 5/6 ● Well drained* Loan ● Deep
3	*Silty loam ● Entisol — 10 YR 3/6 ● Watertable 50 cm* Clay loam ● Deep
4	*Sand ● Entisol — 10 YR 4/4 ● Watertable 60 cm* Flat Silty Clay ● Deep
5	*Sand ● Entisol — 10 YR 5/6 ● Well drained* % Sand ● Deep
6	*Sand ● Entisol — 5 YR 5/6 (Mottle 2. 5 YR 5/8) ● Well drained* Sand ● Deep
7	*Silty clay ● Entisol — 5 YR 5/6 (Mottle 10 YR 6/6) ● Watertable 50 cm* Silty Clay ● Deep
8	*Clay ● Entisol — 10 YR 4/6 ● Well drained* Clay ● Deep

RESULTS AND DISCUSSION

Morphology

Morphologically, there is no profile development in the tin-tailings as a whole, as such horizon differentiation is non-existent. This is because the deposits are young and therefore not much affected by soil forming processes, as the mine ceased operation only about 10 years ago. These soils could thus be classified as Entisols.

Generally, the sandy deposits occur in the well drained areas, while the slimes occur in the depressions, where the watertable varies from 50 – 60 cm depth. During the rainy season the watertable in the depressions could rise to the surface and cause flooding.

The clayey materials appear to be reddish, with colour notation of 5YR 5/6 or redder, could be due to leaching of some iron-rich materials. In some areas, the textural composition changes with depth, especially at sites 3 and 4. At site 4 (see map), the top 30 cm of the deposits are clayey, but at 30 – 45 cm they are sandy with a sand content of more than 95%. At best, we can describe the texture of tin-tailings as variable both vertically and horizontally.

Physical Properties

The textural distribution with depth of the studied samples is given in Table 2. Taking the case of the sandy deposits (sites 1, 5 and 6), it is noted that the sand content is very high with values exceeding 90%. This condition results in

TABLE 2
Textural and Selected Elemental Composition

SITE (SAMPLE) NO.	DEPTH (cm)	TEXTURE (%)			TOTAL ANALYSIS (%)					
		Sand	Silt	Clay	Na	K	Mg	Al	Mn	Fe
1	0 – 15	94.2	1.5	1.9	0.09	1.12	2.23	14.20	0.26	1.65
	15 – 30	90.3	4.2	3.1	—	—	—	—	—	—
	30 – 45	57.5	27.7	13.3	0.08	1.10	0.87	8.78	0.10	3.11
2	0 – 15	58.8	17.4	16.8						
	15 – 30	72.5	14.1	7.8						
	30 – 45	31.2	30.4	31.5						
3	0 – 15	27.1	35.0	27.6						
	15 – 30	5.0	82.5	10.8						
	30 – 45	60.8	26.2	7.7						
4	0 – 15	13.5	35.1	43.4						
	15 – 30	16.6	32.1	43.3						
	30 – 45	95.6	1.9	1.1						
5	0 – 15	97.9	0.9	0.7						
	15 – 30	97.3	1.2	0.6						
	30 – 45	95.5	3.7	1.0						
6	0 – 15	97.7	1.0	0.3	0.06	0.49	—	2.25	0.14	1.63
	15 – 30	96.5	1.5	0.6	—	—	—	—	—	—
	30 – 45	95.4	2.3	1.1	0.07	0.51	0.22	2.25	0.17	1.90
7	0 – 15	3.5	43.4	44.6	0.07	0.80	1.38	16.50	0.12	5.25
	15 – 30	2.7	21.5	71.4	—	—	—	—	—	—
	30 – 45	12.8	41.2	40.8	0.09	1.12	2.23	14.20	0.26	6.03

excessive draining and intensive leaching of bases in the soil, and these will be reflected in the low CEC and bases, given in Table 3. The presence of too much sand in particular soil will slow down the process of soil structure development and as such the soil will retain a single-grain structure unless remedial steps are undertaken quickly.

The slimes, however, are subjected to a different set of conditions. The clay content is quite high, with values exceeding 40% in some cases (sites 4 and 7). Currently, the structure is rather massive, but in time to come the structure may develop, especially if organic matter is present. The development of structure is possible in the presence of clay, silt and sand in a favourable ratio.

Chemical Properties

Table 3 summarizes the chemical properties of the studied soils. Regardless of the textural composition, the bases are very low, except for Ca^{++} in some parts of the soil profile at sites 2 and 4. In terms of total elemental composition, there appears to be a high amount of K, Mg and Al (Table 2). The high amounts of K and Mg can be accounted by the presence of mica and chlorite respectively *(Fig. 2)*. Likewise, total Al is present in high amounts because it is one of the basic chemical constituents of mica, kaolinite and chlorite.

Organic carbon and nitrogen are far too low compared to normal soils under Malaysian conditions. This is somewhat related to the

TABLE 3
Chemical properties of ex-mining land at Kg. Kepayang Baru, Ipoh

SAMPLE	DEPTH (cm)	BASES (meq/100g soil) Na^{+}	K^{+}	Ca^{++}	Mg^{++}	P (ppm)	C (%)	N (%)	Fe_2O_3 (%)	pH (H_2O)	pH_0	CEC meq/ 100 g
1	0 – 15	0.13	0.03	0.71	0.19	2.58	0.34	0.02	1.29	7.30	5.75	1.20
	15 – 30	0.14	0.03	0.89	0.37	6.29	0.15	0.01	1.93	7.19	5.90	1.40
	30 – 45	0.10	0.05	1.38	0.59	1.99	0.30	0.02	2.57	6.40	3.50	2.00
2	0 – 15	0.12	0.04	6.09	1.20	13.84	1.86	0.04	2.64	7.20	5.80	6.90
	15 – 30	0.10	0.05	1.83	0.54	6.24	0.24	0.20	1.50	6.95	4.25	2.90
	30 – 45	0.11	0.05	4.26	1.34	4.24	0.39	0.03	6.69	7.05	4.65	5.80
3	0 – 15	0.11	0.08	5.63	1.78	14.19	0.38	5.06	7.65	5.70	4.10	
	15 – 30	0.15	0.04	2.78	0.83	4.62	0.09	0.04	3.57	7.65	5.80	2.90
	30 – 45	0.18	0.04	2.41	0.77	5.07	0.30	0.02	3.74	7.74	5.30	5.50
4	0 – 15	0.99	0.05	0.28	0.91	6.37	0.21	0.02	5.98	7.55	4.70	7.50
	15 – 30	0.17	0.06	5.04	1.60	4.00	tr	0.01	7.52	7.69	4.15	6.60
	30 – 45	0.17	0.03	1.07	0.38	4.24	tr	0.01	1.50	8.22	5.60	1.00
5	0 – 15	0.11	0.02	0.66	0.27	1.87	0.37	0.01	2.12	6.53	4.00	1.00
	15 – 30	0.19	0.03	0.88	0.37	3.29	0.30	0.02	1.50	8.08	4.50	1.00
	30 – 45	0.17	0.03	0.45	0.41	3.88	0.03	0.02	1.66	7.98	4.50	1.00
6	0 – 15	0.16	0.02	0.47	0.27	1.28	tr	0.02	1.31	7.89	4.45	1.20
	15 – 30	0.09	0.02	0.47	0.32	2.23	tr	0.03	1.66	8.01	5.20	1.10
	30 – 45	0.11	0.02	0.50	0.31	2.70	tr	0.01	1.45	8.01	5.10	1.30
7	0 – 15	0.09	0.11	3.99	1.15	3.41	0.52	0.02	542	6.32	2.55	7.80
	15 – 30	0.12	0.05	4.56	1.25	4.95	0.28	0.02	7.06	6.63	2.75	7.50
	30 – 45	0.11	0.06	3.67	1.23	2.11	0.39	0.03	6.90	6.53	2.85	6.10

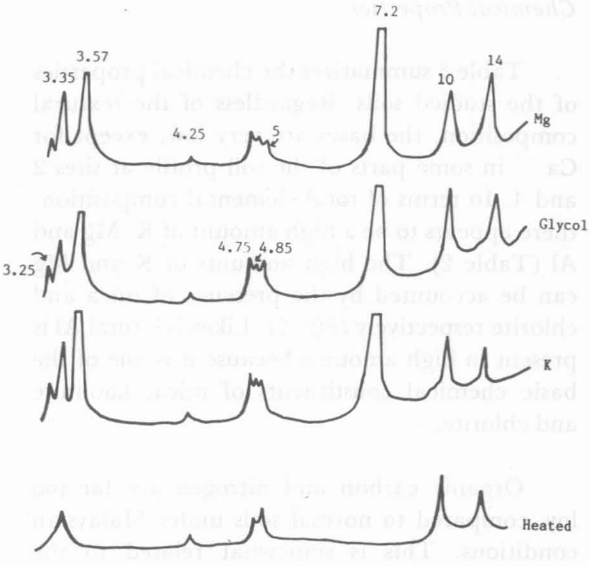

Fig. 2: X-ray diffractograms of the clay fraction of soil sampled at site 7

recent nature of the deposits which have just been exposed by the mining operation. Incorporation of organic manure (cow dung) and/or agricultural waste from the factory (POME) is considered essential to improve the organic matter content of the soils. In so doing, soil structure development is encouraged and more nutrients are added. Also noticeable in the chemical properties is the lack of phosphorus in the soil. P fertilization is a necessity in the amelioration of these soils.

Generally, the pH of these soils is high with values of 6 or more. In some areas (sites 4, 5 and 6) the pH is more than 8 (Table 3). The high pH values is possibly due to the influence of the limestone which underlies the deposits. The pH of water in the mining ponds is even higher; the value is 8.8. In contrast to the pH of tin-tailings in Dengkil, Selangor, where the pH was reported to be 2.8 – 3.0 (Maesschalck and Lim, 1978), the tin-tailings of Kg. Kepayang Baru, Ipoh are better because the problem of acidity does not arise. In fact the pH is a little bit too high, which may reduce the availability of the most micronutrients. This rather high pH can easily be overcome by using acid producing fertilizers such as $(NH_4)_2SO_4$. Continuous application of $(NH_4)_2SO_4$ can lower the pH to a more favourable level for crop growth. When pH is in the region of 6.0, Al precipitate as $Al(OH)_3$ and is therefore rendered unavailable. Although total Al appears to be a dominant element in the soils (Table 2), it does not cause problems as it exists as a mineral component and is therefore not available to plants.

pH_0 is much lower than the soil pH indicating that the soils are net negatively charged (Uehara and Gillman, 1980). The pH_0 value is lowest in the soils at site 7 (Table 3). This low value (<3) is consistent with the recent stage of weathering of the soils where mica and chlorite still exist. The sandy deposits register higher values probably because of the coating of the sand by gibbsite, similar to what has been reported by Shamshuddin and Tessens (1985). However, gibbsite is poorly manifested on the XRD diffractogram because it was removed from clay sample during deferrification by dithionite.

The CEC is low in this soils even for soils with more than 50% clay content. The value at sites 1, 5 and 6 is 2 meq/100 g soil or less. This is related to the mineralogy, in which kaolinite, mica and chlorite are found to be dominant in the clay fraction. The CEC of these soils can probably be improved somewhat by incorporating organic matter into the soil.

The total micronutrients (Zn, Mn, Cu) determined by aqua regia in the soils studied are given in Table 4. Zinc and copper content are moderately high. But this does not necessarily mean that they are available to the plants as the soil pH is very high. Manganese content is exceptionally high regardless of the textural composition, comparable to soils derived from serpentinite reported by Paramananthan (1977). The Mn content in Table 4 obtained by aqua regia are comparable to the values obtained by NAA in Table 2. Manganese exists as impurities in limestone and on weathering it accumulates in the soils. As the pH is high, Mn toxicity will not be a problem. This manganese probably exists as MnO_2.

TABLE 4
Total micronutrient in the ex-mining land at Kg. Kepayang Baru, Ipoh

SAMPLE	DEPTH (cm)	MICRONUTRIENT (ppm) Zn	Mn	Cu
1	0 – 15	30.60	505.34	9.53
	15 – 30	61.17	1779.40	12.78
	30 – 45	75.89	1637.00	24.12
2	0 – 15	101.27	1480.40	22.83
	15 – 30	62.00	797.15	14.40
	30 – 45	135.73	1501.80	43.58
3	0 – 15	129.06	2597.01	37.09
	15 – 30	87.01	2327.40	23.48
	30 – 45	86.18	2455.40	14.40
4	0 – 15	169.07	2355.90	46.82
	15 – 30	159.07	2135.20	41.96
	30 – 45	53.97	1399.30	13.60
5	0 – 15	44.21	1227.80	9.86
	15 – 30	50.88	1227.80	10.83
	30 – 45	56.72	1575.90	10.18
6	0 – 15	42.82	925.30	10.51
	15 – 30	39.77	1419.90	9.21
	30 – 45	40.32	1149.50	9.53
7	0 – 15	115.11	953.70	34.82
	15 – 30	125.67	1622.80	38.72
	30 – 45	177.90	2227.00	47.79

Table 5 gives heavy metal content of soils at site 1, 6 and 7 at 0 – 15 cm and 30 – 45 cm depth. Heavy metals of interest which are known to affect plants and/or humans are As, Co and Cr. The influence of others, such as Dy, V, Sb and V remain to be known. Cobalt content is found to be lower than those found in the sedentary soils of Peninsular Malaysia as reported by Paramananthan (1977). Furthermore, Co is rendered less available by the high pH. Cr is high

TABLE 5
Heavy metal in the ex-mining land at Kg. Kepayang Baru, Ipoh

SAMPLE (Site)	DEPTH (cm)	HEAVY METAL (ppm) As	Dy	V	Co	Sb	Cr	U
1	0 – 15	67.2	5.36	17.8	5.47	0.69	39.10	5.57
	30 – 45	298.3	1.03	55.2	10.32	0.99	–	17.40
6	0 – 15	139.8	6.43	24.9	7.11	0.61	10.36	5.37
	30 – 45	256.9	8.03	43.2	5.85	0.47	9.45	8.41
7	0 – 15	337.2	13.0	167.5	14.90	2.17	134.70	20.10
	30 – 45	389.8	14.7	152.0	22.60	1.96	158.50	19.40

at site 7, but low in the sandy soils (sites 1, 6). Sedentary soils with similar amounts of Cr give rise to toxicity problems in rubber, as reported by Law (1968).

Mineralogical Properties

The clay fraction at site 7 (slime) from the textural analysis was deferrified and X-rayed. XRD diffractograms for Mg, glycol, K and heated samples are given in *Fig. 2*. A Mg saturated sample gave reflections at 14Å, 10Å, 7.2Å, 5.0Å, 4.85Å, 4.75Å, 4.25Å, 3.57Å, 3.35Å and 3.25Å. The 14Å, 7.2Å and 4.75Å indicate the presence of chlorite. This is confirmed by the presence of 14Å reflection in the heated samples. The chlorite appears to be relatively unweathered as there is no 16Å reflection in the glycolated sample. The 16Å reflection would indicate the presence of chlorite-mixed layers.

Other minerals which are present in large amounts are mica (10Å, 5.0Å, 3.35Å) and kaolinite (7.2Å, 3.57Å), shown by their very prominent peaks. The exact amounts of the minerals were not determined. Quartz (4.25Å), gibbsite (4.85Å) and feldspar (3.25Å) are present in small amounts. Like chlorite mica appears to be relatively fresh as there is no indication of the presence of mica-mixed layers. Mica-mixed layers are shown by the presence of XRD reflection between 10 – 14Å in Mg saturated sample. This peak either remains undisturbed or expands to 14Å on glycolation. Part of this peak collapses to 10Å on K saturation.

There are also some halloysite in the soil as shown by TEM. Halloysite is tubular in shape, while kaolinite is hexagonal *(Plate 1)*. The amount of halloysite is less than kaolinite if one refers to the TEM micrographs *(Plate 1b)*.

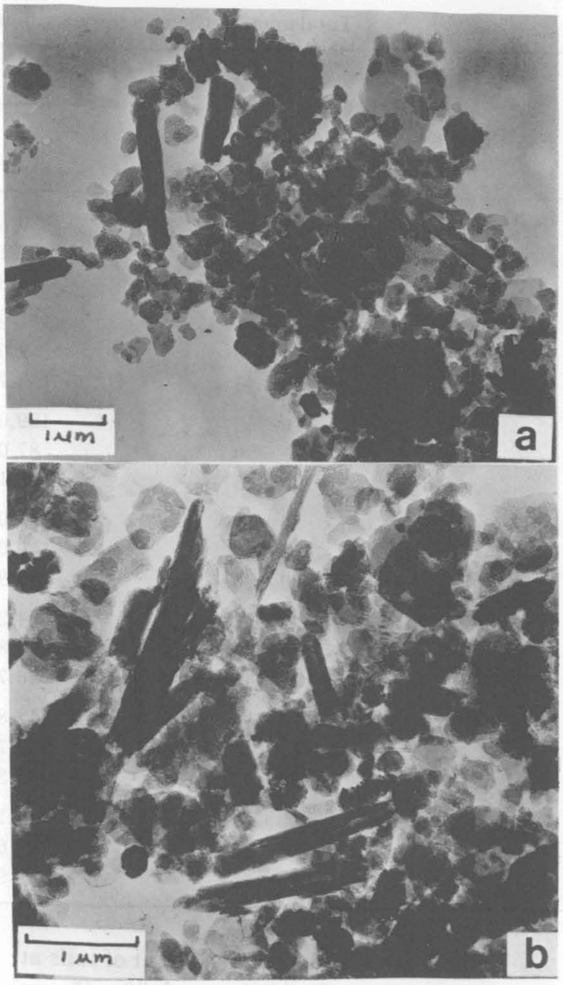

Plate 1: TEM micrographs of the clay minerals showing kaolinite (hexagonal) and halloysite tubular (a × 16,5000, b × 27,500)

General Discussion

It is clear that the soils of the ex-mining land of Kg. Kepayang Baru, Ipoh can be subdivided into three types namely the sandy tailings, the slime and the mixture of sandy tailings and slime. The textural composition is rather similar to those reported by Lim *et al.*, (1981) and Tan and Khoo (1981) in other places in the country. From the point of view of soil formation, the sandy deposits do not retain water, are poorly structured and lack horizonation. On the other hand, hydraulic conductivity is low in the slime.

Incorporation of organic materials into the tailings will increase the organic matter content, thereby increasing water holding capacity, encouraging microbial activities, increasing the CEC and improving the rate of soil formation. Decomposition of the organic materials releases a substantial amount of nutrients into the soil.

Application of organic manures or palm oil mill effluents (POME) over a period of time leads to an accumulation of organic matter content in the Ap horizon.

POME cake has been reported (Zulkifli and Shamshuddin, 1985) to increase soil CEC and decrease soil pH_0. Lowering of pH_0 results in the increase of the net negative charge of the soil (Uehara and Gillman, 1980). POME, with an annual production of around 8 million ton (Tan, 1983) is a potential organic material for amelioration of tin-tailings.

Inorganic fertilizers should also be used to supplement nutrients supplied by the organic manures. In the case of tin-tailings of Kg. Kepayang Baru, the use of $(NH_4)_2SO_4$ is recommended as a source of nitrogen. Continuous application of $(NH_4)_2SO_4$ lower soil pH to a more favourable level. The present pH of more than 7 in some areas can cause micronutrient deficiency.

CONCLUSION

The ex-mining land of Kg. Kapayang Baru, Ipoh can be classified into sandy, clayey (slime) and a mixture of sandy and clayey deposits. The sandy deposit occurs in the well drained areas, while the slime occurs in the poorly drained areas. These soils contain low amounts of bases, phosphorus, nitrogen and organic carbon. The pH is high and the CEC is low. High pH reduces the availability of micronutrients to plants. Mineralogically, the clay fractions are dominated by kaolinite, mica and chlorite. There are no mica or chlorite mixed-layers.

ACKNOWLEDGEMENTS

The authors wish to record their gratitude to Universiti Pertanian Malaysia for financial support, Department of Agriculture Perak for giving permission to use the ex-mining land at Kg. Kepayang Baru, Ipoh for this study and Unit Tenaga Nuklear (Puspati) for allowing the use of NAA facilities.

REFERENCES

GILLMAN, G.P. and UEHARA, G. (1980): Charge characteristics of soils with variable and permanent charge minerals: 11. Experimental. *Soil Sci. Soc. Am. J.* **44:** 252 – 255.

GOBBETT, D.J. (1972): Geological Map of the Malay Peninsula. Geol. Soc. Malays. Kuala Lumpur.

LAW, W.M. (1968): Reconnaissance Soil Survey of the Raub-Temerloh-Jerantut Area of Northwest Pahang. Malayan Soil Survey Report No. 1/1968. Ministry of Agriculture, Kuala Lumpur.

LIM, K.H., MAENE, L.M., MAESSCHALCK, G.G. and WAN SULAIMAN, W.H. (1981): Reclamation of Tin Tailings for Agriculture in Malaysia. *Tech. Bull.* Faculty of Agriculture, UPM.

MAESSCHALCK, G.G. and LIM, K.H. (1978): The effect of organic waste materials, fertilization and mulching on the physical properties and yield of mungbean on tin-tailings. Paper presented at Workshop on Research and Activities of Soil Science Department, UPM, Serdang.

MAENE, L.M., CONNOR, C.L. and YAACOB, O. (1978): Food production on tin-tailings in the Seri Kembangan – Balakong area, Malaysia. *In:* Food and Agriculture Malaysia 2000. Chin, H.F., Enoch, I.C. and Wan Mohamed, W.O. (Edi.). Faculty of Agriculture, UPM, Serdang.

PARAMANANTHAN, S. (1977): Soil Genesis on Igneous and Metamorphic Rocks in Malaysia. D.Sc. Thesis, RUG., Ghent, Belgium.

PARAMANANTHAN, S. (1978): Draft Field Legend in Soil Survey in Malaysia. Cawangan Tanah dan Analisa, Jabatan Pertanian Semenanjung Malaysia, Kuala Lumpur.

SHAMSHUDDIN, J. and TESSENS, E. (1985): Some T_2 terrace soils of Peninsular Malaysia: 111. Surface charge. *Pertanika* **8(2):** 169 – 179.

TAN, W.H. and KHOO, S.H. (1981): The utilization of ex-mining land in Peninsular Malaysia. *Malays. Geo.* **3:** 36 – 46.

TAN, K.P. (1983): Land application of digested palm oil mill effluents to mature oil palm on inland soils – some preliminary results. Proc. Sem. on land Appl. of Palm Oil and Rubb. Fac. Eff. Lim, K.H., Abu Talib, B. and Poon, Y.C. (Edi.). MSSS, UPM, Serdang.

ZULKIFLI, A. and SHAMSHUDDIN, J. (1985): The effect of palm oil mill effluents on charge characteristics of two weathered soils in Peninsular Malaysia. *Porim Bull.* **10:** 10 – 15.

(Received 10 October, 1985)