

Properties of Soils Derived from Some Metamorphic Rocks in Peninsular Malaysia

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ABSTRAK

Sifat-sifat morfologi, fizik, kimia, mineralogi dan mikromorfologi ke atas lima jenis tanah yang terbentuk daripada batuan metamorf (skis kuarza-mika, filit, skis serisit bergrafit, skis amfibol dan serpentinit) telah dikaji. Sifat-sifat ini didapati terpengaruh oleh jenis bahan induk. Tanah-tanah yang terbentuk daripada batuan yang rendah kandungan mineral senang luluhawa dan jumlah ferum rendah (skis kuarza-mika, filit, skis serisit) adalah berwarna kuning kemerahan, bertekstur lempung berkelodak, berstruktur blok serta mempunyai jumlah keupayaan pertukaran kation, ketepuan bes dan ferum oksida bebas yang rendah. Horizon diagnostik pada tanah ini ialah horizon argilik. Tanah-tanah yang terbentuk daripada batuan yang tinggi kandungan mineral senang luluhawa (skis amfibol dan serpentinit) adalah berwarna merah hingga coklat, bertekstur lempung, berstruktur gerintil, serta mempunyai jumlah keupayaan pertukaran kation rendah, ketepuan bes sederhana, kandungan ferum oksida bebas tinggi. Horizon diagnostik ialah oksik. Ciri-ciri pedo yang banyak terdapat dalam kumpulan tanah yang pertama ialah pengisian lempung dan kotoran manakala dalam kumpulan tanah yang kedua pengisian kotoranlah yang banyak sekali.

ABSTRACT

The morphological, physical, chemical, mineralogical and micromorphological properties of five soils developed over some metamorphic rocks (quartz-mica schist, phyllite, graphitic sericite schist, amphibole schist and serpentinite) were examined. These properties were found to be influenced by the parent materials. Soils developed over rocks with low amounts of weatherable minerals (ferromagnesian) and low total iron content (quartz-mica schist, sericite schist and phyllite) are reddish yellow, have silty clay textures and blocky structures, low CEC and base saturation and low free iron oxide content. The diagnostic horizon is argillic. Soils formed over rocks with high amounts of weatherable minerals (amphibole schist and serpentinite) are red to brown, have clayey textures, granular structures, low CEC, moderate base saturation and high free iron oxide content. The diagnostic horizon is oxic. Pedofeatures in the first group of soils are dominated by clay and excremental infillings whilst in the second group, only excremental infillings are dominant.

INTRODUCTION

Metamorphic rocks such as phyllite, sericite schist and quartz-mica schist are some of the common parent materials of soils mapped in Peninsular Malaysia. Although there have been many studies related to the genesis of soils in Malaysia (Eswaran

and Wong, 1977; Lim, 1977; Paramanathan, 1977; Loh, 1981; Zainol, 1984) the weathering of metamorphic rocks in relation to soil formation has received less attention than that of igneous and sedimentary rocks. Properties of soils developed on igneous rocks and sedimentary

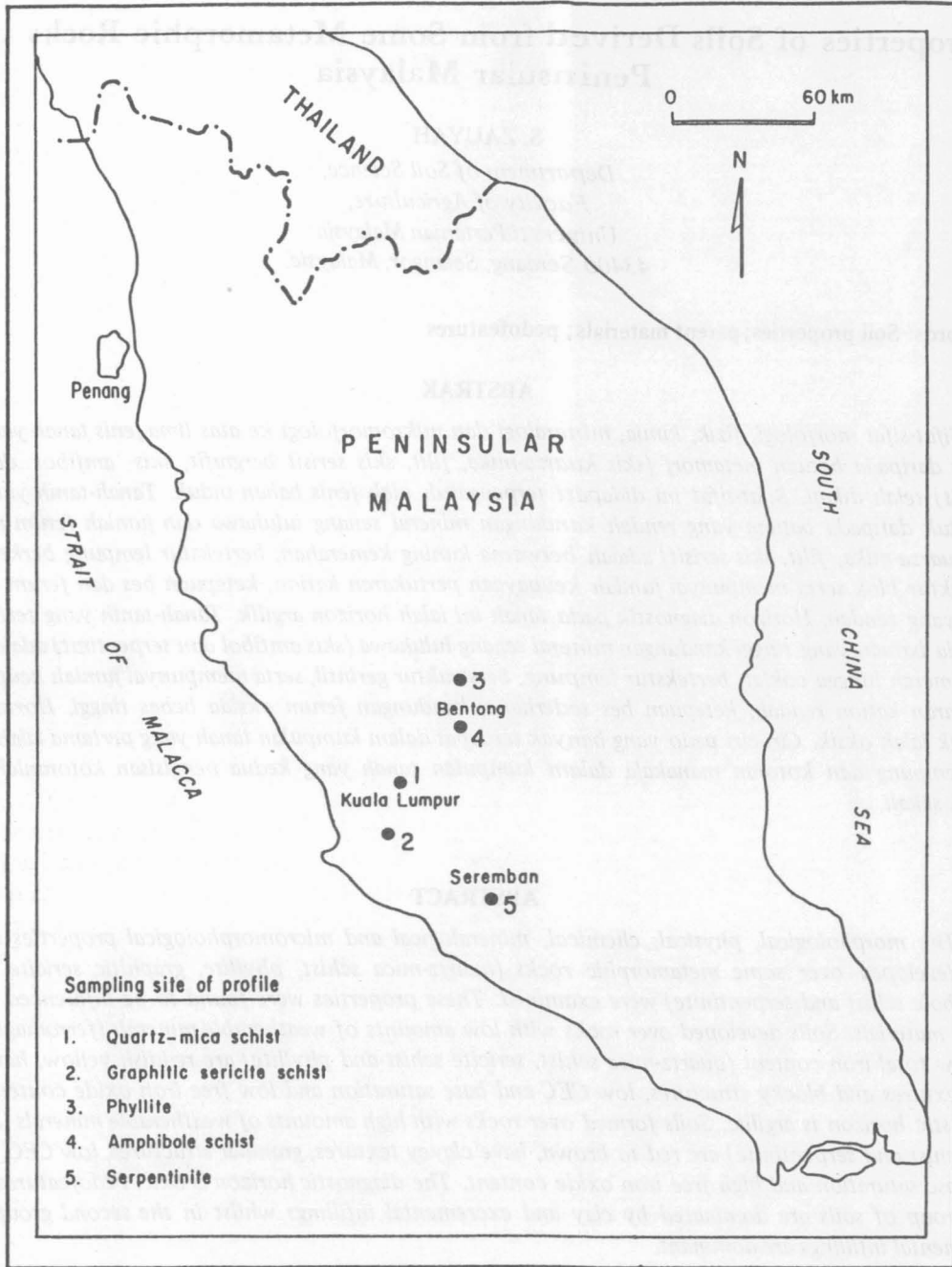


Fig. 1: Map of Peninsular Malaysia showing the locations of the profiles studied.

TABLE 1
Some chemical properties of the paddy and mangrove soil samples

	PADDY		MANGROVE	
	wet	dry	wet	dry
pH (1 : 2)	6.7	4.5	7.2	5.9
Eh (mV)	-180	360	-200	420
EC (mmhos cm ⁻¹)	1.8	0.9	52.5	19.5
Exchangeable cations (meq 100 g ⁻¹)				
Na		0.2		62.5
K		0.7		2.6
Ca		0.4		10.8
Mg		0.9		38.9
Al		1.0		0.0
H		1.1		0.1
Exchangeable ($\mu\text{g g}^{-1}$)				
Fe		178.0		278.0
Mn		74.0		6.4
Water soluble ($\mu\text{g g}^{-1}$)				
Phosphate		25.0		0.6
Sulphate		1450		3125

was higher than for the mangrove soil, as shown in *Figure 1(b)*. Similar changes in the pH of submerged acid soils have been shown by Tomlinson (1957) and Ponnampereuma (1965, 1972). During reduction of the inorganic components of the soil under anaerobic condition, protons were used and therefore the pH increased. The increase in pH of most acid soils upon submergence is largely due to the reduction of Fe (III) to Fe(II) (Ponnampereuma *et al.*, 1966). The fairly stable pH attained after two weeks of submergence was due to the consumption of initially — present electron acceptors and the sustained production of carbon dioxide. The significantly lower pH of the mangrove soil could reflect a small amount of acid-sulphate property for this soil with its high organic matter content.

Changes in EC of the soil solutions of the two submerged soils are shown in *Figure 2(a)*. Note the break in scale between the two soil curves. The EC of the submerged paddy soil attained a maximum during the second week, and then declined to a fairly stable value. Ponnampereuma (1965, 1972) obtained similar results.

The EC of the mangrove soil, however, reduced rapidly to a fairly stable value during submergence. The changes in conductance reflect the balance between reactions that produce ions and those which inactivate them, and it seems that inactivation of ions was prevalent in the mangrove soil. There was a close similarity between the changes in EC and the changes in total soluble cations (Na, K, Ca, Mg, Fe and Mn) in the soil solutions as shown in *Figure 2(b)*. The cations were mainly Na and Mg for the mangrove soil, reflecting sea-water influence.

The EC increased as the total cation concentration increased, and vice versa. The increase in cations of the soil solution was due to the release of soluble Fe(II) and Mn(II) during the reduction of Fe(III) and Mn(IV), respectively, with some of these cations then being displaced from exchange sites on soil colloids into the soil solution (Ponnampereuma, 1972).

Figure 3(a) and *Figure 3(b)*, respectively, show the changes in Mn and Fe concentrations of the soil solutions during submergence. Concentrations of both Mn and Fe in the soil solution of

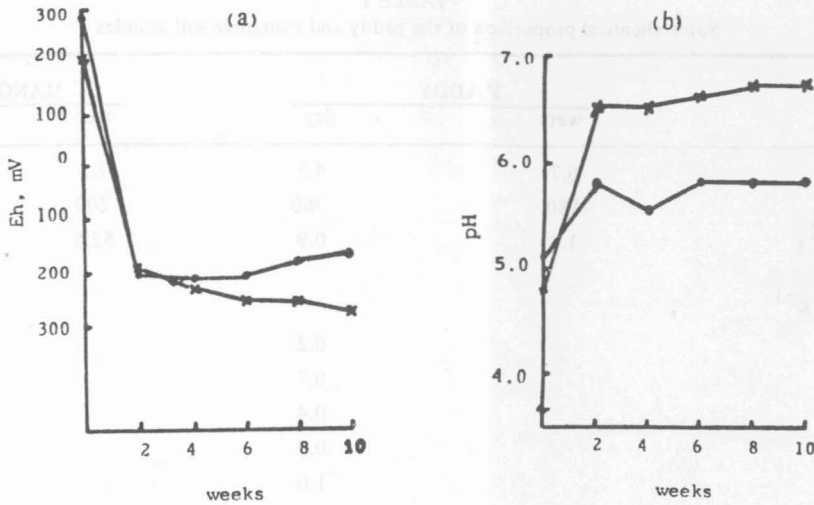


Fig. 1: Changes in Eh and pH of the soils and soil solutions, paddy (x) and mangrove (*), respectively during submergence.

the submerged paddy soil attained a maximum during the second week and then gradually declined to a fairly stable value. Similar changes were observed by Ponnampurna (1965, 1972, 1981). The initial increase in Mn and Fe was due to the reduction of solid-phase Mn(IV) and Fe(III) compounds, functioning as electron accep-

tors, during respiration of anaerobic bacteria. The reduction produced more-soluble Mn(II) and Fe(II) compounds and therefore the amounts of these ions in solution increased (IRRI, 1964; Ponnampurna, 1972). The decrease in concentration might similarly be due to immobilization of Mn and Fe. The soluble Mn and Fe could pre-

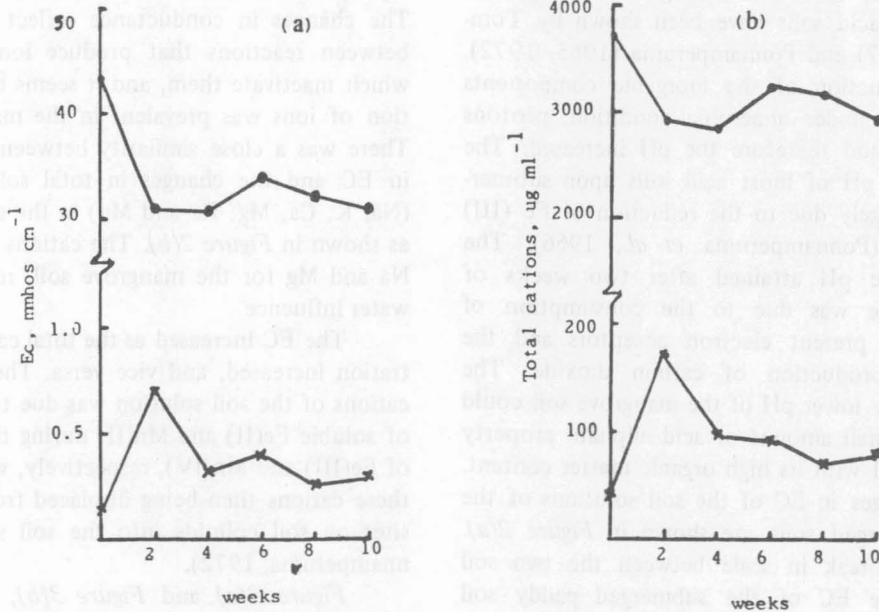


Fig. 2: Changes in Ec and total cations concentration of the soil solutions, paddy (x) and mangrove (*), during submergence.

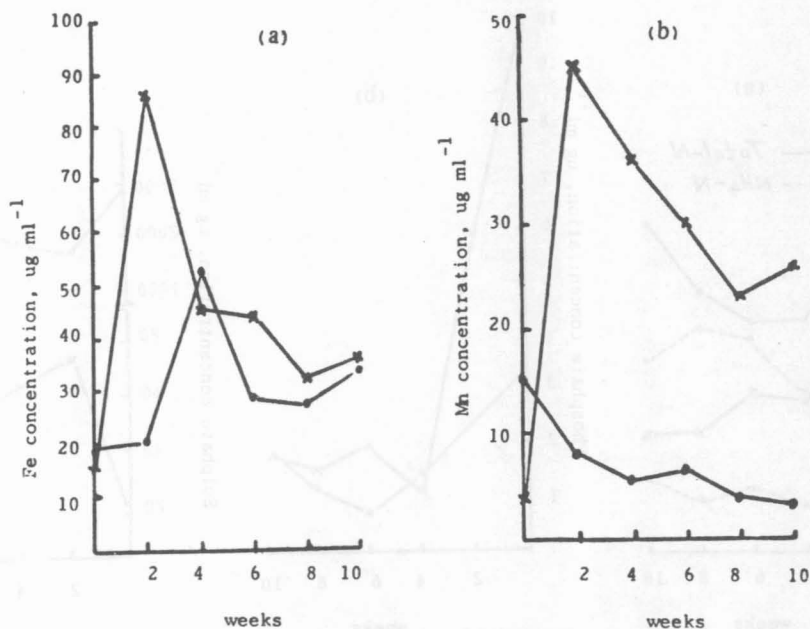


Fig. 3: Changes in Mn and Fe concentrations in the soil solutions, paddy (x) and mangrove (°), during submergence.

precipitate as carbonate (Ponnamperuma *et al.*, 1969) and as sulphide (Ayotade, 1977) as well as being sorbed by Mn(IV) and Fe(III) oxide hydrates. Changes in Mn and Fe of the submerged mangrove soil were slightly different from those of the paddy soil. The concentration of Mn decreased to a fairly stable value during submergence, with the overall values being lower than those obtained for paddy soil. This might be due to the low level of active Mn in the mangrove soil, as indicated by the low amount of exchangeable Mn (Table 1). Soils with low contents of Mn normally show only slight changes of soluble Mn during submergence (Ponnamperuma, 1965).

The total nitrogen in the soil solutions of the submerged soils is shown in Figure 4(a). Both soils showed an increase in total nitrogen during the first two weeks of submergence which then later decreased once more. In a submerged soil, nitrate-N that is initially present should be reduced to gaseous nitrogen, while the mineralization of organic nitrogen should not proceed to the nitrification stage producing nitrate-N due to the absence of oxygen. The process stops instead at the ammonification stage, thus producing ammonium-N (Patrick and Mahapatra, 1968; Patrick and Reddy, 1978).

Comparison between the total nitrogen and ammonium-N in the soil solutions indicates that ammonium-N contributed significantly to the total nitrogen. Higher amounts of ammonium-N were detected in the mangrove soil, which could be related to its high content of organic matter. One of the main factors affecting the production of ammonium-N is the organic matter content of a submerged soil (Ponnamperuma, 1965). The subsequent decrease in ammonium-N concentration could be due to fixation by soil colloids.

Phosphate and sulphate contents of soil solutions from submerged soils also changes during submergence, as shown in Figure 4(b) and Figure 4(c). Phosphate concentration decreased to a minimum during the first four weeks of submergence and then later increased slightly once more. These changes were not similar to the results obtained by Ponnamperuma (1965, 1972), where phosphate concentration increased initially and then decreased once more. The principal effect of anaerobic conditions on phosphorus in soils is a change in the solubility of phosphate (Ponnamperuma, 1972). The increase in pH during submergence will normally increase the concentration of phosphate in the soil solution, since iron and aluminium phosphates liberate

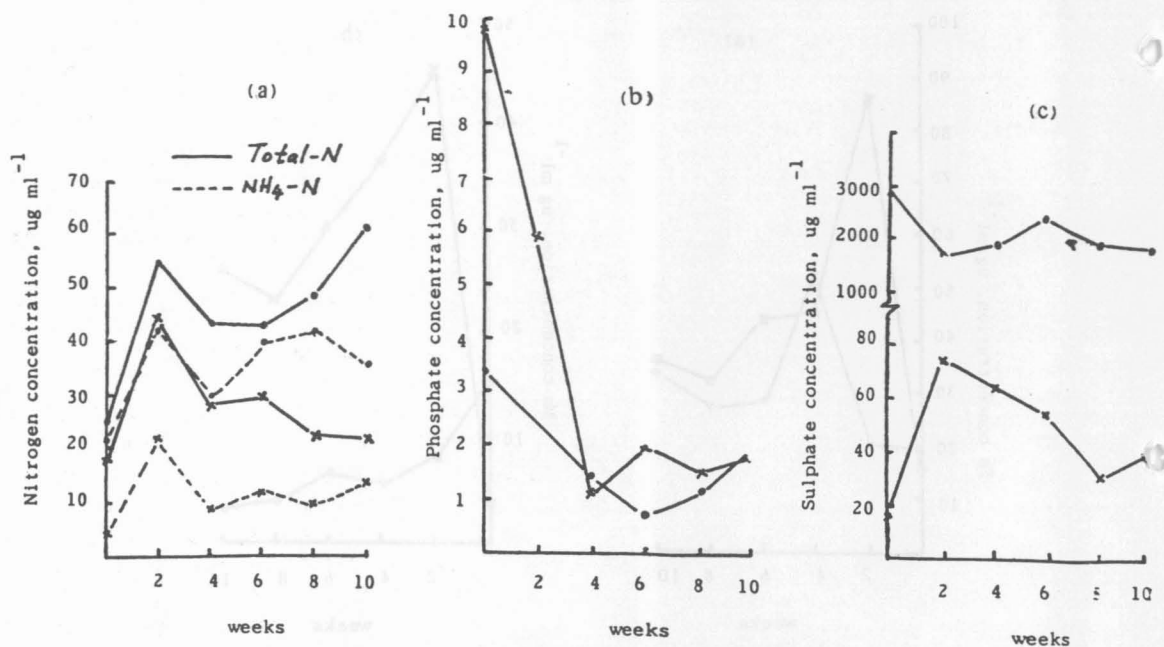


Fig. 4: Changes in nitrogen phosphate and sulphate of the soil solutions, paddy (x) and mangrove (°), during submergence.

phosphate ions as the pH rises (Larsen, 1967). The reduction of Fe(III) to Fe(II) will also cause a release into solution of adsorbed, chemically-bound and occluded phosphate. These might be the likely reasons why the phosphate concentrations in the soil solution of the submerged paddy and mangrove soils increased after decreasing initially. The initial decrease in concentration might be due to a precipitation of phosphate. The concentrations of Mn and Fe were highest during the initial stage of submergence. Therefore a proportion of the Mn and Fe released into the soil solution might form less-soluble precipitates with the phosphate.

The concentration of sulphate in the soil solution of the paddy soil increased during the initial stage of submergence and then decreased. In contrast, it decreased first and then increased for the mangrove soil. Values were also much higher for this soil, further suggesting an acid-sulphate nature for it as discussed previously for pH effects. The changes in water soluble-sulphate varies widely with soil properties (IRRI, 1965; Ponnampuruma, 1981). Reduction of sulphate to sulphide would cause a decrease in sulphate concentration of the soil solution, while

release of sulphate from anion-exchange sites as pH increased would increase its concentration instead.

CONCLUSION

Submergence of dry paddy and mangrove soils changed them from an oxidized to a reduced state, as shown by their negative redox potentials. This resulted in changes in the chemical characteristics of the soil solutions. Therefore, soils under oxidized conditions have different chemical characteristics compared to soils under reduced conditions.

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