

INFLUENCE OF PROLONGED SUBMERGENCE ON THE ELECTROCHEMICAL PROPERTIES OF KARAIKUDI RED SOIL OF LATERITIC ORIGIN

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Karaikudi red soil of lateritic origin was subjected to prolonged submergence under laboratory conditions. The changes in its electrical resistance, pH and soil redox potential were monitored over a period of 60 days. From the initial value of 340 mV, the E_h fell to -360 mV and remained thereafter almost steady. At a steady pH of 6.9 the most probable soil redox equilibrium that controls the E_h value at this level could be the Fe^{+++}/Fe^{++} system. The fall in pH was from 7.5 to 6.9 only, probably owing to the presence of low organic carbon content. The bulk resistance decreased from 300 to 150 ohms due to the release of ions into the soil solution.

Another soil sample was kept under submergence in a glass container for a period of 41 days. The soil solution collected during this period was analysed for Na, K, Ca, Zn, Mn and Fe using AAS. The concentrations of almost all the ions increased with time. The release of iron took almost two days. The E_h values have been correlated with the increasing concentration of Mn and Fe over this period. The rising concentration curves of Mn and Fe are exponential in nature.

Key words: Lateritic soil, variations in SRP, pH and electrical resistance, effect of submergence

INTRODUCTION

The plant roots are surrounded by soil, water and air. This three-phase system that exists around the roots is a dynamic one. A dc electric field arises in the soil due to the uneven distribution of chemical energy. The important electrochemical properties of soil are pH, electrical resistance and soil redox potential (SRP). They influence the ion exchange and the redox equilibria in soil. SRP measurements are carried out with a view to assess soil aeration and also to find out the probable redox systems that control the SRP [1-3].

The objective of this investigation is to find out the variations in SRP, pH and electrical resistance, and also the nature and quantities of cations released when Karaikudi soil of lateritic origin is kept under submergence for a prolonged period under laboratory conditions, without growing any plants in it.

MATERIALS AND METHODS

The experimental cell used was a PVC container of dimensions $15.4 \times 10 \times 10 \times 10$ cm (lbh). This was filled with sieved soil of particle size less than 1 mm. About 1 mm high supernatant water that was maintained above the soil column was monitored using two nickel plated copper electrodes, each of size $9 \times 9 \times 0.2$ cm kept at the sides of the cell, using a Conductivity Bridge Model CB 40.

A platinum foil electrode ($1 \times 1 \times 0.1$ cm) to sense the SRP was fixed at a depth of about 3-4 cm in the middle of the container. A saturated calomel electrode that served as the reference electrode was kept in saturated KCl solution taken in a 100 ml beaker. This was connected to the soil column using a KCl-agar bridge. (Fig. 1).

The SRP was recorded using a Century Data Logger (Printing Voltmeter) Model 101. This has an input impedance of 10^{12} ohms. The pH of the soil was monitored using a digital pH meter. The

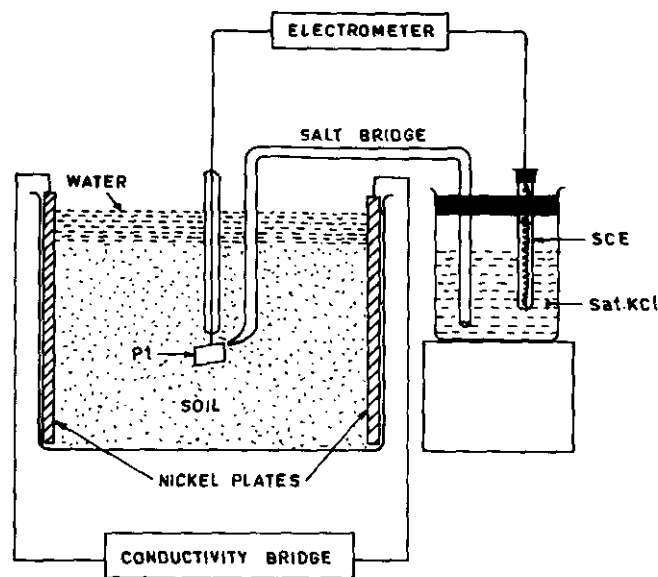


Fig. 1: Experimental set up for the measurements of resistance and redox potential of soil

pH electrode (combined type) was calibrated every day using buffer solution of pH 7. The changes in SRP, pH and resistance were recorded with time.

A 2 mm bore stop cock was fused to the bottom of a one litre tall beaker in which 800 g of soil particle size less than 1 mm was taken. Distilled water was added to it and allowed to percolate. The drained aliquots were collected periodically over 41 days and analysed for Ca, Na, K, Zn, Mn and Fe using Atomic Absorption Spectrophotometer. While making up the soil solution to desired volume, it was necessary to use 0.2N HCl to prevent the precipitation of iron hydroxides.

Both the soil samples studied were kept at a temperature of 28°–35°C during the course of this study.

RESULTS AND DISCUSSION

The soil resistance, pH and SRP decreased with the period of submergence as shown in Fig. 2.

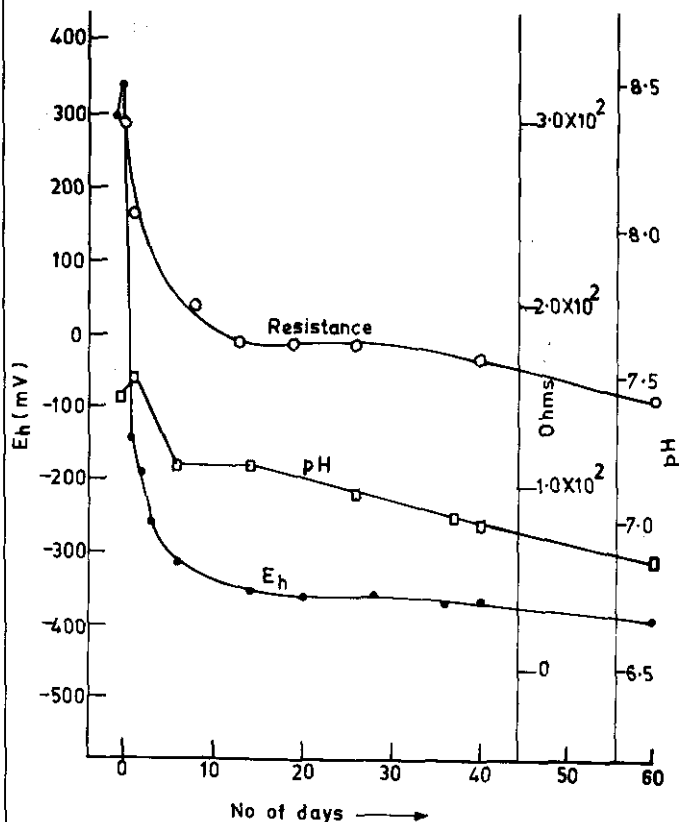


Fig. 2 : Changes in resistance, pH and E_h of the submerged soil with time

During the first day, the E_h value decreased from +340 to -140 mV. From the second to the sixth day it fell to -310 mV. On the 12th day the lowest value, viz. -360 mV was reached. Beyond this period, until the 60th day this value remained almost the same.

Flooding of the soil cuts off oxygen supply. The oxygen available in the soil solution is utilised fast by the aerobic microorganisms. This leads to permanent oxygen deficiency in the soil. This is the main reason for the first rapid fall in SRP. Due to the nonavailability of oxygen the aerobic microorganisms become quiescent or die, while the anaerobic microorganisms grow. The anaerobes utilise the oxidised soil components such as nitrate, manganese dioxide, ferric oxide, sulphate, phosphate and dissimilation products of organic matter, as electron acceptors during their respiration [4]. The order (thermodynamic sequence) in which this reduction takes place is given in Table I.

Table - I: Sequence of anaerobic reduction

Sequence	Electrochemical reactions	E_0
0	$O_2 + 4H^+ + 4e \rightleftharpoons 2H_2O$	0.83
I	$NO_3^- + H_2O + 2e \rightleftharpoons NO_2^- + 2OH^-$	0.43
II	$MnO_2 + 4H^+ + 2e \rightleftharpoons Mn^{2+} + 2H_2O$	0.41
III	$Fe(OH)_3 + e \rightleftharpoons Fe^{2+} + 3OH^-$	-0.13
IV	$CH_3COCO_2H + 2H^+ + 2e \rightleftharpoons CH_3CH_2CO_2H$	-0.18
V	$SO_4^{2-} + 3H_2O + 6e \rightleftharpoons S^{2-} + 6OH^-$	-0.20
VI	$2H^+ + 2e \rightleftharpoons H_2$	-0.42
VII	$CO_2 + 2H^+ \rightleftharpoons HCO_2H$	-0.62
VIII	$H_2PO_4^- + H^+ + e \rightleftharpoons P + 2H_2O$	-0.93

Under strongly oxidised conditions the electron activity is low in soils; hence the SRP is high and positive. Under reduced conditions due to high electron activity SRP is low and negative [5].

The bulk resistance recorded initially was 300 ohms. During the first day it fell to 250 ohms. On the seventh day, the value reached was 200 ohms. The lowest resistivity recorded on the 60th day was 150 ohms. Decrease in resistance indicates the increase in available ions that contribute for the electrolytic conduction. Organic matter present in the soil can promote the release of calcium, magnesium and ferrous ions.

With regard to change in pH, even after 60 days of submergence, the pH has fallen only by 0.6 from its initial value of 7.5. The reason could be the low organic carbon content of this soil. The release of CO_2 by the aerobic microorganisms and decaying organic matter under submerged conditions may be the reason for the initial fall in pH [4,6]. The metabolic products such as organic and inorganic acids produced by the anaerobes may be reason for the lowering of pH in the later stage [7]. The pH of neutral and alkaline soils appear to be regulated by the $CaCO_3 - CO_2 - H_2O$ equilibria. Soils of this type i.e. slightly alkaline type, which shows a slight decrease in pH after 2-4 weeks of submergence, is suited in general for the cultivation of rice [4]. The influence of pH on the solubility of iron is particularly important because of iron deficiency in alkaline soils [8].

The cations estimated, the days on which aliquots were drawn, and the amounts of cations in ppm are shown in Table - II.

Table - II: Amounts of cations in soil solutions determined by AAS in ppm

Days of submergence	Na	K	Ca	Zn	Mn	Fe
1 day	14.2	36.0	50.0	2.82	0.08	0.0
3 days	18.1	34.0	53.0	3.56	0.96	0.6
5 days	15.5	40.0	62.3	3.80	3.48	1.1
7 days	15.8	36.0	76.1	3.72	6.84	4.4
10 days	12.1	32.0	90.0	3.22	3.60	4.6
13 days	10.6	46.0	71.4	3.34	—	—
15 days	9.7	54.0	67.2	3.60	9.96	6.0
31 days	—	79.0	92.0	8.20	12.20	11.2
41 days	—	78.0	88.0	5.20	12.44	12.0

In general, the amount of cations released under prolonged submergence increased with time. The interrelationship between the SRP and the quantities of Mn and Fe released into the solution are shown in Fig. 3.

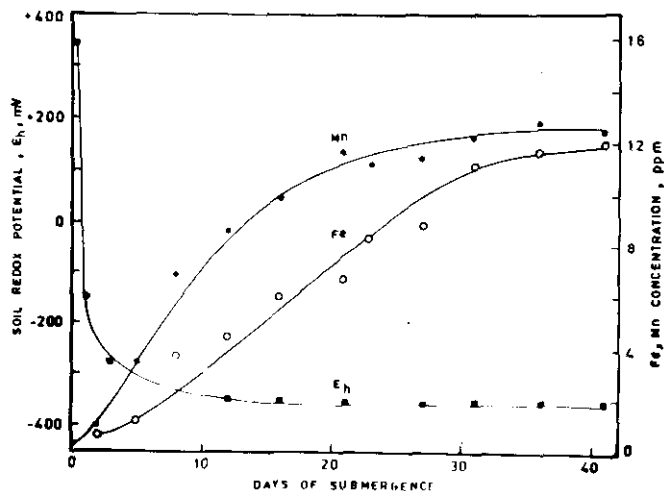


Fig. 3: Relationship between the change in SRP and the release of Fe and Mn from the soil

The fall in SRP is steep. Even after 24 hours of submergence, no ferrous ions are released into the soil solution. However, other cations are released into the soil solution. The curves depicting the release of Mn and Fe are exponential in nature. Manganese concentration reaches its maximum on the 20th day, whereas it is on the 30th day for Fe. The shape of the iron release curve is similar to the bacterial growth curve [9]. It is quite probable that the increase in anaerobes results in the consumption of ferric ions, the electron-acceptor, for respiration. The ferrous ions are released into the soil solution [7,10].

CONCLUSION

Karaikudi soil of lateritic origin has almost a stable pH of 6.9 even under prolonged submergence, and the SRP gets stabilised at about -360mV (E_h), probably controlled by the $\text{Fe}^{+++}/\text{Fe}^{++}$ equilibrium. The release of soluble ions is fairly slow and that of ferrous is the slowest. Incorporation of organic matter is essential to complex the iron. SRP would then get lowered releasing the ferrous ions.

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