ABSTRACT

Soil scientists have been conducting classification and identification studies on the suitability of the soil for crop production, irrigation and construction purposes. The need for the characterization of the soil on the basis of its major properties to support agriculture and the urge to produce more electricity makes one to think of generating electricity from renewable resources. Although electricity is generated using renewable resources like water, air, and sunlight, the soil could also be considered as a promising candidate, since it is available in abundance in all seasons. The soil contains innumerable mineral resources and organic matter that make it an eco-friendly, and a novel conductor of electricity beyond metal. Therefore, the present investigation is focused on the electrical conductivity of the soil. The object of this investigation was to collect the soil from various parts of Tamil Nadu, and subject it to elemental and structural characterization, for electrical conductivity studies. The four types of soil involved in the investigation are mentioned below.

1) Red soil collected from Pudukudi near Tiruchendur.
2) Coastal soil collected from Tiruchendur coastal area.
3) Tamirabarani riverbed soil collected from Tirunelveli.
4) Alluvial soil collected from Vannikonedal village near Tirunelveli.
These soil samples were collected from the top surface (10-15 cm depth) and finely ground and sieved, using a 500 μm mesh. The fine soil particles were studied using Atomic absorption spectroscopy (AAS), Fourier Transform Infrared spectroscopy (FTIR), Scanning Electron Microscopy-Energy Dispersive X-ray spectroscopy (SEM-EDAX), AC impedance study and Ballistic Galvanometer circuit study. This work consists of seven chapters. Chapter I is the introductory chapter and chapter II consists of the principles and instrumentation of all the techniques used for the present study. Chapters III, IV, V and VI explained the characterization of the Red soil, Coastal soil, Tamirabarani River bed soil and Alluvial soil respectively.

**Chapter I** contains the introduction of the previous study and research work based on soil for many purposes mostly agriculture and construction were referred. The previous research work on electrical conductivity of soil were also discussed with the references. The presence of minerals and carbon content in the soil reported by earlier works were cited. The electrical conductivity due to metal mobility and pH of the soil, reported earlier were also referred.

**Chapter II** deals with the treatment of soil, for characterization purposes. The principles and instrumentation involved in AAS, SEM-EDAX, FTIR, AC impedance study, and B.G.circuit were discussed in detail.

**Chapter III** consists of structural characterization and electrical conductivity study of the Red sandy dunal soil of Tamil Nadu (Tiruchendur).

The Red sandy dunal soil of Tamil Nadu is called Theri soil. It is located along the coastal areas of Tuticorin, Tirunelveli and Kanyakumari districts of...
Tamilnadu. The above mentioned soil sample was collected from an area of the village Pudukudi, near Tiruchendur (depth of 10-15 cm from the top surface). The Atomic Absorption Spectroscopy (AAS) study revealed that the presence of zinc is high (3.5 ppm). Next to zinc, iron, potassium, and sodium were further identified. The morphology of this soil was found to contain a random distribution of grain sizes ranging from 50 to 200 μm. The EDAX study also exhibited the presence of iron, sodium and potassium in the Red soil, which was already reported in the AAS. Referring to the FTIR spectra of Red soil a broad peak at 1035 cm⁻¹ was assigned to the presence of phosphorus. The AC impedance study were measured between 323K and 473K over a wide frequency range of 50 Hz to 500 MHz. The obtained impedance data were plotted using ZimpWin software based on Non linear least square fit (NLLS). Each impedance data measured at particular temperature were fitted equivalent circuit to understand the electrochemical capacity of the soil sample. The reciprocal of the bulk resistance gives the specific conductivity of soil sample at that particular temperature. The conductivity measured in the range of 323K to 473K were 1.8804x10⁻⁸ S/cm, 1.437x10⁻⁷ S/cm, 3.427x10⁻⁷ S/cm, 1.112x10⁻⁷ S/cm respectively.

The temperature dependence plot was also exhibited to indicate that conductivity increases as the temperature increases according to Arrhenius equation. The EC (Electrical Conductivity) meter measurement showed that the Red soil has an EC value in the range of 2.226x10⁻⁶ S/cm. As a supporting study of the EC of Red soil cell, it was used in the BG circuit and compared the emf (Electromotive force) with the Daniel cell was found to be 1.047. The OCV (open circuit voltage) measured was 1.32V. These experimental observations reported the EC (Electrical Conductivity) of Red soil.
**Chapter IV** consists of structural characterization and electrical conductivity study of Coastal soil.

The sample was collected from (top surface 10-15 cm depth) selected locations near Tiruchendur coastal area. The AAS study revealed that the presence of sodium is high (5.58 ppm) in the coastal soil. Next to sodium, potassium, iron, zinc, and copper were also confirmed. The morphology of the coastal soil grain was observed, analyzed and understood by the SEM pictures. Their study data ensures the presence of iron, zinc, and potassium already identified using AAS. The FTIR study for Coastal soil in the range of 4000-400 cm\(^{-1}\) showed a broad band at 3393 cm\(^{-1}\) was attributed to the presence of N-H vibrations. The A.C impedance study for coastal soil at 323K to 473K showed equivalent circuits R(CR) two parallel RC circuits connected in series to the resistance showing the Warbug presence in the Nyquist plot. It leads to the formation of a Double layer. The conductivity measurements were in the range of 2.124 x 10\(^{-8}\) S/cm. Further confirmation by the Arrhenius Equation and Arrhenius plot have also been discussed.

The EC meter recorded the conductivity of the coastal soil sample as 1.72x10\(^{-7}\) S/cm. The coastal soil cell has been made and used in the BG circuit, the emf of soil cell compared with Daniel cell was 1.025. The OCV open circuit voltage was measured as 1.36 V. The constant voltage of the coastal soil sample was observed, studied, and experimentally verified.
Chapter V explains the structural characterization and the electrical conductivity study of Tamirabarani River soil. Tamirabarani contain traces of copper hence, its name interpreted by scholars was Tamirabarani -tamiram- (copper) and varuni (stream of river). Due to the presence of copper the soil was predicted to have good electrical conductivity. The sample for this study was collected from (10-15 cm depth) Tamirabarani river bed (Tirunelveli) Tamilnadu. The mineral constituents of the Riverbed soil were evaluated, using the AAS. This study revealed the presence of a high content of 14.5ppm of potassium. Next to potassium was iron and sodium.

The following FTIR (4000 – 400 cm⁻¹) study identified functional groups like the methyl group in the region corresponding to the wave number 2924 cm⁻¹ and 2852 cm⁻¹. The morphology of the soil grains was understood by the SEM picture (50-200 μm). The percentage of iron and copper in the Riverbed soil was further confirmed by SEM-EDAX. The AC impedance study (LCR meter) for Riverbed soil showed a semi circle depicting an equivalent circuit of R(CR).

This represents the behavior of the conducting electrolyte. Further, the conductivity was found to be $1.221 \times 10^{-8}$ S/cm. The conductivity measured from 323K to 473K was plotted in a graph, where the conductivity versus temperature showed Arrhenius behavior (conductivity increases as the temperature increases). Nyquist plot of the Riverbed soil obtained at 323K is shown in Figure1.
Figure 1 Nyquist plot of the Riverbed soil at 323K

The Nyquist plot relates resistance in series with CR, where capacitor C and resistor R are parallel along with the constant phase element. Using the Riverbed soil sample of 300gms dissolved in 600 ml of de ionized water, the soil cell has been made OCV measured as 1.36V. Carbon and Zinc were used as electrodes and employed the in the ballistic galvanometer circuit. This cell was used to compare the emf of the soil cell with the Daniel cell. The ratio was observed as 1.234. The EC meter recorded the voltage of the RB (River bed soil) soil as $3.32 \times 10^{-7}$ S/cm.
Chapter VI deals with structural characterization and electrical conductivity study of alluvial soil. Contaminants in the River and stream create alluvial soil. The alluvial soil collected from the location of the river course of Tamirabarani and Chittar River bed. (10-15 cm depth). The AAS study identified the presence of sodium, potassium, zinc. sodium has a high content of 8.3 ppm, potassium 5 ppm and iron 1.2 ppm. The above mentioned heavy metal distribution was found using AAS, and further identified in the SEM-EDAX study of the alluvial soil- this supports the AAS study. The FTIR shows a broad and intense peak in the range of 3260 cm⁻¹ due to the stretching vibration of O-H. The corresponding wave number ensures the functional group in the alluvial soil. Alluvial soil behavior was different at higher temperatures while recording AC impedance. At 323K and 373K C(RW) an equivalent circuit was observed. The presence of warbug shows the formation of a diffusion layer. The presence of reactants capacitance and reactance resistance also confirms the presence of diffusion layer similar to Warbug. The Arrhenius plot infers the temperature dependence of the conductivity. The conductivity increases as the temperature increases. The conductivity range was between 5.98 x 10⁻⁸ S/cm and 2.647x10⁻⁷ S/cm. The EC meter recorded the conductivity measurement as 1.11x10⁻⁷ S/cm. The Alluvial soil cell has been made and used in BG circuit, the emf of the soil cell compared with the Daniel cell was 1.2685. The OCV (open circuit voltage) measured was 1.37V. The EC of the alluvial soil was observed, studied and experimentally verified.
Chapter VII consists of the summary of the investigation and scope of the future work. The specific conductivity measured from AC impedance study for all the four types of soil were compared. The OCV for all the soil obtained from BG circuit experiment were discussed. The presence of alkali metal, ions contributes to the specific conductivity future study would be focused on exploration of radioactive heavy metals present in the soil samples and its contribution towards specific conductivity.