CHAPTER I

1. Introduction to Soil Electrical Conductivity

1.1 General Introduction

Like the Peel of an orange, the soil covers the underlying geological materials of the Earth. The electrical conductivity of the soil is one of the essential properties that affect crop productivity, soil texture, cation exchange capacity (CEC), drainage of organic matter, salinity, and the subsoil characteristics (Do nahu et al 1987). The EC of the soil varies depending on the amount of moisture held by the soil particles.

The primary mechanism of soil creation is the weathering of rock. Fragmentation and weathering are the main soil forming processes. All rock types (Igneous, metamorphic and sedimentary) may be broken down into smaller particles to create soil (Dexer Perkins 2011). The Physical properties of the soil, such as water content and temperature influence the mobility of the electrical charges in soils (Edward J Plaster 1997). The soil’s structure is the shape that the soil takes based on its physical and chemical properties. The possible choices of soil structure are granular, blocky, columnar, platy and single grained. Each individual weight of the soil structure is called a “Ped” (Black C.A. 1965). Air and water occupies the space between the inorganic and organic particles of soil. The soil’s chemical properties include humus content, base saturation and cation exchange capacity (CEC) influence soil electrical conductivity (Schuffelen A C 1972).
The analytical study of element in the soil shows the presence of silicon, carbon, aluminum, iron and radioactive elements like thorium and uranium (Mayuva et al 2009). The existence of organic compounds in the soil has also been reported (C Du et al 2008).

1.2 Classification of Soil

According to the Unified Soil classification system, silt particle sizes are in the range of 0.002mm to 0.075mm, and sand particles have sizes in the range of 0.075mm to 4.75mm silt; sand gravel is basically little pieces of broken rocks (William A Jury et al 2013).

![Fig. 1.1: Different Layers of Soil](image)

The most common mineral constituent of silt and sand is quartz, also called silica, which has the chemical name “Silicon dioxide”. The common clay minerals are iolite, and kaolin. These minerals tend to form a street or plate like structure. Clay minerals typically have a specific surface area in the range of 10 to 1000 sqm /gram of soil. This helps chemical, electrostatic, and vander-waal interaction.
1.3 Soil Mineral Content

The minerals of soils are predominantly formed by atoms of oxygen, silicon, hydrogen and aluminium organized in various crystalline forms. These elements along with calcium, sodium, potassium, magnesium and carbon constitute over 99% of the solid mass of the soil. Soil science has tended to focus strongly on understanding the mineral components of the soil. The organic parts of the soil come from microbial action on dead plants or animals; organic material is made of carbon compound bacteria, fungi, algae, protozoa and earthworms - all parts of the soil. Inorganic components of the soil are derived from the rocks that originated from the soil.

Soil mineral composition and the amount of soluble salts are related to the total amount of charges in soil. The electrical properties were used to improve the soil characterization of the soil morphology and genesis study. Measuring the conductivity of the soil can determine the concentrations of the available compounds in the soil. Many of these compounds are dissolved in water and break down into ions. These ions are responsible for electrical conduction. Therefore, a healthy soil with high concentration of ionic fertilizer will have a high conductivity. Depleted soil with very few ions will have low conductivity electrolytic material. Earlier investigations on the soil related to its conductivity are reported below.
1.4 Review of earlier soil electrical conductivity based work

Soil moisture plays a major role in the synthesis and formation of organic matter. The universally accepted terminology for soil was defined by Joffe (1936) as “Soil is a dynamic natural body of mineral and organic constituents.” The dynamic nature is solely due to the activity of micro and macro organisms supported by the organic matter. The organic carbon and nitrogen content of the soil increased with rainfall (Manickam T S 1965). The humid substances penetrate the inter lamellar spaces of clay minerals, and influence the interaction of clay with other soil constituents. Palaniappan, 1975 in his book “Organics in soil health and crop production” has stated that and (Kodama et al 1968) confirmed clay rich soil contains high electrical conductivity.

The important physiochemical properties like cation exchange capacity, and soil buffering capacity were discussed by (Drake et al 1982). They emphasized that the physiochemical properties were influenced by the soil’s organic matter content.

Larson W E et al (1984) had revealed that the water retention capacity of the soil is more pronounced with high organic matter content, basically due to its qualitatively net negative charges and the dipolar nature of the water molecules.

Uehara et al (1981) reported that the soil specific surface charge density is nothing but the ion exchange capacity of the soil. (surface charges in the soil formed by the exchange of cat ions and anions).
Parker J C et al (1982) had claimed that the soil’s electrical conductivity (EC) is due to electrolytes in the soil solution and the electrically charged colloid surface. The elevated electrical conductivity increases the apparent dielectric permittivity. Clay has high EC because of the exchangeable cations, and the water film associated with them.

Hendrickx et al (1997) had stated that (Peck 1983), (Hendrickx et al 1990) and (Nielsen et al 1973) have contributed significantly to the moisture studies of the soil. The variability of the soil’s water content affects the soil’s electrical conductivity. Many field observations have shown that the soil’s water content has its own intrinsic spatial variability, due to small differences in the hydraulic properties, vegetation unstable wetting and macropore flow.

Pozdnyakova A I et al in (2001) and (Pozdnyaakova L A 1996) revealed that the electrical potential in soils, clays and other water saturated and unsaturated sediments was due to ionic layers, electro filtration, pH difference and electro osmosis. They asserted that the application of the self-potential method is to study the subsurface water movement.

Anderson et al (2002) had evaluated the salinity in soil. The electrical conductivity in the surface of the soils appears to be of many different kinds. Methods of Self potential, Electrical profiling and Non-contact electromagnetic profiling were used to measure the electrical properties of the basic soil types, such as Spodosol, Histosol and Aridisol (USA Soil Classification) of Russia.
The methods of electrical conductivity (Four electrode probe and Electromagnetic induction) are routinely used to evaluate soil salinity.

Mc Carty et al (2002) revealed the superiority of mid-IR techniques in most cases. Various recent studies have shown that soil fertility is declining in many farmlands, due mainly to inadequate farming practices (Gobeille et al 2006). Technological achievements in the mid–infrared (mid-IR) range during the last decade have made this spectral range much more attractive, and an increasing number of soil studies are being conducted using this spectral range.

T H Ko et al (2005) in their paper, had explained the results of the characterization of red soil in relation with the sorption of H₂S from coal gas at 500°C by spectroscopic techniques, in order to provide more information about red soil. An appreciable amount of the byproduct CO₂, SO₂ and COS is detected by on line FTIR Spectroscopy during the initial and later stages of the sorption process. It has been known for many years that soils have the ability to absorb reductive sulfur containing hydrogen sulfide, Carbonyl sulfide, and Di methyl sulfide.

Linker et al (2006) and (Du et al 2008) showed, that the spectral information related to carbonate and other soil constituents can be used to discriminate between soils, and (Linker et al 2006) further showed, that such an automatic discrimination can improve the estimation of nutrients such as nitrate.
Viscarra Rossel R A et al (2006) studied soil nutrients, such as C, N, P, K, S, Ca, and reported that micronutrients play a primordial role in the development of agricultural crops, and hence, the determination of their concentration is crucial to the application of precision agricultural concept compiled an excellent review of the studies dedicated to the estimation of these parameters using Diffuse Reflectance.

Mikhailova E A et al in (2006) had reported that a large amount of soil organic carbon stored in the form of calcium carbonate has been found in the cultivated moltiols suggesting an increase in the carbonation process with agricultural practices. Dolomite formation appears to be favoured by the presence of clay minerals.

Robert Bobby et al (2007) had studied the electrical conductivity of soil varieties depending on the amount of moisture held by the soil particles. Sand has medium low conductivity. Silts have medium conductivity and clays have high conductivity. Consequently electrical conductivity (EC) correlates strongly to the soils particle size and texture. There are types of sensors commercially available to measure the soil EC in the field. Non-contact EC sensors work on the principle of Electromagnetic Induction.

L R Reyes et al (2007) and (E T Romero 2007) had studied the presence of heavy metals in the soil. The soil at the land fill may became toxic because of the presence of a higher concentration of heavy metal.
Chromium is important from the environmental point of view, since its behavior and toxic properties depend on its oxidation states. A higher concentration of toxic and dangerous heavy metals to the soil is that of Cadmium (Cd), Chromium (Cr), copper (Cu), Nickel (Ni), Lead (Pb), Zinc (Zn). The Cr (VI) concentration in the wells of Buenavista, Guanajuato, Mexico is higher than its permissible level in drinking water 0.05 mg/l. The objective of this research was to determine the elution of chromium with de ionized water from contaminated soil samples, and to determine the oxidation state of Fe (iron) which is an element that can limit chromium. Chromium contaminated soil samples were obtained from Leon, Guanajuato, Mexico- O, Na, Mg, k, Al, Si, Ca, Cr and Fe were found in the chemical analysis by EDS, of the contaminated soil.

Vijayakumar et al (2011) stated that micronutrients play a vital role in maintaining the soil health and the productivity of crops. Soils with finer particles and with higher organic matter content can generally provide a greater reserve of these elements. The processed soil samples were analysed for basic soil parameters like pH, EC, and available minerals like Fe, Mn, Cu, Zn in soil samples. The concentration of the micronutrients in the extract was determined by the AAS. Xiaoquang Dong et al (2011) revealed the importance of the impedance characteristics in soil, by doing the AC impedance study using TH2828A Wide frequency LCR meter from (50 to 60 Hz), and the AC impedance characteristics with different water contents of the soil had been discussed. The results fully illustrate that AC Impedance is one of the basic properties of the soil, and the value of the AC impedance parameter can be reflected in the water content quantitatively.
The measure method of AC impedance has no effect on the physical properties and internal structure of the soil.

In 2011 Diaz et al had presented a work about the presence of Dolomite in soil, which enhances the transport of ions. The calcite detected in the sub soil is interpreted as a precursor of the newly formed Dolomite.

1.5 Aim and scope of present investigation

Soil contains innumerable mineral resources and organic matter which makes it eco-friendly and a novel conductor of electricity. The present investigation reports the results of the elemental, structural characterization along with electrochemical impedance spectroscopy of the following soils.

1) Red soil collected from Pudukudi near Tiruchendur.
2) Coastal soil collected from Tiruchendur coastal area
3) Riverbed soil collected from Tamirabarani riverbed, Tirunelveli.
4) Alluvial soil collected from Vannikonedal village near Tirunelveli.

All the above mentioned soils were collected from 10 to 15cm depth of appropriate places. The as-obtained soil was finely ground and sieved. The fine soil particles were investigated for its physical and chemical properties. The smooth soil particles were investigated using Atomic Absorption Spectroscopy (AAS), Scanning Electron Microscopy (SEM), Energy Dispersive X-ray study (EDAX), and Fourier Transform Infrared Spectroscopy (FTIR) and Electrochemical Impedance Spectroscopy (EIS) techniques respectively.
The AAS was recorded using Perkin Elmer AAS 3300. The Quanta 200 FEG scanning electron microscope was utilized for capturing SEM pictures and EDAX technique was also employed to obtain the percentage of elements present in the sample from the same instrument. The FTIR spectrum at room temperature was obtained using Perkin Elmer Spectrum 100 FT-IR spectrometer. The Electrochemical impedance spectroscopy were carried out over a wide range of frequency from 50Hz to 5MHz at various temperature ranging from 323K to 673K using HIOKI 3532-50 LCR Hitester model. The EIS was measured at different temperatures ranging from 323K to 673K and were exhibited by Nyquist plots using NLLS fit (non linear least square fit). The formation of diffusion layer and double layer had been exhibited. The temperature dependence of the conductivity was verified using Arrhenius plots. ( log sigma (σ) versus 1000/T).