Dielectric Properties of Contaminated and Reclaimed Dry Soils at Radio Frequencies

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Abstract

In present study dielectric properties of contaminated and reclaimed soils were studied. The contaminated soil samples were collected from ten different soil contaminated sites of North Maharashtra region. The Soil samples were analyzed for physical and chemical properties. Then they are reclaimed with the help of Compost, Urea, Single Super Phosphate and Potash according to suggestions given by agricultural experts. The dielectric constant ($\varepsilon'$) and dielectric loss ($\varepsilon''$) of contaminated and reclaimed soil samples are measured in frequency range 20 Hz to 1 MHz using automated LCR meter at 0% (dry) moisture content. The dielectric constant ($\varepsilon'$) and dielectric loss ($\varepsilon''$) of contaminated and reclaimed soil samples show decrease with increasing frequency. The Dielectric constant and Dielectric loss of all soil samples rapidly decreases from frequency 20 Hz to 10 kHz and from frequency 10 kHz to 1 MHz decrease slowly. From this study it is also observed that the Dielectric constant of soil samples decrease after reclamation of contaminated soil samples.

1. Introduction

Many researchers are working on study of dielectric characteristics of soils, rocks and contaminated soils at microwave frequencies and also at radio frequencies (1, 2, 3, 6,7,8,10,11 and 12). The precise dielectric study of earth constituents at high frequency radio wave or at microwave frequencies is required for their use in planning ground penetrating radar survey(2). The objectives of present research work are to provide the detailed ground truth experimental data on the dielectric properties of different types of contaminated and reclaimed soils from North Maharashtra region, to measure moisture content of the soils and to understand contamination and reclamation of the soils.
2. Materials and Method

2.1 Sample preparation: The contaminated soil samples were collected from sites contaminated due to chemical factory, oil mill, sugar factory, textile mill etc. of North Maharashtra region. The soil samples were first sieved by gyrator sieve shaker to remove coarser particles from the samples. The sieved fine particles were dried at temperature $110^\circ$C for about half an hour to remove any trace of moisture completely. This dry sample was referred as dry base (0% moisture content). The Soil samples were analyzed for physical and chemical properties from Soil Testing Laboratory of Government Agricultural college, Pune (soil pH, Electrical Conductivity, Organic Carbon, Calcium carbonate, Nitrogen, Phosphorus, Potassium, Iron, Manganese, Zinc, Copper, Calcium, Magnesium, Particle Density, Bulk Density, Sand, Slit, Clay and Textural Class). Then they are reclaimed with the help of Compost, Urea, Single Super Phosphate and Potash according to suggestions given by agricultural experts.

2.2 Pellet formation: The prepared soil samples are in powder form. We can’t measure capacitance of soil samples with LCR meter when the samples are in powder form. Hence the pellet of each soil sample is formed by using Hydraulic press machine which is available at Godavari foundation’s Engineering College, Jalgaon. Each sample i.e. pellet was coated on both side with air drying silver paste so that it behaved like a parallel plate capacitor. The pellets are inserted between the electrode plates of LCR meter to measure capacitance. The soil sample acts as dielectric medium of capacitor.

2.3 LCR meter: The dielectric constant measurement set-up consists of testing cell and LCR meter. The soil samples are prepared in scientific manner. The prepared soil sample whose dielectric constant is to be measured is compressed into a test slab or disc at a given thickness so that it can be measured in a dielectric cell. A dielectric cell is a test fixture with two plates into which the sample (soil pellet) is installed for evaluation of its electrical properties. When it is connected to an LCR meter, the capacitance (C) measurement can be taken.

Fig.1 Photograph of automated LCR meter setup for measurement of dielectric constant of contaminated and reclaimed soils

An auto balancing Wayne Kerr Ltd, model 4100 (Figure 1) operating at frequency 20 Hz to 1 MHz is used to measure the capacitance of the soil pellets. They provide a wide range of features and offer high performance. We can measure Impedance (Z), Phase Angle (θ), Capacitance (C),...
Dissipation Factor (D), Inductance (L), Quality Factor (Q), AC Resistance ($R_{ac}$) and DC Resistance ($R_{dc}$) of the soil pellets by using this LCR meter.

2.4 Formulae to be used: The Capacitance (C) and Dissipation Factor (D) of the soil pellets are measured with the help of LCR meter. By using following formulae Dielectric constant ($\varepsilon'$), Dielectric loss ($\varepsilon''$) and ac conductivity ($\sigma_{ac}$) of soil samples were calculated (4, 5 and 10).

$$C = \frac{\varepsilon' \varepsilon_0 A}{d} \quad \quad (1)$$

$$\varepsilon'' = D \varepsilon' \quad \quad \quad \quad (2)$$

$$\sigma_{ac} = \varepsilon_0 \varepsilon' \omega \tan\delta \quad \quad (3)$$

Where C – Capacitance, $\varepsilon'$ - Dielectric constant, $\varepsilon_0$ – Dielectric constant of free space, $\varepsilon''$ - Dielectric loss, A - Area of each plate, d – thickness of pellet, D – Dissipation factor, $\sigma_{ac}$ - ac conductivity, $\omega$ - angular frequency and tan$\delta$ - loss tangent or the dissipation factor D.

The dielectric constant is equivalent to relative permittivity. The ratio of energy lost to energy stored in a material is defined as the loss tangent or dissipation factor (11).

3 Results and Discussion:

Fig. 2 and Fig. 3 show the variation of dielectric constants of dry or 0% moisture content (MC) contaminated and reclaimed soil samples at different frequencies respectively. The dielectric constants were measured in the frequency range from 20 Hz to 1 MHz for ten contaminated and ten reclaimed soil samples. For all soil samples it is observed that dielectric constant decrease with increase in frequency (1, 6, and 7). Dielectric constant decrease abruptly up to frequency 10 kHz and then it decrease slowly (1, 6, and 7).
Fig. 4 and Fig. 5 shows the variation of dielectric loss of 0% moisture content contaminated and reclaimed soil samples at different frequencies respectively. The dielectric loss is also measured in frequency range 20 Hz to 1 MHz. The variation of dielectric loss is same as variation of dielectric constant. The dielectric loss of contaminated and reclaimed soil samples in the radio frequency range 20 Hz to 1 MHz is not very significant (6).
Figure 6 (a) to 6 (j) shows the variation of dielectric constant of ten soil samples after reclamation. The difference in dielectric constant is not very significant after reclamation. The reclaiming materials compost, urea, potash and single super phosphate slightly affect on the dielectric constant of soil (6, 7 and 12).
Conclusion

1. The dielectric constant ($\varepsilon'$) and dielectric loss ($\varepsilon''$) of contaminated and reclaimed soil samples decrease with increasing frequency.
2. The Dielectric constant and Dielectric loss of all soil samples decrease rapidly from frequency 20 Hz to 10 kHz while the decrease is slow in frequency range of 10 KHz to 1 MHz.
3. From this study it is also observed that the difference in Dielectric constant of soil samples is not very significant after reclamation of contaminated soil sample.

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