Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2016, 8(1):153-160

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Study of two Indian soils

V. V. Navarkhele

Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, (MS) India

---

ABSTRACT

The paper presents the study of two Indian soils of different colors. It consist microwave dielectric measurement and its comparison with the polynomial empirical model of Hallikainen. The objective of this study was to determine the physical, chemical compositions of these two soils and its behavior for agricultural purpose. The variation in resistivity with water content, physical- chemical properties of the said soils has been also reported in the paper. The dielectric properties that is, dielectric constant (ε′) and dielectric loss (ε″) has been reported at microwave frequency using transmission line waveguide technique. The comparative dielectric study show that there is variation in (ε′) and (ε″) though the texture composition of the two soils is approximately same. The gravimetric water content (θg), volumetric water content (θv), water holding capacity, bulk density, conductivity, P^H and total dissolved solids are also calculated to study the soils behavior for agricultural purpose.

Keywords: Black and white soil samples**;** Dielectric study; Physical-Chemical analysis; Resistivity; Waveguide transmission line technique.

INTRODUCTION

Knowledge of dielectric constant of soil at microwave frequencies is valuable in microwave remote sensing. It determines the response of the soil to an incident electromagnetic wave. This response is composed of two parts (real and imaginary), which determine the wave velocity and energy losses respectively. In a non-homogeneous medium such as soil, the dielectric properties have a strong impact on its microwave emission. However, the relationship between soil dielectric constant and the soil physical properties is not straight forward. A large number of studies have been performed during the last decades to find out this relationship since it play an important part in the soil moisture retrieval algorithms from remote sensing data [1-4]

The real part of complex dielectric constant is an important parameter for soil moisture estimation that is useful in agriculture. The soil water is the most important physical property of the soil that affects intensively many physical and chemical reactions of the soil as well as plant growth. The theoretical basis for soil moisture measurement is based on the large contrast between the dielectric constant of water (80) and that of dry soil (3 to 5) [5, 6]. The dependence of soil dielectric properties on moisture can be observed with either passive or active microwave sensors through its effect on the soils emissivity and reflectivity [7].

In the present experimental study the author has reported the microwave dielectric behavior of soil- water mixture of black and white soil samples and the results are compared with the polynomial empirical model of Hallikainen [8]. The measurements were carried out at 11.00 GHz frequency and at room temperature (30^0C) using X – band set up. The accuracy of measurement is up to ± 0.3 % in dielectric constant and 2 % in dielectric loss can be obtained with this experimental technique. Various physical and chemical properties of the said soils have been also reported to study its behavior for agricultural purpose.

EXPERIMENTAL SECTION

Dielectric Data analysis

Theoretically, the dielectric properties of the material depend on the concentration, activity of permanent electrical dipole molecules, ionic conduction and degree of dipole alignment with the applied time varying- electric field. Therefore, when sample holder is filled with material, the dielectric properties are affected by the composition of the material and temperature which affects molecular movement.

The microwave soil dielectric measurement uses absorption of microwave energy corresponding to the rotational energy of the water molecules. When electromagnetic field is applied to the dielectric material, it is dissipated in the dielectric material as a result of dielectric relaxation process. The interaction of the electromagnetic field depends upon the complex dielectric constant relative to the free space [9].

In an alternating electric field, complex dielectric constant varies with applied frequency. This frequency dependence complex dielectric constant can be described by the relation:

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \tag{1}$$

The real part (ε') is called as the dielectric constant and the imaginary part (ε'') is called the dielectric loss. The (ε') describes the ability of a material to store electromagnetic energy, and the imaginary component represents loss of electromagnetic field in the material [10].

When a plane wave is incident normally upon a dielectric medium in free space, part of it is transmitted into the medium and part is reflected at the interface between free space and dielectric medium. The real part (ε') of the complex dielectric constant and loss (ε'') of the medium is given by the equations;

$$\varepsilon' = \lambda_O^2 \left[\frac{1}{\lambda_c^2} + \frac{\beta^2 - \alpha^2}{4\Pi^2} \right] \tag{2}$$

$$\varepsilon'' = \frac{\lambda_0^{\ 2} \alpha\beta}{2\Pi^2} \tag{3}$$

In above equations λ_0, λ_c, α and β are free space wavelength, cutoff wavelength attenuation constant and phase constant respectively. These parameters can be obtained from experimental observations. Putting λ_0, λ_c, α and β in equations (2) and (3), the dielectric properties was determined [11].

Experimental procedure for Dielectric properties

The experimental technique used for dielectric measurement is that of Roberts S. and Von- Hipple [12]. The method consists of reflecting microwaves at normal incidence in TE mode from a dielectric sample placed against a perfectly reflecting surface. The reflection sets up standing waves in space in front of the sample. The separation of the first minima from the face of the sample will depend upon wavelength of the EM wave in the sample and on sample dimensions and hence on dielectric constant. Further, the change in wavelength shall cause shift in the minima and in turn a change in half power width of the standing wave pattern. Also, losses in the dielectric shall decrease to Voltage Standing Wave Ratio (E_{max}/E_{min}) and so tan δ may be related to this decrease in VSWR. A least squares fit program was developed to determine the dielectric properties. This program provides precise calculations of high and low loss materials depending on the character of input data.

Prior to measuring the dielectric properties, the soil samples were dried by heating in an oven and allowed to cool in a dessecator. The cooled dry soil sample of known weight was placed in the empty dielectric cell and slightly pressed by a specially designed mechanical system to remove air and discontinuities in the sample. The dielectric cell with sample was connected to the other end of the source of the microwave bench set up. The signal generated from the source was allowed to incident normally on the dielectric sample. The values of power (current) at different points of standing waves have been measured as a function of probe position. About (80–100) points were recorded for a single standing wave pattern. The measurement of dry soils was conducted for three different thicknesses and averaged them to obtain accurate values. The values of λ_0 , λc, α and β was obtained from the experimental observations and fitting them in equation (2) and (3) the dielectric constant and loss was determined. To measure the dielectric properties of wet soils, a predetermined amount of distilled water was added to the soils; the combination was mixed well and then stored in the dessicator in order to cure for 24 hours. Using similar procedure the dielectric properties of wet soils was determined.

Soil Resistivity

Knowledge of soil resistivity is the key factor to decide its structural stability. It varies widely from field to field and changes seasonally. It depends on water content, chemical composition, soil type (sand, clay and silt), and temperature. It has a direct impact on the degree of corrosion in underground pipelines. The decrease in soil resistivity relates to an increase in rusting corrosion activity of the soil therefore the protective treatment is necessary. Soil resistivity data is also useful to make sub-surface geophysical survey. It affects the design of a grounding system. When it is possible to choose the location of the earth connection, resistivity measurement helps to qualify the soil [13-17].

The variation in resistivity with water content of the said soil samples by percentage of weight and volumetric is also reported in this work. It is measured in laboratory at temperature (22 ^{0}C) with an indigenously developed resistance meter. The Wenner equation was used to determine the resistivity.

Soil sampling

The soil samples were collected from the field at the depth of 5 to 12 cm in the vicinity of Marathwada region of Maharashtra state of India. These soil samples were selected for study, due to their different colors, also to get an idea about the chemical compositions responsible for the colors, and to verify the effect of color on agricultural production. The soil samples were taken from different location and mixed thoroughly to make one composite sample. The soil samples then brought to laboratory in a polythin air tight bag so as to avoid the moisture evaporation. Immediately in the laboratory the gravimetric and volumetric water content was measured. After drying the soil samples in air for few days the other parameters were determined.

Soil Characterization

Soil P^H was measured in water at a soil: water ratio of 1:5 using a P^H meter after shaking the suspension for 15 min and equilibration for 15 min. The same suspension was used to measure the electrical conductivity (EC) after allowing them to settle for half an hour using a conductivity meter. The chemical and texture analysis of the soils was obtained from the Government soil survey office of Aurangabad, which is based on the agricultural classification system. The gravimetric water content, volumetric water content, soil melting capacity, water holding capacity, bulk density, porosity, air-filled porosity, conductivity and total dissolved solids (TDS) was determined in laboratory.

RESULTS AND DISCUSSION

Microwave dielectric behavior of soil- water mixture of black and white soil samples was reported using X- band and the data was compared with polynomial empirical model. The dielectric data shows that the real part of the complex dielectric constant initially increases slowly up to the transition point and after that it increases sharply. The slow rise in dielectric constant is due to the bound water. At moisture level less than the transition point, water is tightly bound to the soil particles by metric and osmotic forces (bound water). It is difficult for those water molecules to polarize at the applied field. As soil water increases, water is able to move more freely around the soil particles and this free water have a dominant effect on the dielectric constant. The results are in the agreement with the results of Hallikainen et al., Wang et al, Godio et al., 2007, Boyarskii et al [4, 6, 9].

The experimental dielectric data of black and white soil samples is graphically illustrated in Figure 1(a) and 1(b) respectively. The experimental data show slightly higher values of dielectric constant for black soil than that of white soil. This is due to the textural composition of the two soils. The texture analysis of the black and white soils is given in Table 1**.** Generally, the clay content of soil decides water holding capacity and dielectric constant. The black soil has slightly higher content of clay (59.47%) than that of white soil (52.24%). Therefore the dielectric constant of black soil is higher than that of white soil.

Table 1 Soil texture

Sr. No.	Soil texture	Black soil	White soil
1	Coarse Sand (Percentage)	4.23	15.67
2	Fine sand (Percentage)	4.80	5.97
3	Silt (Percentage)	31.50	26.12
4	Clay (Percentage)	59.47	52.24

Table 2 Soil Physical properties

Sr. No.	Physical properties	Black soil	White soil
1	Gravimetric water content (θg)	0.12 $g.g^{-1}$	0.01 $g.g^{-1}$
2	Volumetric water content(θv)	0.14 $cm.cm^{-3}$	0.02 $cm.cm^{-3}$
3	Soil melting capacity	0.350 %	0.440
4	Water holding capacity	48.83 %	35.00 %
5	Bulk density	1.19 g/cm^3	1.16 g/cm^3
6	Soil porosity	0.55	0.56
7	Air – filled porosity	0.41	0.54

Table 3 Soil Chemical properties

Sr. No.	Chemical Composition	Black soil	White soil
1	Organic carbon	0.71%	0.85 %
2	Available phosphorus (Kilo/hectare)	29 %	32 %
3	Available potassium(Kilo/hectare)	366 %	380 %
4	Combined calcium	58.24 %	79.04 %
5	Combined magnesium	15.62%	14.20 %
6	Combined sodium	9.5%	10.5 %
7	Free calcium carbonate	3.85%	6.10 %
8	Conductivity	1340 µ℧ /cm	220 µ℧ /cm
9	Total dissolved solids (TDS)	670–1005 ppm	121–165 ppm
10	pH	7.9	7.7

The polynomial empirical data for black and white soil samples is approximately same and it is graphically illustrated in Figure 2(a) and 2(b) respectively. The comparison of experimental and polynomial data is given in Figure 3(a) and 3 (b) respectively. The comparison shows that the experimental and polynomial dielectric data of black and white soil is not same, though the textural composition of the two soils is nearly same. Since the polynomial empirical model is based only on fine sand, silt and clay. The effect of coarse sand, organic matter and other compositions of soils were shown by the experimental results not by the empirical model. Therefore there is variation in experimental and empirical dielectric data of the two soils.

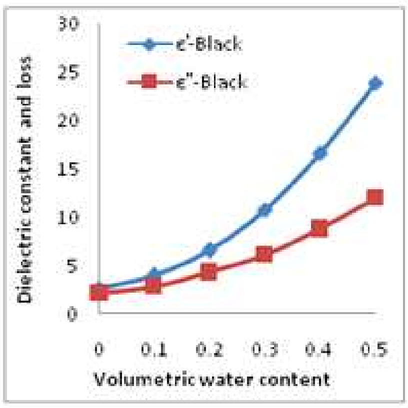

Figure 1 (a): Experimental data of dielectric constant and loss of black soil at 11.00 GHz frequency

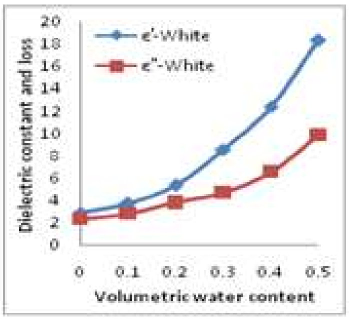

Figure 1 (b): Experimental data of dielectric constant and loss of White soil at 11.00 GHz frequency.

The variation in the resistivity of black and white soils with water content is given in Figure 4(a) and 4(b**)** respectively. The resistivity of both the soils decreases with water content in both the methods and attain a constant value at saturation. It is also observed that, the resistivity of white soil is higher than that of black soil in both the methods. This indicates that the black soil has higher water retentive capacity than that of white soil. Due to this property the black soil is better for agricultural purpose than that of white soil.

The study also shows that, the color of the soil does not matter for agricultural purpose. The white soil has all those ingredients which are available in black soil. The two soils has slight difference is physical-chemical properties. Therefore white soil is equally good for agricultural productivity.

The chemical compositions of the white soil show higher percentage of the ingredient like calcium carbonate, this make it possible to use white soil for construction and other applications where calcium carbonate is used. White soil is a popular building material in the rural India, where it occurs, since it is soft, durable (when it is mixed properly with water for two/three days), and commonly occurs in easily accessible surface exposures. Even today, in southern part of India white soil is used as a mixture (Mixture of white soil and water) in between the two bricks/ stones for construction purpose as an alternative for cement.

The physical and chemical analysis of black and white soil samples is given in Table 2 and 3 respectively. The physical properties like gravimetric water content, volumetric water content, water holding capacity, bulk density, porosity, air-filled porosity of both the soils was determined in laboratory. These parameters are related with soil water content and are higher for black soil than that of white soil.

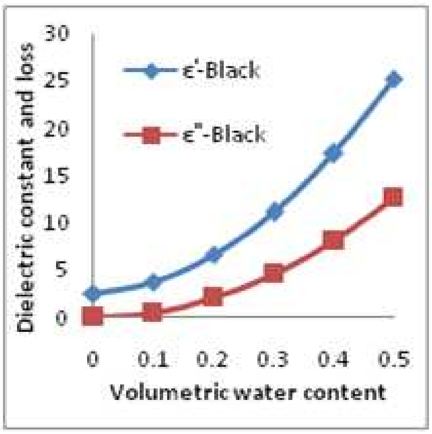

Figure 2 (a): Polynomial empirical data of dielectric constant and loss of black soil at 11.00 GHz frequency

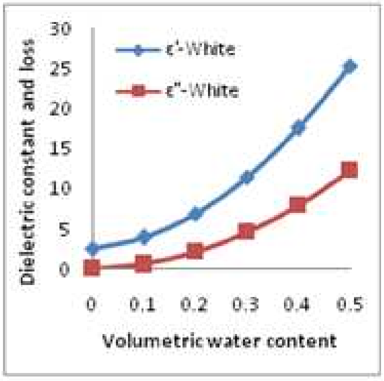

Figure 2 (b): Polynomial empirical data of dielectric constant and loss of White soil at 11.00 GHz frequency

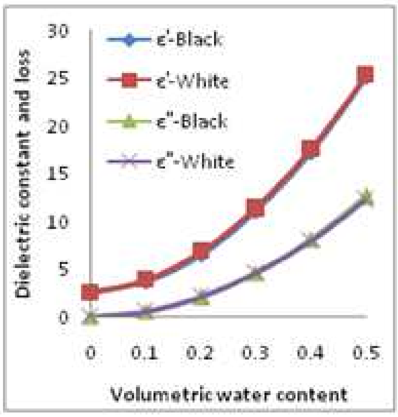

Figure 3 (a): Polynomial empirical data of black and white soil at 11.00 GHz frequency

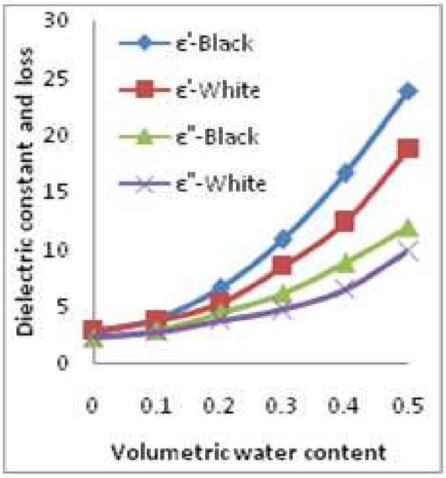

Figure 3 (b): Experimental data of black and white soil for 11.00 GHz frequency

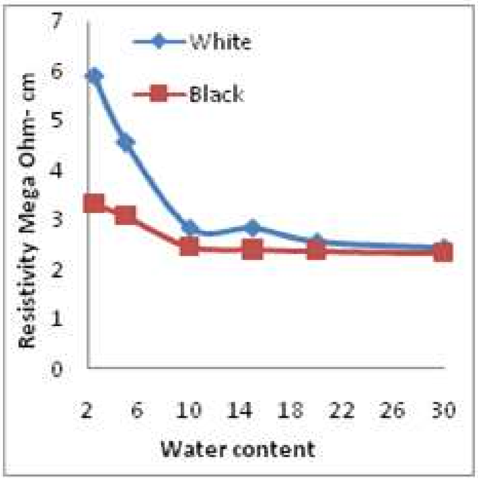

Figure 4 (a): Variation in resistivity of black and white soil with water content by percentage of weight

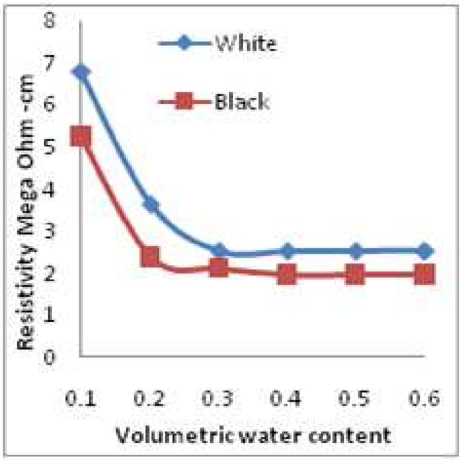

Figure 4 (b): Variation in resistivity of black and white soil with volumetric water content

CONCLUSION

The dielectric behavior of soil-water mixture of black and white soil samples have been reported at 11 GHz frequency. The real part of the complex dielectric constant is exponential function of water content, and can be used to determine water content. The experimental results were compared with the polynomial empirical model. The comparative study shows that the experimental results are more accurate, since it is carried out at higher frequency.

The variation in resistivity with water content of the said soil samples has been reported. The resistivity decreases by adding water content and reaches to a constant value. It is higher for white soil and lower for black soil. Due to lower water resistance or higher water retentive capacity black soil is good for agriculture purpose.

The color of the soil does not matter the agricultural productivity. Due to higher percentage of calcium carbonate, the white soil is used for construction and other applications where calcium carbonate is used.

Acknowledgement
The author is thankful to University Grant Commission, New Delhi, for financial assistance.

REFERENCES

[1] MA Hilhorst; C Dirksen; FWH Kampers; RA Feddes, Dielectric relaxation of bound water verses soil metric pressure, *Soil Sci. Soc. Am. J*.,**2001**, 65,

[2] SC Dodson; FT Ulaby; MT Hallikainen; MA El-Rayes, *IEEE Trans. On Geosciences and remote sensing,* **1985**, GE.-23, 25 – 45

[3] Godio; Open ended coaxial cable Measurements of saturated sandy soils, *American journal of environmental sciences*, **2007**, 3(3):pp 175-182.

[4] DA Boyarskii; VV Tikhonov; and NYU Komarova, Model of dielectric Constant of bound water in soil for applications of microwave remote sensing. *Progress in Electromagnetics research,***2002**, 35: 251-269.

[5] JR Wang ;TJ . Schmugge, *IEEE Trans. On Geosciences and remote sensing,* **1980**, 288- 295.

[6] MT Hallikainen; FT.Ulaby, A free - space system for dielectric measurements in the 3-18 GHz frequency range,Univ. of Kansa, *Center for research, Inc., Lawrence, KS, RSL Tech. Rep***. 1983,** 545-3**.**

[7] Kraszewski; Microwave Aquametry- Electromagnetic Interaction with Water Containing Materials. Piscataway. NJ: (IEEE Press), **1991**.

[8] MT Hallikainen; FTUlaby; MC Dobson; MA El-Rayes; and Lin-Kun Wu,**1985**. IEEE Trans. *On Geoscience and remote sensing,* **1985**, Ge.-23, No.1.

[9] Bilskie; Using dielectric properties to measure soil water content, *Sensors*, **1997**, 14.

[10] KA Smith; CE Mullins, Soil analysis, Physical methods. Marcel Dekker, New York, **1991**, Vol. 3: 37.

[11] NE Hill; W E Vaughan; AR Price; M Davies, *Dielectric properties and Molecular behavior, Van Nostrand Reinhold, London,* **1969**, 135-152

[12] S Robert; and A Von Hipple, A new method for measuring dielectric constant and loss in the range of centimeter waves. *J. Appl. Phys,* **1946**, 17: 610.

[13] TA Jhon; and CM Anaele, Seasonal variation of soil resistivity and Soil temperature in Bayelsa state, *American J. of Engineering and Applied sciences*, **2010**, 3(4): 704-709.

[14] Barker; Depth of investigation of collinear symmetrical four- electrode arrays. *Geophysics*, **1989**, 54: 1031-1037.

[15] CB Eric; EF Thomas; L Andreas, *Earth and Environmental Sci*., **2006,** 7, No.6: 393404.

[16] KR Sheets; JMH Hendricks, *Water Resour. Research*, **1995**, 31: 2401-2409

[17] Ferhat Ozcep, Okan Tezel & Metin Asci, *International Journal* of *Physical sciences*, **2009**, 4(6), 362-365.