Study of dielectric and physiochemical propertiesof soil at Bastar region of India

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Abstract:
In the upcoming awareness for different soil types and its impact on various physical, chemical properties and holding capacity, it is critical to investigate the impact of inorganic materials on soil dielectric potential at microwave frequencies. In this regard, different soil specimens were gathered from varioussites of Dantewada district around NMDC Dantewada agricultural land (Villages- Kirandul, Bade- Bacheli, Bacheli,Bhanshi). Surprisingly, not much has been reported towards the chemical propertiesof the key constituents of these different soils. In the present study, we therefore investigated the different properties of soils, particularly to the dielectric potential from different locations, at microwave frequency. The data revealed the sensitivity towards various soil types and thus helped in determining the soil texture. Furthermore, by knowing the electrical conductivity and dielectric potential of soil samples, various chemical parameters including the different percentages of clay, slit and different physical properties were thus explored.These findings concluded that at different locations, there is remarkable variation in physical and chemical properties of soils. Also, the observed values of soil dielectric characteristics are in good accord with previous research. As a result, researchers working in the field of agriculture might benefit from these characteristics.

Keywords: Dielectric potential, Conductivity,Relaxation Time, Microwave frequency, Emissivity.

Introduction:

During past 30 years of time span we have seen tremendous amount of evidencesof different verity soils that helps agriculturists. This indication has also shown a growing number of effective preventive measures through thorough research. In today's wellbeing context, when resources are limited, concerns regarding the time and expense of developing and implementing care plans are critical.Soil, being the top most layer of the earth's land surface, contains all the essential nutrients and thus provides the major support to all the plants used for different purposes in agriculture. Since the composition of soil is usually varied, with some elements required in larger quantities whereas some are required in small quantities.

Furthermore, the complex dielectric permittivity, relative to free space, determines how electromagnetic radiation at microwave frequencies interact with geological materials. The dielectric characteristics of soil are influenced by its physical qualities, like sand, silt, and clay, as well as its chemical properties, such as nitrogen, sodium, potassium, iron, and magnesium. Researchers studying the dielectric characteristics of soils used a variety of approaches to investigate the dielectric parameters of diverse materials. [1-12].

The physico-chemical constituents of soil are the main function of the different studies that estimate the dielectric properties at microwave frequencies of the soil. [13]. Various factors such as the dielectric properties of soil which mainly includes natural, artificially created electrical fields are mostly affected byinorganic ions, in soils. The soil-forming processes results fromthe electrical charges dispersion and properties in different soil profiles. Chemical, physical and electrical characteristics are all included in soil. Physical qualities include texture, colour and grain size; chemical properties include organic matter, nutrients, pH, and many more; and electrical conductivity, dielectric constant and permeability are electrical properties.Dielectric properties are the key characteristic feature with regard to electrical features in every material. Scientists and engineers gained vital information from the most exact measurements of these characteristics in order to appropriately incorporate the material into its intended application. Measurements of the soil dielectric constant are reviewed, and the dielectric constant's influence on several soil characteristics is calculated. Moisture content is given considerable consideration because of its practical importance in remote sensing and single most significant quantity in terms of soil dielectric characteristics.The results of several investigations on the change of dielectric properties of fertilised soils at microwave frequencies have been published. According to many scientific studies, larger pore space provides ample area for crop grains to develop, resulting in enhanced soil productivity. [14]. Heiniger R. W. et al. [15] showedthat the soil testing is required to assess the availability of nutrients and to create fertiliser recommendations for best crop performance. Navarkhele V. V. et al. [16] and Shaikh A. A. and Navarkhele V. V. [17] have also revealedat X-band microwave frequencies, the dielectric characteristics of black soil with respect to inorganic and organic materials. Chaudhari H. C. and Shinde V. J. [18] have determined a. c. electrical conductivity (σ), and relaxation time (τ) of soil from experimentally measured values of complex dielectric constants of red and black soils. Gadani D. H. et al. [19] Using a precision LCR metre, researchers investigated the dielectric characteristics of moist and fertilised soils at radio frequencies. Their findings demonstrate that when the concentration of nutrients in the soil increases, so does the dielectric constant and dielectric loss. The individual dielectric constants of its elements, such as sand, silt, clay, inorganic and organic substances, and so on, make up the dielectric constant of a non-homogeneous material like soil. The dielectric characteristics of soil at microwave frequencies are predicted to be a function of its physico-chemical components, according to several research. [20-24].

The experimentally obtained dielectric constant and dielectric loss values for soils with various physical and chemical characteristics are presented in this paper. These data are used to determine the a.c. electrical conductivity and relaxation time.

MATERIALS AND METHODS:

Soil Sampling:

Soil specimen are gathered from different locations of Dantewadadistrictaround NMDC Dantewada agricultural land(Villages- Kirandul, Bade- Bacheli, Bacheli ,Bhanshi) at a depth spanning from 0 to 20 cm followinga crisscrosssequence. For each sample, five holes were excavated. After thoroughly combining all of the foregoing soil specimens, a composite specimen of around 3 to 4 kg indicating one site was collected. While preparing composite samples representing all of the locations, this technique was repeated.At first the coarser particles are removed using thegyrator sieve shaker that helps remove the topsoil samples. TheseFine particles are sieved out and after that left to dry in a hot air oven at a temperature of approximately 110°C for around 24 hours to eliminate any remaining moisture.

Theory

At the analysis laboratory, the chemical and physical characteristics of soil samples are measured. The study makes use of a large number of soil samples with various chemical and physical characteristics. The physico-chemical and dielectric characteristics of soils are the only ones covered in this study. The empirical formula on soil composition can be used to calculate the field capacity (FC).

FC= 25.1 - 0.21 (% Sand) + 0.22 (% Clay) Wilting coefficient (Wp) is calculated by using the Wang and Schmugge model.

$Wp = 0.06774 - 0.00064 \times sand + 0.00478 \times clay$

$weight = 0.45 \times wp + 0.165$

The complex dielectric constant is calculatedusing the relation

$\varepsilon^* = \varepsilon' - j\varepsilon''$

Where ε'=dielectric constant, ε''=dielectric lossfactor.Since soil's dielectric constant is determined by its moisture content, the salt content of water will affect its dielectric characteristics. In agriculture, salt content makes it more harder for crops to collect soil moisture, reducing plant development and yield. Monitoring was required to keep track of variations in salinity and predict additional deterioration. This paper presents the experimentally obtained dielectric constant and dielectric loss values for soil with different salt levels.

The dielectric constant ε', dielectric loss ε''emissivity ep(q) and a.c. conductivity (σ) ofthese soil samples are then determined from thefollowing relations:

$\varepsilon^* = \varepsilon' - j\varepsilon''$

Where ε'=dielectric constant, ε''=dielectric loss factor. Since the dielectric constant of a soil depends on the moisture, the presence of salts in water will also affect its dielectric properties.

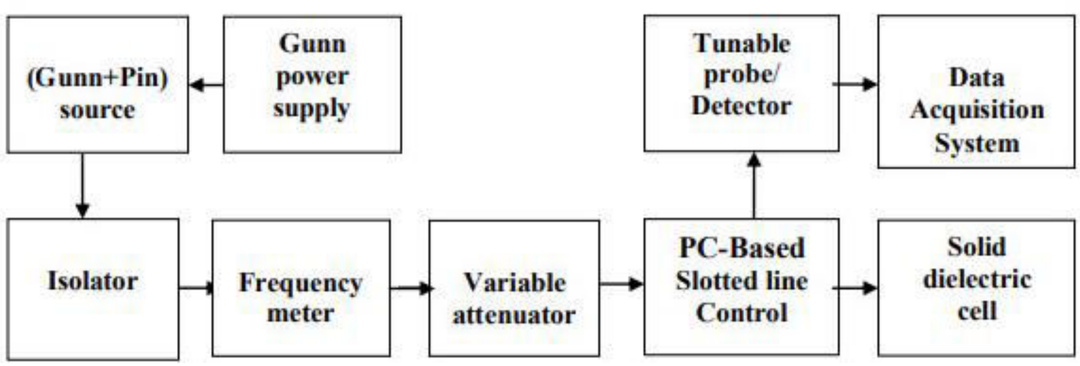


Figure 1: Block diagram of microwave bench setup for the measurement of dielectric constant of Soils.

The dielectric constant ε', dielectric loss ε'' emissivity ep(q) and a.c. conductivity (σ) of these soil samples are then determined from the following relations:

$$\varepsilon' = \frac{g_\varepsilon + \left(\lambda_g / 2a\right)^2}{1 + \left(\lambda_g / 2a\right)^2}$$

$$\varepsilon'' = \frac{\beta_\varepsilon}{1 + \left(\lambda_g / 2a\right)^2}$$

a = Inner width of rectangular waveguide.

lgs = wavelength in the air-filled guide.

ge = real part of the admittance

βϵ = imaginary part of the admittance

Soils samples of different moisture contents are prepared by adding measured amount of distilled water to dry soil. The moisture content is percentage by dry weight Wc (%) is calculated using following relation.

Wc (%) = [(weight of wet soil - weight of dry soil) / (weight of dry soil)] x 100

This soil sample is considered as dry or 0 % moisture content soil sample. Then on the basis of volumetric analysis 5%, 10%, 15%, 20%, 25% and 30% moisture content soil samples were prepared and dielectric constant is measured using X band microwave set up.

Result and Discussion:

This research aids in identifying the values of various soil physio-chemical characteristics as well as nutrient concentrations.

It is noticed that the value of dielectric constant rises with moisture level increment. The value of dielectric loss varieswith different soil samples as shown in Table 1.

The electrical conductivity and dielectric constant of soil can be used to describe its texture.

1. Dielectric Constant

Table 1: Dielectric constant of different soil samples

S.No.	Sample	Dielectric constant
1.	S1- Kirandul	3.11
2.	S2- Bacheli	3.14
3.	S3 – Bhanshi	3.15

The environmental hazard mainly includes excess nitrogen fertilizer in soil. To prevent overuse, the amount of accessible nitrogen in the soil must be determined and taken into account when determining the nitrogen fertiliser rate. There are several sources of nitrogen that must be considered when determining a region's N budget. When planning nitrogen programmes and evaluating environmental consequences, the mobility factor of nitrogen in the soil must be considered. The kind of soil and climatic circumstances have a big impact on nitrogen loss from the soil. Sandy soils lose nitrogen due to leaching, whereas heavy, poorly drained soils lose nitrogen due to de-nitrification. Because Minnesota's soil and climate are so diverse, the N cycle should be interpreted differently depending on where you are. Also from graph 9, dielectric constant has positive correlation with nitrogen available in soil.

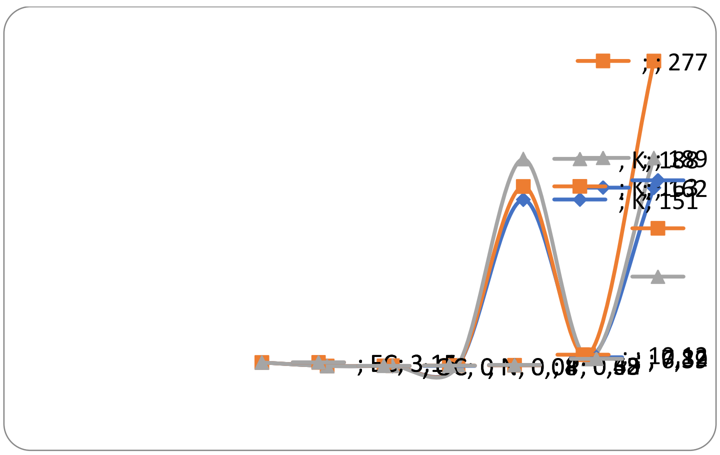
Phosphorus is an element of plants' complex nucleic acid composition that controls protein production. As a result, phosphorus plays a crucial role in cell division and the creation of novel tissues. Phosphorus is also connected to the plant's complex energy changes. Adding phosphate to low-phosphorus soil encourages root development and winter hardiness, accelerates tillering, and speeds up maturity. Also from graph 1, dielectric constant has positive relation with phosphorus available in soil.

Each plant nutrient in soil has a distinct and distinct activity. The behavior of each nutrient is determined by a number of factors, including the parent minerals involved, as well as the nutrient's solubility and transportation. Unlike nitrogen and phosphorus, potassium has little to no association with organic matter. Potassium levels in soil will range from 6.39 percent to more than 10.12 percent. While overall potassium concentration is essential, it has little bearing on a soil's ability to provide potassium to developing plants.Plants take potassium in greater levels than magnesium and calcium; in fact, nitrogen being the solitary nutrient that plants absorb in greater amounts than potassium. Many plant activities require potassium, including enzyme activity, food absorption, transpiration and respiration. Potassium is unique in that it does not create plant compounds and instead remains in ionic state in the plant. Potassium that remains in plant residues and manure after harvest is promptly restored to the soil by water soaking through the organic matter and manure.

2. Chemical Analysis Report

Table 2: Various parameters determining the chemical analysis of different soil samples

S.No.	pH	EC	OC	N	P	K
		dSm-1	%	(kg/ha)		
1.	5.6	0.05	0.45	151	7.82	162
2.	5.04	0.08	0.38	163	10.12	277
3.	5.08	0.04	0.62	188	6.39	189



Graph1: Variation of Dielectric constant with PH, EC, OC, N, P and K

Soil fertility is based on organic carbon. It helps plants development by releasing nutrients, promoting structural, biological, and physical wellbeing, and acting as a barrier against hazardous chemicals.

Enhancing total organic carbon in soil reduces atmospheric carbon dioxide while also improving soil quality. The total of organic carbon intakes (plant and animal wastes) and losses from soil (decomposition, erosion, and offtake in plant and animal production) is the quantity of organic carbon stored in soil. Soil type determines the best attribute of soil to store organic carbon (percent clay). Plant development will be maximized while emissions of organic carbon from the soil are reduced, resulting in the most organic carbon retention in the soil.

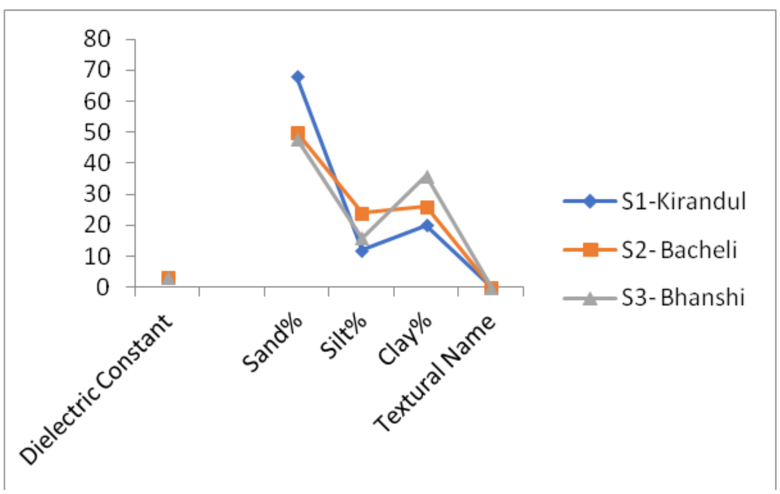
From graph 2 and table 2, it is observed that sand percentages decreases with increase of dielectric constant whereas it increases with the increase in percentage of silt and clay in soil.

3. Physical Analysis Report

Table 3: Various parameters determining the physical analysis of different soil samples

S.No.	Sand%	Silt%	Clay%	Texture Name
1.	68	12	20	Loam
2.	50	24	26	Loam
3.	48	16	36	Clay Loam

S.No.	Bulk Density (Mg/m3)	Particle Density (Mg/m3)	Porosity(%)	Maximum water holding capacity(%)
1.	**1.52**	**2.40**	**36.67**	**47.58**
2.	**1.50**	**2.53**	**40.71**	**46.14**
3.	**1.45**	**2.58**	**43.80**	**49.66**



Graph2: Variation of Dielectric constant with sand %, silt%, clay% and texture Name.

Also, the specific gravity, water content, bulk density, PH and grain size analysis was done in order to determine the porosity with the help of water content and specific gravity analysis as shown in Table 3.

Table 4: Various parameters determining the porosity analysis of different soil samples

S.no.	Test	Values								
1	Specific Gravity	2.58								
2	Water Content	19.50%								
3	Bulk Density	20.03KN/m3								
4	pH	6.9								
5	Grain Size analysis	Size (mm)	4.75	2.36	1.18	0.60	0.425	0.300	0.150	0.75
		%finer	99.4	98.9	97.9	97.2	95.9	95.6	92.1	74.7
		Sand %	**24.7**		**Silt &Clays%**			**74.7**		

Conclusion:

The pH of the soil, its physical properties, and the amount of organic matter in the soil are all essential. Grapes should be grown in a pH range of 5.5 to 7.0, depending on the variety. Unbalance soil can be balanced using lime to raise pH or sulphur to lower pH up to some specific range. As long as the soil drains adequately, silt loam and clay loam soils will sustain good grape growth. The pH of soil samples varies with soil texture and simultaneously varies dielectric constant of different soil samples. These variations have been found to be strongly dependent on the soil texture. The majority of experts agree that the ideal soil type for producing grapes is sandy loam. The optimum combination of features may be found in this sort of soil. It flows well yet has a considerable quantity of nourishing plant substances and a pH range that is typically within the desired range. From our analysis,it is observed that soil sample of this region is a sandy loam variety.

Also, soil dielectric constant is influenced by bulk density and hence porosity. The dielectric constant has a positive relationship with bulk density, according to the findings. It is simple to comprehend and evaluate satellite data if you know the correlation coefficient of various soil characteristics and nutrients with dielectric constant. The findings will aid in the prediction of soil texture, nutrient type, and concentrations in the soil. These predicted dielectric constant values may be used to calculate emissivity and scattering coefficient, which can be used to construct microwave remote sensing devices.

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