Physico-chemical and Dielectric properties of soil samples at X-band microwave frequency of Nasik region

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Abstract: The dielectric properties of material are function of its chemical constituents and physical properties. This paper presents the measurement of dielectric properties of soil samples of Nasik region. Soil samples were collected from agricultural land of Nashik region. The soils were categorized as loamy sand, sandy loam and clay loam. The soils were analyzed for the status of available nutrients. The pH and Electrical Conductivity of soil samples were measured by using soil testing kit. An automated X-band microwave set-up in the TE_{10} mode with Reflex Klystron source operating at frequency 9 GHz is used for measuring dielectric constants. Further, the data on the physical and chemical properties of these soils are also reported .These properties are important in better understanding of soil physics, agricultural application and analyzing the satellite data in remote sensing.

Keyword: Dielectric constant, tangent loss, microwave conductivity, relaxation time

INTRODUCTION

Indian agriculture occupies an eminent position in global cultivation of rice, wheat, sugarcane, pulses and vegetables.Soil is the unconsolidated or loose covering of fine rock particles that covers the surface of the earth [1]. Soil testing is the only way to determine the available nutrient status in soil and the only way we can develop specific fertilizer recommendations. Characterization of soil helps in determining soil potentials and identifying the constraints in crop production besides giving detailed information about different soil properties [2]. Nowadays, large numbers of chemical fertilizers are used instead of manures. Due to this the crop productivity increases speedily but the health of soil decreases. So management of natural resources is possible only after characterization and identification of constraints limiting crop production [3].

High yielding crop cultivars were highly responsive to fertilizers [4]. Soil characterization in relation to evaluation of fertility status of an area or region is an important aspect in context of sustainable agricultural production [5]. The interaction of electromagnetic waves with the geological material depends upon the complex dielectric permittivity, relative to the free space. Since farmers cultivate annual crops more than once a year, this leads to delay in remedial action for the coming season. Hence, rapid measurement and monitoring of soil nutrient variability is needed to satisfy the precision farming requirements. These problems can be solved by measuring electrical conductivity (EC) of soil [6].

Different studies predict that the dielectric properties of soil at microwave frequencies are the function of its physico-chemical constituents. The physical capacities of a soil are influenced by the size, proportion, arrangement and composition of the soil particles [7]. Ground-based studies of the dielectric properties of different earth constituents at microwave frequencies are important as they provide a successful interpretation of various remote sensing data. Microwave remote sensing techniques are now a day's widely adopted and used to estimate the presence of natural resources underneath the ground surface. The study of dielectric properties of earth constituents at microwave frequencies plays vital roll as they provides interpretation of various remote sensing data [8]. The present study has been undertaken to have an idea of electrical properties of different soils of Nasik region in Maharashtra state. In this paper, the experimentally determined values of real and imaginary parts of complex dielectric constant have been shown for soils.From this microwave conductivity and relaxation time is determined.

EXPERIMENTAL DETAILS

Materials and methods

Soil samples were collected in the depth of 0-20cm from 10 sites from Nasik District. Soil samples were completely air dried and passed through 2mm sieve and stored in properly labelled cloth bags as per the standard procedures. Quartering technique was used for the preparation of soil samples. The sieved out particles are then oven dried to a temperature around 110° C for several hours in order to completely remove any trace of moisture. Such dry sample is then called as oven dry or dry base sample when compared with wet samples.

The choices of measurement technique, equipment, and sample holder design depend upon the dielectric materials to be measured, and the frequency or frequency range of interest [9].

1. Study Area

The geographical area of Nasik District is 15.63 lakh ectares and cultivated area is 8.09 lakh hectares. The average rainfall of Nasik District is 1161mm. The maximum temperature of Nasik District in summer is 42.5°C and the minimum in winter is less than 5°C. The humidity range is from 43% to 62%. The major soil is of shallow red (536.7 ha), medium red/black (170.3 ha) and deep black (101.9 ha).The Nasik district is famous for grapes and onion. In Nasik district, season-wise crops are taken i.e. in rainy season- cotton, soya bean, in winter- wheat and in summer-onion.

RESULTS AND DISCUSSIONS:

1. **Bulk density and Porosity-**

The bulk density of soil indicates the degree of compactness of the soil and is defined as the mass per unit volume which includes space occupied by solids and pore space [10]. Bulk density of studied region varied from 1.14 to 1.37 mg m^{-3}. Porosity of soil sample ranged from 48.11 to 55.30%. Good water holding capacity shows good physical condition of soil. The maximum WHC was observed from 33.19 to 48.01%.

2. **Soil pH and Electrical conductivity-**

It is very important because soil solution carries its nutrients such as Potassium (K), Phosphorus (P), and Nitrogen (N) that plant need in specific amount to grow and fight off disesases [11]. The pH value of analyzed soil sample ranged from 6.50 to 8.50. The electrical conductivity of a soil solution increases with the increased concentration of ions [12]. Conductivity depends upon the dilution of soil suspension. The EC values ranged from 0.10 to 0.25 dSm^{-1}.

3. Organic Carbon-

The source of organic carbon in the cultivated soil included crop residue, animal manure, cover crops, green manure and organic fertilizers, etc.Most living things in soils, including plants, insects, bacteria & fungi are dependent on organic matter for nutrients & energy [13]. OC values were recorded in between 0.31 and 1.86 %.

4. Calcium carbonate-

The presence of calcium carbonate in the soil is due to climatic factors. The effect of carbonate on soil fertility is not uniform. The calcium carbonate values ranged from 0.75 to 23 %.

5. Organic Matter-

The organic matter is a vital store of available nutrients. The nutrient supply in soil depends on the level of organic matter, $CaCO_3$ content, degree of microbial activity, change in pH, types and amount of clay and status of soil moisture [14]. The available nitrogen in the soil ranges from 56 to 203 $kgha^{-1}$. It shows the soils from the areas having low nitrogen status. Potassium is essential for photosynthesis, for protein synthesis for starch formation and for translocation of sugars [15]. The available potassium ranges from 185 to 375 $kgha^{-1}$. All soil samples have higher content of available potassium. In the present study available phosphorus ranges from 2.22 to 38.53 $kgha^{-1}$. The low status of available phosphorus was found nearly in all the soils in the area.Calcium is the secondary nutrient element required by all higher plants absorbed as Ca^{++}ion [16]. In the present study available iron ranges from 0.18 to 11.65 ppm, available maganese ranges from 0.95 to 7.35 ppm and available zinc ranges from 0.11 to 0.45 ppm, available copper ranges from 0.96 to 2.93 ppm.

Table shows the Physico-chemical characteristics of different samples

a) Chemical Properties of Soil

Sample No.	PH[1:2.5]	E.C [dSm-1]	Organic Carbon %[]	Calcium carbonate [%]	Available nitrogen [Kg/ha]	Available phosphorous [Kg/ha]	Available Potassium [Kg/ha]	Available iron [ppm]	Available manganese [ppm]	Available zinc [ppm]	Available copper[ppm]
1	7.6 Mildly alkaline	0.13 Normal	0.46 medium	2.0 Slightly calcareous	56 Very low	11.64 Low	333 Very high	5.84 High	7.35 High	0.37 Low	1.34 High
2	6.5 Slightly acidic	0.13 Normal	0.31 low	2.5 Moderately calcareous	203 Low	38.53 Very low	339 Very high	5.04 High	7.35 High	0.45 Low	2.45 High
3	6.9 Neutral	0.12 Normal	0.42 low	1.5 Slightly calcareous	158 Low	16.08 Medium	343 Very high	4.90 High	7.35 High	0.45 Low	1.85 High
4	6.7 Neutral	0.13 Normal	0.43 medium	0.75 Barely calcareous	158 Low	13.58 Low	240 Moderately high	6.03 High	5.72 High	0.37 Low	2.93 High
5	7.1 Neutral	0.10 Normal	0.53 medium	1.75 Slightly calcareous	147 Low	10.81 Low	221 Moderately high	8.3 High	5.21 High	0.24 Low	1.60 High
6	6.7 Neutral	0.20 Normal	0.45 medium	2.75 Moderately calcareous	169 Low	31.88 High	355 Very high	11.65 High	7.35 High	0.41 Low	1.71 High
7	8.3 Moderately alkaline	0.25 Normal	0.55 medium	22.75 Highly calcareous	158 low	2.22 Very low	185 medium	0.18 low	2.30 High	0.15 Low	1.04 High
8	8.4 Moderately alkaline	0.25 Normal	1.86 Very high	23.0 Highly calcareous	169 Low	7.76 Low	228 Moderately high	0.64 Low	0.95 Low	0.22 Low	0.96 High
9	8.5 Strongly alkaline	0.20 Normal	1.18 Very high	22.75 Highly calcareous	158 Low	25.23 Moderately high	375 Very high	1.27 Low	3.56 High	0.19 Low	2.28 High
10	8.5 Strongly alkaline	0.19 Normal	1.71 Very high	22.0 Highly calcareous	158 Low	3.33 Very low	286 High	0.66 Low	2.11 High	0.11 Low	1.49 High

Table - 1 (b) Physical Properties Soil

Sample No.	Sand [%]	Silt [%]	Clay [%]	Textural class	Bulk density [mgm^{-3}]	Particle ensity [mgm^{-3}]	Maximum water holding capacity [%]	Porosity [%]	Wilting point [W_p]	Field capacity	Transition moisture [W_t]	γ
1	28.75	37.50	32.75	Clay loam	1.14	2.54	34.27	55.12	0.2058	26.2675	0.2658	0.3637
2	23.25	55.25	20.75	Silt loam	1.14	2.55	47.14	55.30	0.1520	24.7825	0.2394	0.3943
3	21.50	63.75	14.00	Silt loam	1.37	2.64	39.36	48.11	0.1209	23.6650	0.2242	0.4120
4	43.22	23.85	32.35	Clay loam	1.19	2.57	40.16	53.70	0.1947	23.1408	0.2604	0.3701
5	35.4	50.80	13.4	Silt loam	1.29	2.62	33.19	50.77	0.1091	20.6140	0.2184	0.4188
6	40.6	51.09	7.80	Silt loam	1.34	2.63	35.49	49.05	0.07904	18.2900	0.2037	0.4359
7	41.4	52.00	6.20	Silt loam	1.33	2.61	38.80	49.05	0.07088	17.7700	0.1997	0.4406
8	23.75	36.50	38.75	Clay loam	1.26	2.59	37.57	51.36	0.2377	28.6375	0.2814	0.3456
9	42.0	25.50	31.75	Clay loam	1.19	2.57	48.01	53.70	0.1926	23.2650	0.2593	0.3713
10	39.50	32.00	28.00	Clay loam	1.27	2.59	44.17	50.97	0.1763	22.9650	0.2513	0.3805

Table- 1(c) : Electrical properties of soil

Specification	ε'	ε"	tanδ=ε"/ε'	σ=ωεοε"	Γ=ε"ωε'	emissivity
Sample 1	0.5680	0.02112	0.037177	0.0105624	2.12209E-13	0.9802672
Sample 2	0.5672	0.02156	0.038015	0.0107847	2.16357E-13	0.9801660
Sample 3	0.5762	0.02575	0.044689	0.0128800	2.62508E-13	0.9812422
Sample 4	0.5689	0.02097	0.036859	0.0104881	2.11037E-13	0.9803721
Sample 5	0.5684	0.02130	0.037465	0.0106520	2.14159E-13	0.9803157
Sample 6	0.5684	0.02097	0.036894	0.0104889	2.10868E-13	0.9803116
Sample 7	0.5681	0.02101	0.036979	0.0105082	2.11158E-13	0.9802793
Sample 8	0.5706	0.02000	0.035051	0.0100035	2.01889E-13	0.9805765
Sample 9	0.5683	0.02125	0.037395	0.0106308	2.13708E-13	0.9803076
Sample 10	0.5691	0.02138	0.037568	0.0106937	2.15249E-13	0.9803962

CONCLUSION

The study helps in determining the values of different physico-chemical parameters and nutrient concentrations of soil from Nasik region. The bulk density ranged between (mg m^{-3}) 1.14 to 1.37, Porosity ranged between (%) 48.11 to 55.30,water holding capacity ranged between (%) 33.19 to 48.01 shows that the quality of soil is good. pH ranged between 6.50 to8.50 which is within the range of cultivation. Electrical conductivity ranged between (dSm^{-1}) 0.10 to 0.25 is also in recommended range. Organic carbon ranged between (%) 0.31 to 1.86, calcium carbonate ranged between (%) 0.75 to 23, available N ranged between ($kgha^{-1}$) 56 to 203, available P ranged between ($kgha^{-1}$) 2.22 to 38.53. According to this N and P is less in soil .So 25% more than recommended N and P dose of organic manures and chemical fertilizers should be applied to the soil for better growth of appropriate crop. Available K ranged between ($kgha^{-1}$) 185 to 375 which is in high range. The crops like soybean, cotton, maize, rice, tur, onion can be taken in kharif season .Also the crops like wheat, gram, and onion can be taken in rabbi season according to availability of water. In summer season groundnut, onion can be taken. Soil in Sinnar tahsil is suitable for bajra, tomato, maize, soyabean, wheat, onion, cotton. Soil in Igatpuri is suitable for rice, wheat, pulses, tomato, etc.

The trend of variation of dielectric constant & emissivity for the samples from sample 1 to 10 are nearly same. The dielectric constant of soil increases from 0.5672 to 0.5772 for sample S1 to S10 for frequency 9.0 GHz. The emissitivity increases from 0.9801 to 0.9812. From the recent study, the dielectric constant of soil sample are directly propertional to tangent loss (tanδ), relaxation time (Γ), emissitivity (e) and microwave conductivity(σ)

Soil texture has remarkable effect on the dielectric properties.

All these parameters are useful for researchers working in the field of agriculture and microwave remote sensing. The physico-chemical properties, physical parameters are useful to prepare soil health card which may be further used to predict the soil fertility.

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