Study the dielectric behavior of soil of Surajpur District at X-band frequency

Surendra Kumar[1], Ashutosh Pandey[1*], S. K. Shrivastava[2]

[1&1*]Department of Physics, Dr. CV Raman University, Bilaspur, C.G., India.

[2] Department of Physics, Rajeev Gandhi Govt. Post Graduate College, Ambikapur, (C.G.) India

Abstract

With the increase in research on the various types of soils and their influence on the properties of soil such as physical, chemical and biological properties, it is necessary to understand the effect of inorganic material present in soil on the dielectric properties of soil at microwave frequencies. With this objective, soil samples were collected from different locations of Surajpur district, Chhattisgarh. Detailed studies on the chemical properties of soil are still under investigations. Hence, we have investigated the properties of soil particularly dielectric properties of soil collected from different locations at microwave frequencies. The analyzed data explained the sensitivity of different types of soil which contributed in understanding the texture of soil. Also, determination of dielectric properties aids in understanding different chemical and physical properties of soils. The results revealed that there was significant variation in the properties of soils including physical and chemical depending on the location from where the soil was collected. These results were in agreement with the literature reported earlier. This paper would be beneficial to the researchers who are involved in agricultural research, development and innovation.

Keywords: Surajpur; Dielectric properties; Microwave X-band frequency; Soil.

1. Introduction

In the past three decades the tremendous research on soils has revealed the facts on different soils which are useful for agriculturists. These indications also focused on the measures that need to be taken in order to preventive measures that are necessary to preserve the quality and properties of soils. From the point of welfare of public and environment, it is important to focus on the point that when limited resources are available, it is required to properly plan to conserve these resources and work towards the development. Soil is the uppermost layer of earth possesses essentials that are vital for growth of plants. However, because the soil is not uniform throughout and the composition is varied, in some parts the elements are present in large amounts and in some parts the elements are present in minute quantities. The analysis of soil to understand its suitability for various purposes is critical to make the maximum benefit of the resource.

Soil as described earlier is a thin layer of the planet earth which acts as a nutrient substrate for plant growth. Soil gives a developing substrate for plant life to meet our meals and fiber requirements. Soil fertility is one of the maximum vital variables that regulate crop increase and production. Soil is taken into consideration to be an important component of environment which should be conserved in the context of the surroundings, and it truly is essential to analyze the ability total impact of upkeep measures. Each time a soil degrades; related ecological components degrade as nicely. Soils are perhaps the maximum vital herbal sources for agricultural operations. Agriculture and its allied pastimes, which can be founded on the research of soil resources, are accountable for the manufacturing of fodder, meals, and gas to satisfy the ever-increasing demands of humans and animals. Plant desires sufficient extraordinary soil to include their roots and deliver vital nutrients. Soil is used to domesticate meals, fiber, and decorative plant life, and lumber, regularly, biofuels. Varied soil management methods are desired for various agricultural purposes [1]. Moreover, commercial product variations are reliant on agriculture and forest merchandise which might be at once derived from the soil. For long-time period manufacturing, it is essential to be acquainted with soil's ability, boundaries, and makes use of, as well as the way to hold soil without deteriorating it. It is also essential to place broken land lower back into use after right reclaiming. Knowledge of these kinds of soil, in addition to its distribution, is vital for powerful planning and most reliable are the use of in agriculture output. The one and most effective way to make a soil inventory is to conduct a soil evaluation. Soil evaluation facilitates determine soil potency and agricultural manufacturing regulations, and also provide enormous facts on many soil factors [2]. Soil is agriculture's most essential asset, and it should be managed nicely with the intention to maintain agricultural output and soil health. Soil checking out has been one of the greatest instruments for determining the bodily residences and nutrient content material of a land so as to determine the fertilizer necessities for a crop or farming pattern, as nicely as to determine the revitalization needs if the soil is saline in appeal. The exceptional contemporary method for collecting the financially possible potential crop yields through boosting inputs useful resource utilization and maintaining soil exceptional is fertilizer administration depends on soil analyses [3].

Chhattisgarh is divided into three major regions based on geography. The regions are plains of Chhattisgarh, Northern hill regions and the Bastar plateau. Chhattisgarh state is surrounded by Andhra Pradesh in south, Uttar Pradesh in north, Orissa in east and Madhya Pradesh in West. Chhattisgarh is known as ‘Rice bowl’ in the central part of India. This is because the land is suitable for growth of Rice and paddy is the principal crop of the state. Most of the states in Chhattisgarh are covered with soils have yellow and red soil. The yellow color is due to the iron oxides that are present in soil, and the red color of soil is due to the presence of hydroxides ferric oxides in un-hydrated state. The state has four dominant types of soils that cover the landmass; they are names as Bhata, Dorsa, Matasi and Kanhar. The soil is rich in minerals that include Nitrogen (N), Potassium (K), Phosphorus (P), Lime and Potash. The soil has a sandy texture that is favorable for growth of plants. The state also has red and yellow colored loamy soils. The soils based on their color and textures have different water holding, water percolation and production abilities. The state of Chhattisgarh has different soil types, Loamy soils also known as Matasi has a yellow color with mixture of clay, it has low moisture absorbing capacity, and the best for growing paddy. Clay soil also known as Kanhar, which is dark black in color and has great capacity for absorbing moisture. Clay-loamy is other type of soil which is a mixture of Kanhar and Matasi and is known as Dorsa, it has a brown to yellow color. Laterite is another type of soil that is present in the state, it is red is color and has a sandy to coarse texture that is known as Bhata.

Surajpur is a district which falls in the northern part of Chhattisgarh. This district is composed of six Taluka or tehsils which are named as Ramanujnagar, Premnagar, Surajpur, Pratappur, Bhaiyathan and Odagi. The geographical location of Surajpur is 23.22°N latitude and 82.85°E longitude. The district has warm and temperate climate, it has a rainfall of around 1000-1050 mm. The major crops grown here are Rabi crops and Kharif crops. The main types of soils present in this region are Entisol (Bhata-gravely), Inceptisol (Matasi-Sandyloam), Alfisols (Dorsa-clayloam), Vertisols (Kanhar-clayey) and Others (Sandy) [4], [5].

Materials like metals are good conductors of electricity, in contrast to these di-electrics are materials which have poor conduction capacity and are bad electrical conductors. Since a few years the studies of analyzing the dielectrics of various soils, products of agriculture and minerals have been realized. The complexity of dielectric permittivity which is relative to free space regulates the behavior of electromagnetic radiations when different frequencies are used. The properties with respect to dielectric behavior depend on the physical characteristics as well as chemical characteristics of soil [6]. The physical characteristics may be such as texture, density and composition and the chemical characteristics may be amounts of sodium, potassium, nitrogen, iron as well as magnesium. Numerous researches have been focused on analyzing the dielectric properties of materials [7–13]. The physical and chemical elements of soil are important in order to study the dielectric properties at different microwave frequencies [14]. Different factors which affect the dielectric characters of soil comprise of electric fields that are naturally or artificially generated and has a major effect on the in-organic ions in soils. Soil is formed due to dispersion of electric charges and profiles of soil. Soil has physical, chemical as well as electric properties. The physical characteristics of soil involve roughness, texture, color, particle size, density. Chemical characteristics of soil include organic and inorganic content, N, P, K, minerals, nutrients, pH. Electric properties of soils include electric conductivity, dielectric behavior, resistivity and permeability. The dielectric properties greatly rely on the electrical properties of materials. Important information on measuring the characteristics of soil is reported by researchers which is useful for specific application. Also testing the soil for analyzing the nutrients present in soils is important to understand the nutrients present in soil and develop fertilizers that can improve the soil performance in growing plants [15], [16].

Numerous literatures have focused on studying the dielectric properties of soils where measurement using microwave has been widely considered. The dielectrics of soils rely on the amount of moisture present in soil [17]. Moisture content is a very important property of soil as it greatly contributes to remote sensing and determines the quality of soil and its applicability. Various methods are developed to analyze the dielectric properties of soil at particular microwave frequencies [18-19]. Also literature on different soils are also reported, for instance, data is available on the dielectric constant of red soil, black soil and brown soil has been analyzed in GHz frequency range [20-21]. Another study reported the soil with diesel content in particular frequency [22]. The dielectric properties of soil which were collected from Bidar, Karnataka were analysed [23]. Numerous techniques are available to analyze the dielectric properties of agricultural food materials and the reports on the properties in microwave regions have been reported [24]. Density, temperature, moisture content and frequency are the important factors that affect the dielectric properties of soil. Research on analyzing the dielectric properties of soil as function of different microwave frequencies has been reported [25]. Dielectric properties of stones which are used for constructions and it were seen that the absorption of moisture causes increase in the dielectric properties, also limestone and sand were said to have less value of dielectric constant [26]. Coal and limestone were used for studying the dielectric properties at frequency of 11.7 GHz [27].

As per the available literature it is seen that soils having large pores has a positive effect on enhancing the productivity of soil and results in improvement in growth of crops [28]. The dielectric properties of soil at X-band frequency of microwave for organic and inorganic materials were studies [29]. A more detailed investigation on studying the properties such as electrical conductivity, relaxation time for red and black soils were studied [30]. Studying the dielectric properties of soil which is moist was investigated using a LCR meter at radio frequencies and it was seen that the increase in the nutrients of soils results in increase in the dielectric constant as well as the dielectric loss [31]. For non-homogenous soils, the dielectric constants of individual elements such as sand, clay, organic-inorganic content, silt etc together will determine its total dielectric constant. Also, the dielectric behavior at different microwave frequencies depends on the physico-chemical properties of soil [32]–[36].

In this paper the real and imaginary parts of dielectric constant have been studied for soils with different moisture or water content. This result shows bound water in soil water affects the dielectric properties of soil and relationship between dielectric properties with gravimetric water content is nonlinear.

2. Methodology

2.1 Soil Sampling

The samples of soil were collected from different locations of Surajpur districts from a depth of about 0 to 20 cm in a criss-cross method. For every sample, five pits were digged. All the samples were thoroughly mixed and a composite having mass of 3-4 kg was made, this indicated one site. This process was repeated for all the samples from different locations. Firstly using sieve coarse particles were removed and top soil was removed [37]. The particles which had fine sizes were screened using sieves and allowed to dry for 24 h in oven having temperature of 110 ^{o}C to remove moisture from the sample. Six locations were selected from the district of Surajpur, Chhattisgarh. The locations were which were selected for the particular study were the blocks of Ramanujnagar, Prem nagar, Surajpur, Bhaiyathan, Pratappur, and Odgi. Figure.1 shows the map of the study area that is selected for this work.

Figure 1 Map of the study area

2.2 Theory

The physical and chemical properties of the soils that were collected from different locations were analyzed in laboratory using different analysis techniques [38].

2.2.1 Moisture in soil

As already discussed, the amount of moisture that is present in soil is important factor as they affect the dielectric properties of soil. The moisture content in soil can be evaluated by estimating the bulk density of soil and the density of particle [38]. If the mass of water can be in terms of bulk density and particle density can be expressed as seen below

$$\text{Mass of water} = \frac{mass\ of\ water}{Mass\ of\ dry\ soil} = \frac{mw}{ms} = \frac{\rho w * b}{\rho p * c} \dots\dots\dots\dots\dots..(i)$$

Where b is the bulk density

p is the particle density

ρ_w is the density of water

b is the depth of water

c is the equivalent solid depth

The mass of water can be expressed as the difference between the readings before (m_s) and after addition of water (m_s+w). The knowledge of m_g is not sufficient for estimating the depth of water in field when the volume of water is not unknown. Hence m_v can be defined as a ratio of corresponding depth to equivalent depth.

$$\text{mv} = \frac{Volume\ of\ water}{Bulk\ volume\ of\ soil} = \frac{b}{D} \dots\dots\dots\dots\dots\dots\dots..(ii)$$

Where D is the depth of soil

If m_v is 0.38, it means that 380 mm of water is detected in 1000 mm of soil. As the relation is simple and directly proportional to other parameters measuring, this measurement can be stated to be the most serviceable statement for content of water in soil. Equation 2 can be used to define the equivalent depth of water can be expressed as shown below:

$$b = mvD \dots\dots\dots\dots\dots..(iii)$$

Using the above expression, the porosity of soil can be determined. The porosity of soil can also be expressed

$$P = \frac{Total\ pore\ volume}{Bulk\ volume\ of\ soil} = \frac{(a+b)A}{DA} = \frac{(a+b)}{D} \dots\dots\dots\dots (iv)$$

Here,
a represents airspace
A denotes region
The value of P may vary between 0.3 to 0.6 (30 % and 60%)
Therefore, in a soil sample that is saturated all the volumes of pores will be filled with water saturated (m_v) = P. The pore which is filled with air can be expressed as

$$P = \frac{air\ pore\ volume}{Bulk\ volume\ of\ soil} = \frac{aA}{DA} = \frac{a}{D} \dots\dots\dots\dots (v)$$

Relative saturation m_vt is also used often, this is the ratio of m_v to its saturated volume m_vs, and this can be represented as shown below

$$\text{mvt} = \frac{bA}{(a+b)A} = \frac{b}{a+b} = \frac{mv}{mvs} \dots\dots\dots\dots (v)$$

Basically, wet mass, dry mass of soil and bulk volume are analyzed and m_g, m_v, and b can be estimated. If b of soil is determined the remaining values can be calculated using the above relations.
Another equation that is necessary for the experiments is m_g. It can be expressed as shown below

$$mg = \frac{m(s+w) - ms}{ms} \dots\dots\dots\dots (vi)$$

Here
m $_{(s+w)}$ is the ratio of moist soil to dry soil
Also, the equation to convert m_v to m_s can be written as shown below

$$mv = \frac{\text{ρb}}{\text{ρsoil}} mg \dots\dots\dots\dots (viii)$$

2.2.2 **Dielectric constant**
Dielectric constant (ε') can be understood as the capacity or the efficiency of a material to store energy specifically electrical energy. The dielectric losses can be understood as the loss of electrical energy in form of heat. The real part of dielectric constant explains the degree of polarization, the greater the value of dielectric constant, greater will be the degree of polarization. The imaginary part of dielectric constant explains the polarization losses from the material due to the alternating electric fields. The complex dielectric constant is estimated using the equation below

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

Here, ε' is the dielectric constant
ε'' is the dielectric loss
q is the emissivity and
σ is the conductivity

The relations between different electrical parameters can be given as shown below.

$$\varepsilon' = \frac{g_e + \left(\frac{\lambda_{gs}}{2a}\right)^2}{1 + \left(\frac{\lambda_{ge}}{2a}\right)^2}$$

$$\varepsilon' = \frac{\beta_e}{1 + \left(\frac{g_e}{2a}\right)^2}$$

Here, a is the inner width of rectangular waveguide

λ_{gs} is the wavelength of the air-filled guide

λ_{ge} is the admittance of real component

β_{ϵ} is the admittance imaginary part

3. Results and discussion

3.1 Physical properties of soils

This study is beneficial in understanding the different physical properties of soil and the nutrients present in soil of Surajpur district. The soil was collected from different taluk's of Surajpur i.e., Ramanujnagar, Premnagar, Surajpur, Bhaiyathan, Pratappur, Odgi. Properties such as colour, bulk density, particle density, texture, porosity and capacity to hold water are determined. These properties are very important for growth of crops and also to improve the quality of soil. So, we have determined the properties, most of the soil that is available is black soil. The physical properties of soil can be determined in laboratory. The texture of the soil can be estimated by methods of filtration and sedimentation. To determine the type of soil, soil triangle experiments are performed. The soils are powered and dried in the oven before the experiments. The physical parameters of soil collected from different talukas in the Surajpur District, Chhattisgarh, India are shown in Table 1 and 2. It can be observed that the texture of soil is mostly loamy slits or loamy sands.

Table 1 Physical properties of soils from different locations

S. No	Location	Bulk density (kg/m^3)	Particle density (kg/m^3)	Water holding capacity % (Max)	Porosity (%)
1	Ramanujnagar	$1.55*10^{-6}$	$2.61*10^{-6}$	42.6	40.8
2	Prem nagar	$1.57*10^{-6}$	$2.59*10^{-6}$	45.3	39.5
3	Surajpur	$1.53*10^{-6}$	$2.57*10^{-6}$	43.5	40.6
4	Bhaiyathan	$1.61*10^{-6}$	$2.55*10^{-6}$	47.6	37.0
5	Pratappur	$1.57*10^{-6}$	$2.52*10^{-6}$	47.2	37.9
6	Odgi	$1.59*10^{-6}$	$2.54*10^{-6}$	43.8	37.5

Table 2 Physical properties of soils at different locations

S. No	Location	Texture	% Sand	% Slit	% Clay
1	Ramanujnagar	Loamy (Slity)	50	35	10
2	Prem nagar	Loamy (Slity)	50	36	8
3	Surajpur	Loamy	70	20	12
4	Bhaiyathan	Loamy (Sand)	85	5	10
5	Pratappur	Loamy (Sand)	80	10	11
6	Odgi	Loamy (Sand)	87	6	7

3.2 Dielectric properties of soil from different locations

The soil which was collected from the different taluka's of Surajpur district was analyzed to determine its dielectric parameters. The real and imaginary parts of the dielectric constant as a function of soil's moisture content is determined and presented in Tables 3, 4, 5, 6, 7 and 8. It can be seen that the soil which has low moisture constant has low dielectric constant, with increase in moisture content.

Table.3 Real and imaginary part of dielectric constant at different moisture contents (10%, 20%, 30%, 40%) of Ramanujnagar block at X-Band Frequencies 9.84 GHz

S. No.	Sample	Real part of Dielectric constant					Imaginary part of Dielectric constant				
		Dry soil	10%	20%	30%	40%	Dry soil	10%	20%	30%	40%
01	S1	3.12	7.31	10.61	15.78	19.31	0.12	0.19	0.25	0.31	0.49
02	S2	3.15	7.33	10.62	15.81	19.36	0.13	0.20	0.26	0.32	0.50
03	S3	3.16	7.36	10.69	15.83	19.38	0.14	0.21	0.27	0.33	0.51
04	S4	3.21	7.38	10.72	15.86	19.41	0.15	0.22	0.28	0.34	0.52
05	S5	3.28	7.39	10.74	15.88	19.47	0.16	0.23	0.29	0.35	0.53
06	S6	3.31	7.41	10.78	15.91	19.49	0.17	0.24	0.30	0.36	0.54

Table.4 Real and imaginary part of dielectric constant at different moisture contents (10%, 20%, 30%, 40%) of Prem Nagar block at X-Band Frequencies 9.84 GHz

S. No.	Sample	Real part of Dielectric constant					Imaginary part of Dielectric constant				
		Dry soil	10%	20%	30%	40%	Dry soil	10%	20%	30%	40%
01	S1	3.42	8.31	11.61	14.78	18.31	0.13	0.20	0.27	0.36	0.48
02	S2	3.55	8.33	11.62	14.81	18.36	0.14	0.21	0.28	0.37	0.49
03	S3	3.56	8.36	11.69	14.83	18.38	0.15	0.22	0.29	0.38	0.51
04	S4	3.51	8.38	11.72	14.86	18.41	0.16	0.23	0.30	0.39	0.52
05	S5	3.62	8.39	11.74	14.88	18.47	0.17	0.24	0.31	0.40	0.53
06	S6	3.81	8.41	11.78	14.91	18.49	0.18	0.25	0.32	0.42	0.54

Table. 5 Real and imaginary part of dielectric constant at different moisture contents (10%, 20%, 30%, 40%) of Surajpur block at X-Band Frequencies 9.84 GHz

S. No	Sample	Real part of Dielectric constant					Imaginary part of Dielectric constant				
		Dry soil	10%	20%	30%	40%	Dry soil	10%	20%	30%	40%
01	S1	3.62	7.81	12.61	15.78	19.31	0.14	0.21	0.28	0.38	0.46
02	S2	3.65	7.83	12.62	15.81	19.36	0.15	0.22	0.29	0.39	0.45
03	S3	3.68	7.91	12.69	15.83	19.38	0.16	0.23	0.30	0.40	0.44
04	S4	3.69	7.96	12.72	15.86	19.41	0.17	0.24	0.31	0.41	0.42
05	S5	3.72	7.98	12.74	15.88	19.47	0.18	0.25	0.32	0.42	0.41
06	S6	3.89	7.99	12.78	15.91	19.49	0.19	0.26	0.33	0.43	0.40

Table.6 Real and imaginary part of dielectric constant at different moisture contents (10%, 20%, 30%, 40%) of Bhaiyathan block at X-Band Frequencies 9.84 GHz

S. No	Sample	Real part of Dielectric constant					Imaginary part of Dielectric constant				
		Dry soil	10%	20%	30%	40%	Dry soil	10%	20%	30%	40%
01	S1	3.12	7.21	10.51	14.78	18.31	0.12	0.19	0.25	0.31	0.49
02	S2	3.15	7.23	10.52	14.81	18.36	0.13	0.20	0.26	0.32	0.50
03	S3	3.16	7.26	10.59	14.83	18.38	0.14	0.21	0.27	0.33	0.51
04	S4	3.21	7.28	10.52	14.86	18.41	0.15	0.22	0.28	0.34	0.52
05	S5	3.28	7.29	10.54	14.88	18.47	0.16	0.23	0.29	0.35	0.53
06	S6	3.31	7.31	10.58	14.91	18.49	0.17	0.24	0.30	0.36	0.54

Table. 7 Real and imaginary part of dielectric constant at different moisture contents (10%, 20%, 30%, 40%) of Pratappur block at X-Band Frequencies 9.84 GHz

S. No	Sample	Real part of Dielectric constant					Imaginary part of Dielectric constant				
		Dry soil	10%	20%	30%	40%	Dry soil	10%	20%	30%	40%
01	S1	3.62	9.21	11.51	13.78	19.31	0.14	0.21	0.28	0.38	0.46
02	S2	3.65	9.23	11.52	13.81	19.36	0.15	0.22	0.29	0.39	0.45
03	S3	3.66	9.26	11.59	13.83	19.38	0.16	0.23	0.30	0.40	0.44
04	S4	3.61	9.28	11.52	13.86	19.41	0.17	0.24	0.31	0.41	0.42
05	S5	3.68	9.29	11.54	13.88	19.47	0.18	0.25	0.32	0.42	0.41
06	S6	3.71	9.31	11.58	13.91	19.49	0.19	0.26	0.33	0.43	0.40

Table. 8 Real and imaginary part of dielectric constant at different moisture contents (10%, 20%, 30%, 40%) of Odgi block at X-Band Frequencies 9.84 GHz

S. No	Sample	Real part of Dielectric constant					Imaginary part of Dielectric constant				
		Dry soil	10%	20%	30%	40%	Dry soil	10%	20%	30%	40%
01	S1	3.42	11.21	12.51	13.78	19.31	0.13	0.20	0.27	0.36	0.48
02	S2	3.55	11.23	12.52	13.81	19.36	0.14	0.21	0.28	0.37	0.49
03	S3	3.56	11.26	12.59	13.83	19.38	0.15	0.22	0.29	0.38	0.51
04	S4	3.58	11.28	12.52	13.86	19.41	0.16	0.23	0.30	0.39	0.52
05	S5	3.62	11.29	12.54	13.88	19.47	0.17	0.24	0.31	0.40	0.53
06	S6	3.81	11.31	12.58	13.91	19.49	0.18	0.25	0.32	0.42	0.54

4. Conclusion

In this study we have collected soil samples from six different locations in the district of Surajpur, Chhattisgarh, India. All the samples were tested to determine the physical properties and dielectric properties of soil. It was seen that the soil is mainly loamy with silty and sandy textures. The dielectric constant and losses were evaluated as a function of moisture content. It was seen that the value of dielectric constant increased with increase in the moisture content of soil. The study also explained that the optimum level of moisture in the imaginary part of dielectric constant was not influenced by the texture of soil. However, when the soil was dry or has least moisture content the imaginary part of dielectric constant was significant. The study clearly showed that the dominant type of soil in the district was mostly loamy sand. Also, porosity and bulk density has an effect on the dielectric constant of soil.

References

[1] D. Davidson, "Soil Science and Management. By E.J. Plaster (ed.). Published by Delmar Cengage Learning (www.cengage.com), 2014. xi + 544 pp. £139.00. (ISBN-10: 0840024320).," *Soil Use Manag.*, vol. 30, no. 3, pp. 444–444, Sep. 2014, doi: 10.1111/SUM.12126.

[2] M. Khan and J. Kamalakar, "Physical, physico-chemical and chemical properties of soils of newly established Agro-biodiversity Park of Acharya NG Ranga Agricultural University, Hyderabad, Andhra Pradesh," *Int. J. Farm Sci.*, 2014.

[3] "(PDF) Studies on bioefficacy of triasulfuron and carfentrazone-ethyl for the control of broad leaf weeds from wheat." https://www.researchgate.net/publication/268387888_Studies_on_bioefficacy_of_triasulfuron_and_carfentrazone-ethyl_for_the_control_of_broad_leaf_weeds_from_wheat (accessed Mar. 24, 2023).

[4] "Agriculture Contingency Plan for District: Surajpur State: CHHATTISGARH 1.0 District Agriculture profile".

[5] "About District | District Surajpur, Government of Chhattisgarh | India." https://surajpur.nic.in/en/about-district/ (accessed Mar. 27, 2023).

[6] "Dielectric properties of black soil with organic and inorganic matters at microwave

frequency." https://www.researchgate.net/publication/290741148_Dielectric_properties_of_black_soil_with_organic_and_inorganic_matters_at_microwave_frequency (accessed Mar. 27, 2023).

[7] V. Yadav, A. Kumar, S. Sharan, and A. K. Sinha, "Analyses of dielectric properties of fertilizers (urea and diammonium phosphate) in aqueous solution at different temperatures in microwave frequency," *Int. J. Phys. Sci.*, vol. 5, no. 16, pp. 2466–2470, 2010, Accessed: Mar. 27, 2023. [Online]. Available: http://www.academicjournals.org/IJPS

[8] L. K. Dospatliev, I. T. Ivanov, B. K. Paarvanova +, N. T. Katrandzhiev, and R. T. Popova, "Determining the relationship between the dielectric properties and the basic physical and chemical parameters of the air-dry soil," *Int. J. Sci. Res. Publ.*, vol. 4, no. 7, 2014, Accessed: Mar. 27, 2023. [Online]. Available: www.ijsrp.org

[9] P. R. Chaudhari, "Variation of Dielectric Constant of Indian Soils with Their Physical Parameters at C-Band Microwave Frequency," *Int. J. Innov. Res. Sci. Eng. Technol.*, vol. 03, no. 08, pp. 15396–15400, Aug. 2014, doi: 10.15680/IJIRSET.2014.0308045.

[10] "Dielectric Properties of Soils at X-band Microwave Frequency | Request PDF." https://www.researchgate.net/publication/259865236_Dielectric_Properties_of_Soils_at_X-band_Microwave_Frequency (accessed Mar. 27, 2023).

[11] A. Buliya, K. C. P. K. C. Pancholi, and R. K. P. R. K. Paliwal, "Effect of Cow Manure on Dielectric Properties of Clay Loam Soil at Microwave Frequency," *Int. J. Sci. Res.*, vol. 2, no. 2, pp. 374–375, Jun. 2012, doi: 10.15373/22778179/FEB2013/126.

[12] F. M. Francisca, M. A. Montoro, F. M. Francisca, and M. A. Montoro, "Measuring the dielectric properties of soil-organic mixtures using coaxial impedance dielectric reflectometry," *JAG*, vol. 80, pp. 101–109, May 2012, doi: 10.1016/J.JAPPGEO.2012.01.011.

[13] A. Comegna, A. Coppola, G. Dragonetti, and A. Sommella, "Dielectric Response of a Variable Saturated Soil Contaminated by Non-Aqueous Phase Liquids (NAPLs)," *Procedia Environ. Sci.*, vol. 19, pp. 701–710, Jan. 2013, doi: 10.1016/J.PROENV.2013.06.079.

[14] J. R. Wang and T. J. Schmugge, "An empirical model for the complex dielectric permittivity of soils as a function of water content," *IEEE Trans. Geosci. Remote Sens.*, vol. GE-18, no. 4, pp. 288–295, 1980, doi: 10.1109/TGRS.1980.350304.

[15] Z. Haj-Amor *et al.*, "Soil salinity and its associated effects on soil microorganisms, greenhouse gas emissions, crop yield, biodiversity and desertification: A review," *Sci. Total Environ.*, vol. 843, Oct. 2022, doi: 10.1016/J.SCITOTENV.2022.156946.

[16] R. W. Heiniger, R. G. McBride, and D. E. Clay, "Using Soil Electrical Conductivity to Improve Nutrient Management," *Agron. J.*, vol. 95, no. 3, pp. 508–519, May 2003, doi: 10.2134/AGRONJ2003.5080.

[17] "IEEE Transactions on Geoscience and Remote Sensing | Standard Journal Abbreviation (ISO4) - Academic Accelerator." https://academic-accelerator.com/Journal-Abbreviation/IEEE-Transactions-on-Geoscience-and-Remote-Sensing (accessed Mar. 27, 2023).

[18] "Moisture dependent Ku band microwave characteristics of red soil | Request PDF." https://www.researchgate.net/publication/283527401_Moisture_dependent_Ku_band_microwave_characteristics_of_red_soil (accessed Mar. 27, 2023).

[19] "Estimation of dielectric constant of soil from the given texture at microwave frequency | Request PDF." https://www.researchgate.net/publication/290902042_Estimation_of_dielectric_constant_of_soil_from_the_given_texture_at_microwave_frequency (accessed Mar. 27, 2023).

[20] "Ku band microwave transmission and reflection of moisture-laden brown and black soil | Request PDF." https://www.researchgate.net/publication/292012211_Ku_band_microwave_transmission_and_reflection_of_moisture-laden_brown_and_black_soil (accessed Mar. 27, 2023).

[21] S. Nagar, A. Baruah, B. Das, K. P. Mishra, M. Kalita, and S. S. Haque, "Variability of dielectric constant of dry soil with its physical constituents at microwave frequencies and validation of the CVCG model 0 P N Calla Internatio nal Centre for Radio Science, 'OM NIWAS' A-23," *Indian J. Radi o Sp. Phys.*, vol. 33, pp. 125–129, 2004.

[22] S. Darayan, C. Liu, L. C. Shen, and D. Shattuck, "Measurement of electrical properties of contaminated soil," *Geophys. Prospect.*, vol. 46, no. 5, pp. 477–488, Sep. 1998, doi: 10.1046/J.1365-2478.1998.00104.X/CITE/REFWORKS.

[23] H. C. Chaudhari $ and V. J. Shinde, "Dielectric properties of black and red soils at microwave frequency," *Indian J. Radio Sp. Phys.*, vol. 39, pp. 103–106, 2010.

[24] S. O. Nelson, "Fundamentals of Dielectric Properties Measurements and Agricultural Applications," *http://dx.doi.org/10.1080/08327823.2010.11689778*, vol. 44, no. 2, pp. 98–113, 2016, doi: 10.1080/08327823.2010.11689778.

[25] S. O. Nelson, "Measurement of microwave dielectric properties of particulate materials," *J. Food Eng.*, vol. 21, no. 3, pp. 365–384, Jan. 1994, doi: 10.1016/0260-8774(94)90080-9.

[26] . K. D. and M. Vyas, "Measurement of Dielectric Properties of Marble Stone Samples in The Frequency Range 0.2GHz 20GHz," *Int. J. Sci. Res. Phys. Appl. Sci.*, vol. 7, no. 4, pp. 1–7, Aug. 2019, doi: 10.26438/IJSRPAS/V7I4.17.

[27] S. O. Nelson, "Determining dielectric properties of coal and limestone by measurements on pulverized samples," *J. Microw. Power Electromagn. Energy*, vol. 31, no. 4, pp. 215–220, 1996, doi: 10.1080/08327823.1996.11688312.

[28] M. D. Meena *et al.*, "Municipal solid waste (MSW): Strategies to improve salt affected soil sustainability: A review," *Waste Manag.*, vol. 84, pp. 38–53, Feb. 2019, doi: 10.1016/J.WASMAN.2018.11.020.

[29] "Dielectric properties of soils with organic matter at S-band microwave frequency | Request PDF." https://www.researchgate.net/publication/259865241_Dielectric_properties_of_soils_with_organic_matter_at_S-band_microwave_frequency (accessed Mar. 27, 2023).

[30] "Effect of salinity on the dielectric properties of water." https://www.researchgate.net/publication/262012448_Effect_of_salinity_on_the_diele

ctric_properties_of_water (accessed Mar. 27, 2023).

[31] "Dielectric Properties of Dry and Wet Soils At X-B and Microwave Frequency – Material Science Research India." http://www.materialsciencejournal.org/vol5no1/dielectric-properties-of-dry-and-wet-soils-at-x-b-and-microwave-frequency/ (accessed Mar. 27, 2023).

[32] "Dielectric properties of soils in the 0.3-1.3-GHz range.," *IEEE Transactions on Geoscience and Remote Sensing*. https://sci-hub.se/10.1109/36.387598 (accessed Mar. 27, 2023).

[33] P. Hoekstra and A. Delaney, "Dielectric properties of soils at UHF and microwave frequencies," *J. Geophys. Res.*, vol. 79, no. 11, pp. 1699–1708, Apr. 1974, doi: 10.1029/JB079I011P01699.

[34] T. Schmugge, "Microwave remote sensing of soil moisture," *Appl. Remote Sens. to Agrometeorol. Proc. Ispra-Course, Ispra, 1987*, pp. 257–284, 1989, doi: 10.1007/978-94-009-2235-8_11/COVER.

[35] "IEEE Xplore: IEEE Transactions on Geoscience and Remote Sensing." https://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=36 (accessed Mar. 27, 2023).

[36] M. Hallikainen, "Microwave Dielectric Behavior of Wet Soil-Part 1: Empirical Models and Experimental Observations," *IEEE Trans. Geosci. Remote Sens.*, Jan. 2000, Accessed: Mar. 27, 2023. [Online]. Available: https://www.academia.edu/50982635/Microwave_Dielectric_Behavior_of_Wet_Soil_Part_1_Empirical_Models_and_Experimental_Observations

[37] "Study of dielectric and physiochemical properties of soil at Bastar region of India." https://www.researchgate.net/publication/358274382_Study_of_dielectric_and_physiochemical_properties_of_soil_at_Bastar_region_of_India (accessed Mar. 27, 2023).

[38] "Characterization of Soil-Physical Properties, Surajpur, India." https://www.researchgate.net/publication/361262216_Characterization_of_Soil-Physical_Properties_Surajpur_India (accessed Mar. 27, 2023).