Estimation of Dielectric Behaviour of Soil in Relation to Balasore District in Odisha

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In the present paper an attempt has been made to estimate dielectric behaviour of soil in relation to Balasore district of in Odisha. MUT as Soil is a heterogeneous mixture of silicate particles, humus, and a type of insoluble salts and oxides of metals known as the solid-liquid-gaseous phase. Organic matter level and structural improvement of soil can be built up, to a varying degree, and maintained by continuous judicious application of manures, even under tropical conditions prevailing in India. It has been found that the dielectric constant of soil is dependent on the soil texture. Dialectic constant of soil are strongly dependent on soil moisture and soil texture. Moisture is soil significantly affect the dielectric properties of soil. Such study of soil in also useful in microwave remote sensing and agriculture in order to increase its productivity.
Keywords: Soil texture, heterogeneous, humus, organic matter, soil, remote sensing, phase.

1. Introduction

Odisha extends from 170 49' to 220 34' N latitude and from 810 29' E to 870 29' E longitude on the eastern coast of India. It has an area of about 155,707 sq. km. according to the census of India. It is bounded by Bay of Bengal on the east, West Bengal on the North-east, Jharkhand on the North, Chhattisgarh on the West and Andhra Pradesh on the South. There are thirty district in Odisha. Balasore is very important district at the point of geographical, agricultural, and farming.

Fig.: 1. Map of Odisha

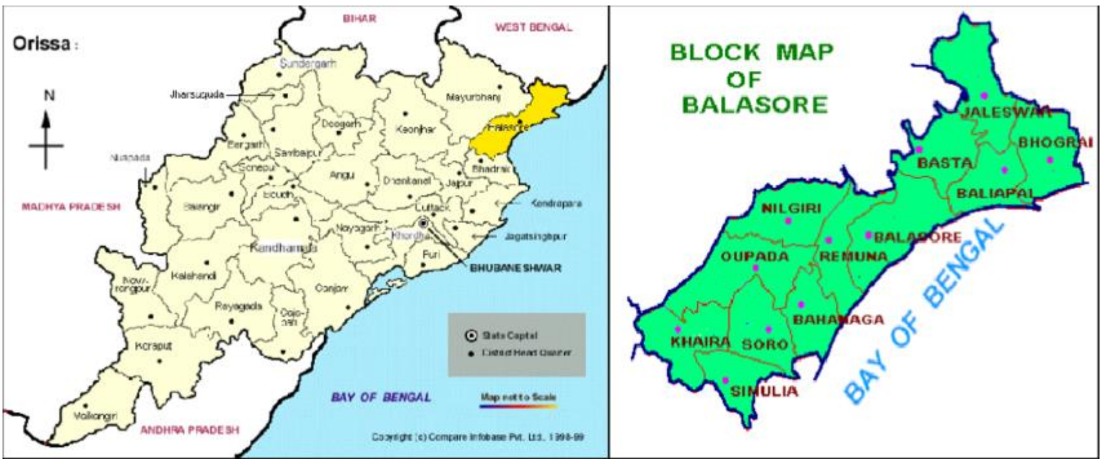

Fig.:2. Map of Balasore district

The textural analysis of soil is very important for assessment of dielectric behavior of soil. Moisture content in voids plays a significant role to maintain agricultural production as well as microwave dielectric study. Although soil is composed of discrete soil components and particle groups. A soil mass is always treated as a continuum for engineering analysis and design. The specific values of properties such as strength, permeability and compressibility depend on the size and shape of the particles. There is a considerable change in the shape, size of the particle depending on the arrangements of pore space in the soil. The effective size of a pore can be measured by the amount of force required to withdraw water from the pore. The fabric and fabric element are also very important to enhance production of agriculture. The term fabric refers to the arrangement of particles, particles group and free spaces in a soil. The term structure is sometimes used interchange with fabric. It is preferable however to use structure to refer to the combine effect of fabric, composition and inter-particle forces. To maintain proper porosity vermi compost is applied from the farmer time to time or according to crop cycle is changed.

Soil constituents play a significant role in determining the electrical properties of soil. These properties serve as a measure of how soil responds to electrical current. Parameters such as electrical conductivity, dielectric constant, dielectric loss, emissivity, permeability, and tangents loss are utilized to gauge plant health and soil fertility. It is worth noting that the structure of soil influences the values of its electrical properties. Furthermore, electrical properties demonstrate a dependency on and exhibit variations due to soil temperature, soil moisture content, soil texture, organic matter, and soil mineral composition. In the field of agriculture, electrical properties are employed to assess and predict soil and plant quality. The electrical properties of soil serve as a bridge in comprehending and estimating various physical and chemical properties of the soil. The electrical properties of soil are crucial for understanding its behaviour and impact on agricultural production. The dielectric constant of a soil refers to its ability to store electrical energy in response to electromagnetic waves. It is influenced by the soil constituents. Microwave remote sensing plays a significant role in studying the dielectric properties of soil, particularly in assessing soil fertility. Soil is related with fertility and production. Soil characteristics are typically defined by the size of its particles, and it is known to contain more than eighteen essential elements. Particle size analysis separates the inorganic mineral portion of the soil into classified grades according to particle size and determines their relative proportion by weight. The determination involve three distinct stages viz.

Removal of cementing agents like organic matter and calcium ions and complete dispersion of the soil samples in an alkaline medium. Dispersion is brought about effectively by a combination of physical and chemical means. Organic matter, free iron oxide and flocculating ions such as calcium and magnesium are combated chemically and the dispersion process is speeded up by addition of dispersing agents and mechanical shaking.

Separation of the coarse sand fraction (International system) by wet sieving followed by separation of total sand fraction (USDA) system by dry sieving.

Determination of the clay fraction (both systems) and silt fraction (International system) in the dispersed sample by pipetting known volume of the sample or by measuring specific gravity with a special hydrometer, each after calculated times which ensure that the required fraction is being determined.

The velocity of sedimentation is related to the particle size by Stoke' s law. The law dictates the rate of fall of small spherical particles through a viscous fluid. (Note: The soil particles are dispersed in water after removal of cementing agents viz. organic matter, calcium carbonate etc. by using dispersing agent like sodium hexametaphosphate or calgon) . These actually increases the zeta potential (ζ)of the medium .Particles greater than 0.05mm are separated by sieving. Using Stoke's law the depth to which particles larger than 0.02mm in equivalent diameter will settle in 5 minutes and the depth to which particles larger than 0.002mm will settle in 5hrs.30 minutes are calculated. Aliquotes pipette from these depths after the appropriate times will contain only particles smaller than the two cut off diameters mentioned above.

2. Stoke's Law

A particle failing in a vacuum will encounter no resistance, as it is accelerated by gravity and hence its velocity increases as it fails. A particle failing in a fluid on the other hand will encounter a frictional resistance proportional to the product of its radius and velocity and to the viscosity of the fluid.

The resisting force or the viscous drag due to friction was shown by Stokes G.G (1851) to be $F = 6\pi\eta rv$ (1)

Where η = viscosity of the fluid

r = radius of the particle

v = velocity of the particle

Initially, as the particle begins to fail, its velocity increases. Eventually a point is reached at which the increasing resistance force equals the constant downward force, and the particle then continues to fail without acceleration at a constant velocity , known as terminal velocity v_t.

The downward force due to gravity

$$F = mg = \frac{4}{3}\pi r^3(\rho - \sigma)g \quad (2)$$

Where ρ =density of the spherical material.

σ = density of liquid

Setting the two forces equal, we get Stoke's law

$$\frac{4}{3}\pi r^3(\rho - \sigma)g = 6\pi\eta rv \quad (3)$$

Or $v_t = \{ \frac{2}{9}\eta(\rho - \sigma)g)\, r^2\}$ (4)

Or $v_t = Kr^2$ (5)

Where K = proportionality constant $=\{ \frac{2}{9}\eta(\rho - \sigma)g\}$

Also $v_t = \frac{\text{distance(h)}}{\text{time(t)}}$ (6)

Therefore $\frac{h}{t} = Kr^2 = \{ \frac{2}{9}\eta(\rho - \sigma)gr^2\}$ (7)

Simplifying we get $t = \{ 9\eta - h)/2(\rho - \sigma)gr^2\}$ (8)

As r= diameter (d)/2

Equation (8) becomes,

$t = \{ 18\eta h)/(\rho - \sigma)gd^2\}$ (9)

Assumptions in Stoke's law

- The particles must be large in comparison to liquid molecules so that Brownian movement will not affect the fail.
- The volume of liquid should be greater in comparison with the size of the particles. The fail of the particle must not be affected by proximity of the wall of the vessel or of adjacent particles.
- Particles must be smooth and rigid, a condition which is difficult to be fulfilled by soil particles.
- It is a well-known fact that the soil particles are not spherical exactly but are irregularly shaped with a large number of plate-shaped particles present in the clay fractions. Since particles with different shapes fail with different velocities, the term equivalent or effective radius is used to overcome this difficulty in Stoke's Law. Effective radius is defined as the radius of a sphere of the same materials which would fall with the same velocity as the particle in question.
- There must be no slipping between various particle – a postulate which is well fulfilled in case of soil particles due to the presence of water hull around them.
- The velocity of fall must not exceed a certain critical value so that , the viscosity of the liquid remains the only resistance of the fall.
- In addition to the effect of size and shape of the particles upon the applicability of Stoke's law in particle size analysis there are certain experimental limitations that must be considered in the use of this principle. Since the rate of fall varies inversely with the viscosity of the medium, it is important to maintain a known constant temperature during the analysis. A constant temperature also helps to prevent convection currents which might arise as a result of difference in temperature near the walls of the vessel and within the suspension. Such currents may also be set up during stirring which is more difficult to eliminate than those arising out of temperature variation.
- The density of the soil particle is another factor which effects the accuracy of Stoke's law. Density depend upon the mineralogical and chemical constitution of the particles as well as upon their degrees of hydration. Usually ρ is taken to be 2.65 and σ , 1.00 for mechanical analysis.

Determination of soil textural class:

The texture of soil is determined from the relative proportion of sand ,silt and clay. Two systems of soil texture classifications, as suggested by ISSS and USDA, are in common use. Both the system make use of an equilateral triangle whose area is divided into 12 compartments, each representing a textual class. The difference is primarily due to differences in size ranges of sand and silt fractions. The triangle based on ISSS size fraction is given in Fig. 2.2. For the determination of soil textural class, locate the clay and sediment percentages on the respective sides of the triangle. Draw a line inward parallel to the sand axis in the former case and parallel to clay axis in the latter case.

The compartment in which two lines intersect in the texture of the soil.

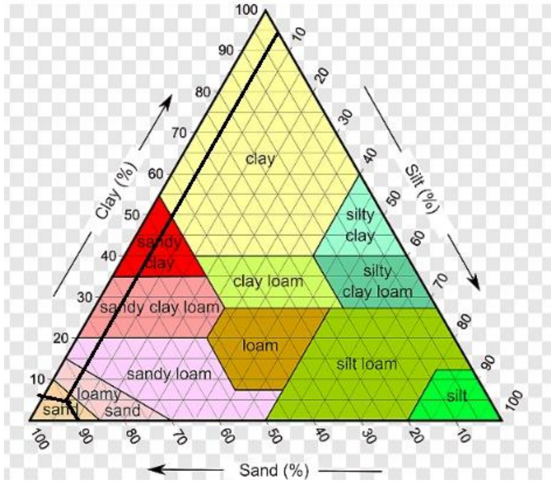

Fig.:3. Triangular textural diagram

Particle Density(D_p):

Particle density(D_p) is usually defined as mass(weight) per unit volume of soil solids. It is generally expressed in g/cm. For mineral soils the value usually varies between 2.60 and 2.75 g/cm.

Principle:

A given amount of dry soil when immersed in a definite volume of water, expels air and results in displacement of an equal volume of water. The volume of soil particles is determined by measuring the volume of water displaced in the pycnometer bottle.

Equipment:

- A pycnometer
- Pipette(20ml capacity)
- An analytical balance
- Hot plate or water bath

Calculations

Wt of water filled pycnometer = W_{pw} gram

Wt of dry soil = 10 gram

Wt of pycnometer + water + soil = W_{psw} gram

Volume of water displaced (volume of soil solids) = $(W_{pw}+10 - W_{psw})cm^3$

Particle density of soil = $(10/W_{pw}+10 - W_{psw})g/cm^3$

Bulk density(D_b):

Bulk density(D_b) is defined as the mass (weight) of a unit volume of dry soil. This volume includes both solid and pores. The values for clay , clay loam and silt loam surface soils varies from 1.00 to 1.60 g/cm^3, for sand and sandy loams from 1.20 to 1.80 g/cm^3. Fine-texture soils tend to have lower bulk densities and therefore higher porosities in comparison to the coarse textured soils due to loose packing of the clay particles. Bulk density measurement for soils is important since it determines the degree of compactness as a measure for soil structure and is used for calculating pore space of soils.

Total Porosity:

Porosity of a soil sample is the volume which is occupied by air and water. Mathematically , it is the ratio of volume of pore space to total volume of soil. Porosity is governed by the arrangement or orientation of the solid particles. Total porosity gives an idea only about the total storage capacity of soil for fluids or gases.

The volume percentage of the total soil bulk not occupied by the solid particles usually it is expressed as

$$\%\text{ pore space} = \left[100 - \frac{(D_b \times 100)}{D_p}\right]$$

This is obtained as follows:

By definition $$D_p = \frac{W_s}{V_s} \quad (10)$$

$$D_b = \frac{W_s}{V_s + V_p} \quad (11)$$

Where $W_s =$ weight of soil solid

$V_s =$ volume of solid

$V_p =$ volume of pores

$V_s + V_p =$ total soil volume

$D_b =$ bulk density

$D_p =$ particle density

$$W_s = D_p V_s \quad (12)$$

$$W_s = D_b\,(V_p + V_s) \quad (13)$$

Hence $$D_p . V_s = D_b\,(V_p + V_s) \quad (14)$$

Or $$\frac{D_b}{D_p} = \frac{V_s}{V_s + V_p} \quad (15)$$

It can be written that $$\%\text{ solid space} = \frac{D_b}{D_p} \times 100 \quad (16)$$

Also since (% pore space + % solid space)= 100 (17)

% pore space = 100 - % solid space (18)

$$= 100 - \frac{D_b}{D_p} \times 100 \qquad (19)$$

Dielectric constant of soil:

Complex dielectric constant has been calculated by following relation:

$$\in^* = \in' - j\in'' \qquad (20)$$

The real part $\in'$ is called the dielectric constant and the imaginary part $\in''$ is called the dielectric loss. The dielectric constant describes the ability of a material to store electromagnetic energy, and dielectric loss represents loss of electromagnetic field in the material.

The table represent the real and imaginary part of dielectric constant at different moisture level (0%, 10%, 20%, 30%, 40%). Moisture content of soil is an important parameter that influences the properties of soil.

Analysis of effect of moisture content on dielectric properties of soil:

The table given below represent the real and imaginary part of dielectric constant at different moisturelevel (0%, 10%, 20%, 30%, 40%) . Moisture content of soil is an important parameter that influences the electrical properties of soil.

Table: 1. Dielectric constant and dielectric loss at moisture content (0%,10%, 20%, 30%, 40%)

S.No.	Sample	Real part of dielectric constant					Imaginary part of dielectric constant				
		Dry soil (0%)	10%	20%	30%	40%	Dry soil(0%)	10%	20%	30%	40%
01	**S_1/ Banisiha, Balasore**	3.03	6.23	11.01	16.24	26.78	0.10	0.17	0.28	1.1	1.03
02	**S_2/ Balasore**	3.05	6.29	11.06	16.31	26.81	0.15	0.19	0.31	1.4	1.17
03	**S_3/ Hajipur, Balasore**	3.08	6.44	11.11	16.47	26.87	0.17	0.23	0.34	1.7	1.23
04	**S_4/ Ghasua, Balasore**	3.10	6.73	11.17	16.66	26.90	0.23	0.19	0.37	1.8	1.31
05	**S_5 /Santapada, Balasore**	3.13	6.81	11.21	16.89	26.93	0.28	0.24	0.41	1.11	1.43

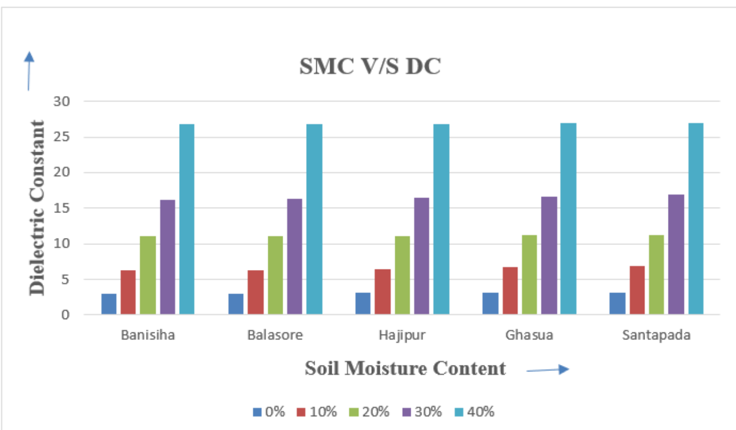

Fig.:4. Dielectric Constant of all samples

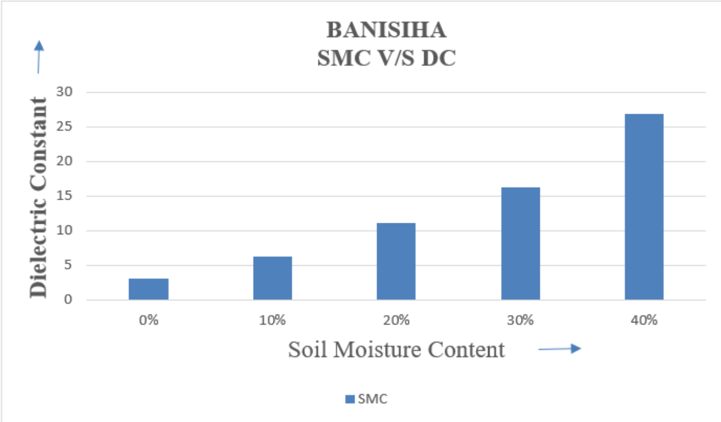

Fig:5. Soil moisture content v/s dielectric constant (Banisiha)

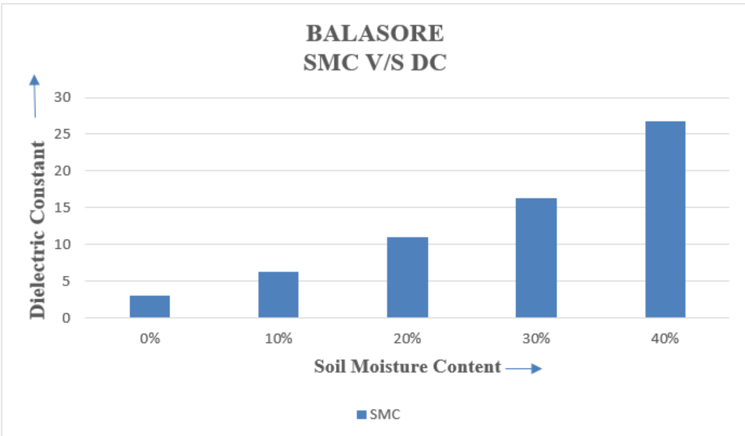

Fig:6. Soil moisture content v/s dielectric constant (Balasore)

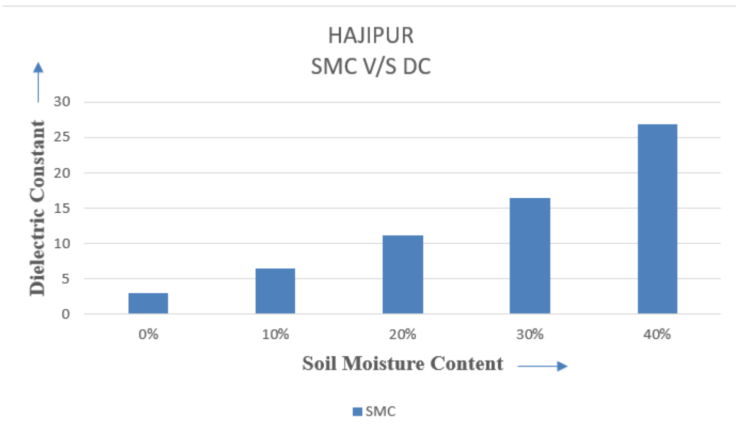

Fig:7. Soil moisture content v/s dielectric constant (Hajipur)

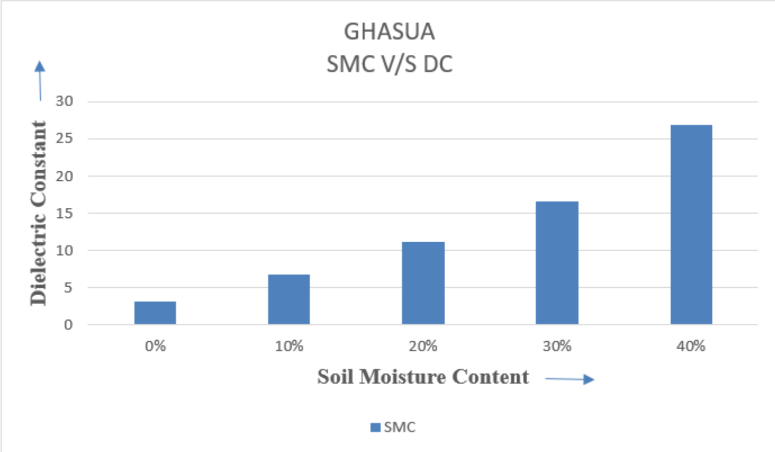

Fig:8. Soil moisture content v/s dielectric constant (Ghasua)

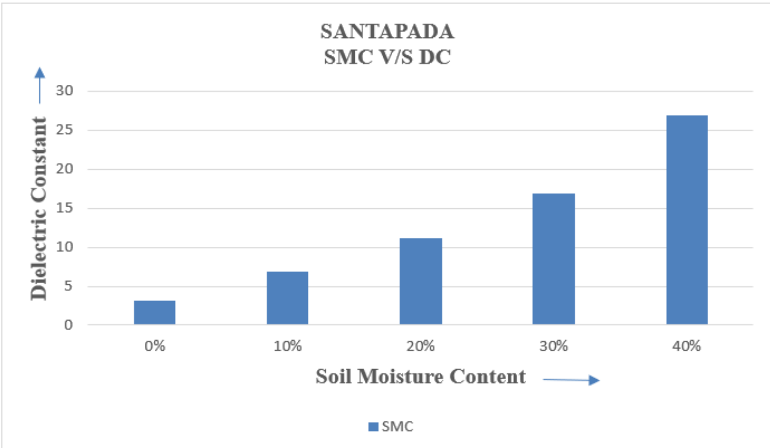

Fig:9. Soil moisture content v/s dielectric constant (Santapada)

3. Conclusions:

Soil is really key part of human being as well as animal. Without soil it cannot be existence of environment. All states have specific properties of soil. Soil involvement in production is very important. There are several properties of soil such as physical properties, chemical properties and geographical properties. The available nutrients play important role in the production of food grains and also in agriculture. There are a lot of nutrients but eighteen elements enriches the supportive environment. The parameter such as moisture content, pH, electrical conductivity, organic carbon, soil texture, macronutrients, and micronutrients affect the dielectric behaviour of soil. The samples are collected from Banisisha, Balasore, Hajipur, Ghasua and Santapada then after result deta have been analyzed. The different values have been shown for different parameter in relation to percentage of sand, silt, clay. It has been observed that the value of dielectric constant of dry soil vary in between 3.00 to 3.15. Again, it has been found that the value of dielectric constant at 10% moisture is in between 6.21 to 6.82. Also, it has been obtained that the value of dielectric constant at 20% moisture is in between 11.00 to 11.21. It has been calculated the value of dielectric constant at 30% moisture, exhibits in between 16.22 to 16.90. The value of dielectric constant at 40% moisture has been estimated in between 26.77 to 26.95. Lastly it has been concluded that dielectric constant are very important parameter and panacea for progressive farmers.

Finally, it has been concluded that the dielectric behaviour and soil moisture content are part and parcel of soil. It plays pivotal role in agriculture and farming. A material is classified as dielectric if it has the ability to store energy when it is exposed to an external electromagnetic field. This is essentially the ability of the material to polarize by an external electromagnetic field. Dielectric permittivity is a complex number which describes the behaviour of material when it is exposed to an electric field and is the fundamental parameter that controls the propagation of electromagnetic waves in any material. It has been seen that dielectric constant varies in between 3.00 to 26.95

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