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**ANALYSIS OF X-BAND MICROWAVE ATTENUATION USING  
ELECTRICAL CONDUCTIVITY, PH, AND ORGANIC CARBON  
PARAMETERS IN COALFIELD AREAS OF SURGUJA DISTRICT,  
CHHATTISGARH**

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## **ABSTRACT**

Soil properties play a significant role in determining the propagation characteristics of microwave and millimeter-wave signals in terrestrial environments. The present study investigates selected soil physicochemical parameters, including electrical conductivity (EC), pH, organic carbon (OC), and soil organic matter (SOM), in and around the Amera Coal Field region of Surguja District, Chhattisgarh, India. Soil samples were collected from five representative locations, namely Parsa, Ramgarh (Sitabengra), Amera Village, Latori (Navapara), and the Amera Coal Field area. Standard laboratory methods were employed for the determination of EC, pH, and OC, while SOM was estimated using the Van Bemmelen conversion factor. The results revealed considerable spatial variation in soil characteristics across the study area. The highest mean EC value was observed inside the Amera Coal Field ( $0.687 \text{ dS m}^{-1}$ ), whereas the highest pH and OC values were recorded at Parsa (5.86) and Amera Village (0.902%), respectively. Estimated SOM values ranged from 0.936% to 1.555%. Statistical analysis using mean, standard deviation, and coefficient of variation indicated significant heterogeneity among the sampling sites, reflecting the influence of mining activities and local environmental conditions. Since soil electrical and dielectric properties are closely related to moisture retention, ionic concentration, and organic matter

content, variations in EC, pH, OC, and SOM are expected to influence electromagnetic wave propagation characteristics. The findings provide important baseline information for future modelling of microwave and millimeter-wave attenuation in the X-band frequency range under mining and dust-affected environments. The study contributes to understanding the relationship between soil quality and radio-wave propagation in coalfield regions.

**KEYWORDS:** Electrical conductivity, Soil pH, Organic carbon, Soil organic matter, Microwave propagation, X-band, Amera Coal Field, Surguja District.

## 1. INTRODUCTION

### • **Microwave Communication and X-band Propagation**

Microwave Communication systems play an important role in modern wireless communication, radar systems, satellite communication, and remote sensing applications. The propagation characteristics of microwave signals are strongly influenced by environmental and atmospheric conditions. Factors such as dust particles, soil characteristics, humidity, and suspended pollutants can affect the attenuation and propagation behavior of microwave signals, particularly at higher frequency bands. Among different microwave frequency ranges, the X-band is widely used because of its high transmission capability, better resolution, and operational efficiency. X-band frequencies are extensively applied in radar communication, satellite systems, weather monitoring, and defense applications. However, the propagation of X-band microwave signals may be significantly affected by environmental conditions present in industrial and mining regions.

### • **Mining Environment and Microwave Attenuation:**

Coal mining regions generally contain large amounts of airborne dust particles and altered soil conditions due to continuous excavation, transportation, and industrial activities. These environmental disturbances may influence microwave attenuation characteristics and signal propagation behavior. The coalfield areas of Surguja are important mining zones characterized by extensive coal extraction activities and dust-rich environmental conditions. Continuous mining operations in these regions produce suspended dust particles and modify the physical and chemical properties of the surrounding soil. Such environmental conditions make the region suitable for studying microwave attenuation under dust storm conditions.

### • **Importance of Soil Parameters:**

Soil parameters such as Electrical Conductivity (EC), pH, and Organic Carbon (OC) provide important information regarding the environmental and chemical characteristics of soil.

Electrical Conductivity represents the conductive behavior of soil and is associated with dissolved ions and moisture content. Organic Carbon is related to organic matter and moisture retention properties, while pH indicates the acidic or alkaline nature of the soil. Variations in these soil parameters may influence the interaction between electromagnetic waves and the surrounding environment. Therefore, the analysis of these parameters is important for understanding microwave propagation characteristics in coal mining environments.

- **Scope of the Study:**

In the present study, soil samples were collected from five different coalfield sites located in the Surguja district. From each selected site, five soil samples were collected and analyzed in the laboratory for Electrical Conductivity, pH, and Organic Carbon. The study focuses on analyzing the possible relationship between these soil parameters and X-band microwave attenuation under dust storm conditions in mining environments. The investigation may help in understanding environmental effects on microwave propagation and may contribute to future microwave communication link planning in coal mining regions.

## 2. Literature Review

Soil quality is an important indicator of environmental health, particularly in regions affected by mining activities. Open-cast coal mining alters the physical and chemical characteristics of soil through excavation, overburden dumping, coal transportation, and dust deposition. These changes can significantly influence soil fertility, nutrient availability, and ecological sustainability.

Several researchers have reported that mining activities affect soil electrical conductivity (EC), pH, and organic carbon content. Electrical conductivity is commonly used as an indicator of soluble salt concentration and ionic activity in soil. Elevated EC values have frequently been observed in mining-affected areas due to the accumulation of dissolved minerals and anthropogenic inputs. Changes in EC may influence soil structure, nutrient mobility, and plant growth (**Rhoades, 1996**).

Soil pH is one of the most important chemical properties controlling nutrient availability and microbial activity. Mining operations can alter soil acidity through weathering of exposed materials, oxidation of sulphide-bearing minerals, and continuous deposition of mine-derived particulates. Studies conducted in coal mining regions have reported acidic soil conditions and considerable spatial variability in pH values depending on local geological and environmental conditions (**Brady and Weil, 2016**).

Organic carbon (OC) and soil organic matter (SOM) are key indicators of soil productivity and environmental quality. Organic matter improves soil structure, water-holding capacity, nutrient retention, and biological activity. However, mining activities often reduce vegetation cover and disturb the natural accumulation of organic residues, resulting in lower OC and SOM levels in affected soils. Variations in organic carbon content have been widely used to assess the degree of soil degradation and ecological recovery in mining landscapes (**Nelson and Sommers, 1996**).

Statistical approaches such as mean, standard deviation (SD), coefficient of variation (CV), and correlation analysis are frequently employed to evaluate spatial variability and relationships among soil properties. These methods provide a quantitative basis for understanding soil heterogeneity and environmental impacts in mining regions. Although several studies have investigated soil properties in coal mining areas, limited information is available regarding the variability of EC, pH, OC, and SOM in the Amera Coal Field region of Surguja District, Chhattisgarh. Therefore, the present study aims to assess selected soil quality parameters and evaluate their spatial variation across mining and surrounding village environments.

### **3. Objectives of the Study**

The present study is aimed at investigating the influence of soil environmental parameters on X-band microwave attenuation in coalfield regions of Surguja under dust storm conditions. The research focuses on understanding how variations in Electrical Conductivity (EC), pH, and Organic Carbon (OC) may affect the propagation and attenuation characteristics of microwave and millimeter wave signals in mining environments.

The main objectives of the study are as follows:

1. To analyze X-band microwave attenuation in selected coalfield regions of Surguja district.
2. To measure Electrical Conductivity (EC), pH, and Organic Carbon (OC) values of soil samples collected from different mining sites.
3. To investigate the relationship between soil parameters and microwave attenuation characteristics.
4. To study the influence of environmental soil conditions on the propagation behavior of microwave and millimeter wave signals.

5. To estimate the possible attenuation behavior of microwave signals based on variations in EC, pH, and Organic Carbon values.
6. To evaluate the effect of dust storm conditions and mining environments on microwave communication systems.
7. To develop an environmental understanding of signal attenuation characteristics for future microwave and millimeter wave propagation studies in coal mining regions.

#### 4. Study Area

The present study was conducted in the Amera coalfield region located in the Lakhanpur block of Surguja district, Chhattisgarh, India. Surguja district is situated in the northern part of Chhattisgarh and is characterized by rich mineral resources, extensive forest cover, agricultural land, active coal mining activities. The Amera coalfield represents an important mining area of the district, where continuous extraction and transportation of coal have influenced the surrounding environmental conditions [5],[6].

The study area experiences a tropical monsoon climate with distinct summer, monsoon, and winter seasons. During summer and prolonged dry periods, substantial quantities of dust are generated from mining operations, transportation of coal, exposed overburden dumps, and unpaved roads. These dust particles can alter local environmental conditions and may affect the propagation characteristics of microwave and millimeter-wave signals in the surrounding atmosphere[5]. For the present investigation, soil samples were collected from five representative location, namely Village Parsa, Village Ramgarh (Sitabengra), Village Amera, Village Latori (Navapara), and locations situated inside the Amera Coal Field. These sites were selected to represent different levels of mining influence, ranging from relatively less disturbed village environments to highly mining-affected locations within the coalfield region. Such site selection provides an opportunity to compare variations in soil characteristics under different environmental conditions.

The study region is characterized by mixed land use consisting of agricultural fields, rural settlements, vegetation cover, and mining zones. The physical and chemical properties of soil in the area are influenced by geological conditions, climatic factors, vegetation, and mining activities. Therefore, the selected sampling locations provide a suitable framework for investigating variations in Electrical Conductivity (EC), pH, and Organic Carbon (OC), which are important indicators of soil quality and environmental conditions. The investigation of these soil properties is important for understanding environmental conditions prevailing in the coalfield region and for assessing their possible influence on X-band

microwave and millimeter-wave propagation under dust-prone conditions. Consequently, the Amera coalfield region of Surguja district provides an appropriate study area for evaluating the relationship between soil characteristics and microwave propagation behavior in mining-affected environments [5], [6].

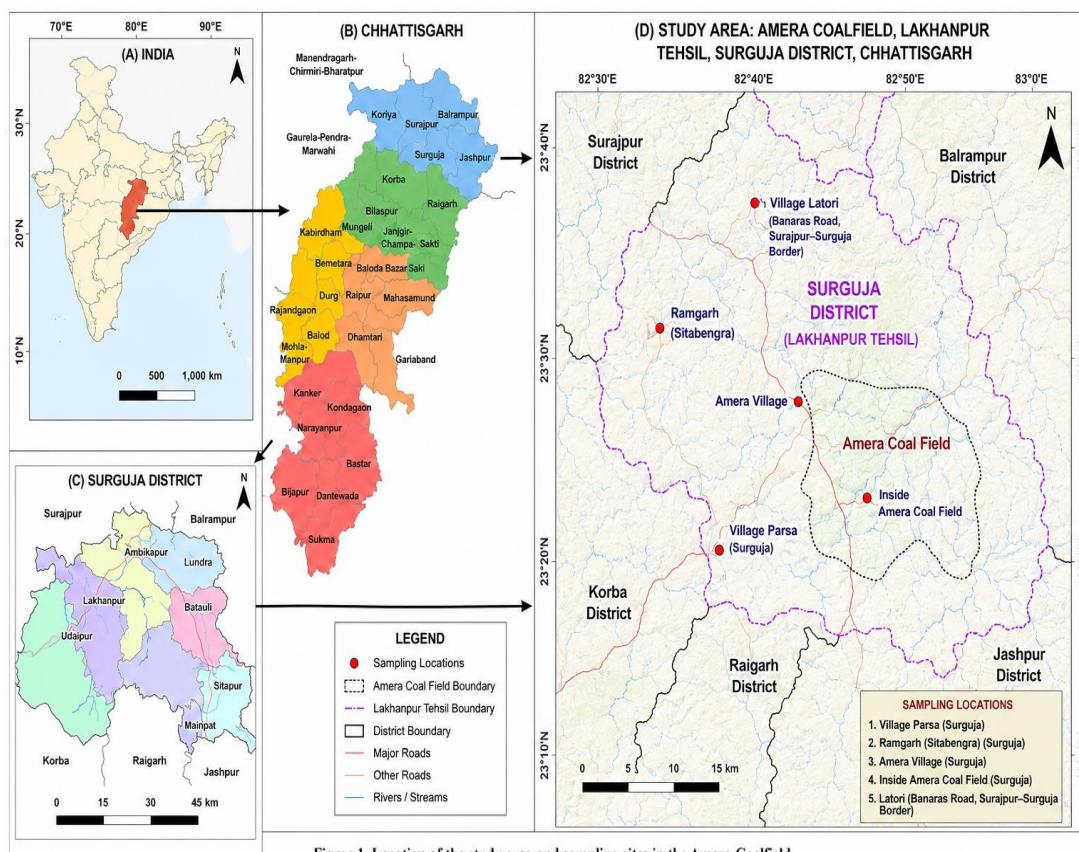


Figure 1. Location of the study area and sampling sites in the Amera Coalfield, Lakhapur Tehsil, Surguja District, Chhattisgarh, India.

Figure 1 Shows the location of the study area and selected sampling sites in Surguja District, Chhattisgarh. The sampling sites were chosen to represent different environmental and mining conditions in and around the Amera Coal Field region. The inset maps indicate the geographical position of Surguja district within Chhattisgarh and India.

## 5. MATERIAL AND METHODS

### 5.1 Study Area and Sample Collection

The present study was carried out in coalfield regions of Surguja district of Chhattisgarh. Five different sampling sites were selected from mining areas affected by coal extraction, transportation, and dust generation activities. These locations were selected because mining operations continuously influence the surrounding environmental and soil conditions. The samples were collected from all selected sites for laboratory analysis. One selected

site contained seven soil samples, while the remaining sites contained five samples each, depending on the availability of suitable sampling locations and environmental conditions. The samples were collected carefully from the upper soil surface and stored in clean polythene bags. Each sample was properly labeled according to its sampling location to avoid confusion during laboratory testing and data analysis.

#### 4.2 Laboratory Analysis of Soil Parameters:

The collected soil samples were tested in the laboratory for Electrical Conductivity (EC), pH, and Organic Carbon (OC). These parameters were selected to study the environmental condition of soil in coal mining regions. Electrical Conductivity analysis was carried out to examine the conductive nature of the soil samples. The pH values were measured to determine whether the soil is acidic or alkaline in nature. Organic Carbon analysis was performed to estimate the amount of organic matter present in the soil samples. The measured values of all parameters were recorded carefully for further analysis and comparison among different sampling sites.

#### 4.3 Experimental and Data Analysis:

The experimental analysis was performed to study the possible effect of soil parameters on X-band microwave attenuation. The measured values of Electrical Conductivity, pH, and Organic Carbon were compared for different sampling sites located in coal mining regions. The experimental data obtained from laboratory measurements were arranged site-wise and analyzed for comparison among different coalfield locations. Variations in Electrical Conductivity, pH, and Organic Carbon values were examined using the recorded observations. The analysis was carried out to identify the possible relationship between soil environmental parameters and X-band microwave attenuation characteristics under dust storm conditions in mining environments.

**Table-1: Measured Soil Parameters (EC, pH, and OC) at different Sampling Locations.**

Site Name	Sample No.	Electrical Conductivity (EC)	pH	Organic Carbon (OC)
<b>Village-Parsa</b>	S <sub>1</sub> - NH Right Side	0.17	6.2	0.48
	S <sub>2</sub> -NH Left Side	0.20	5.7	0.79
	S <sub>3</sub> - 2 km from NH toward coalfield	0.10	5.4	0.33
	S <sub>4</sub> - 3 km from NH toward coalfield	0.08	5.2	1.24
	S <sub>5</sub> - Road Coal Dust	0.28	6.8	1.04
<b>Village-RamgarhSitabengara</b>	S <sub>1</sub> -Entry gate Ramgarh	0.32	3.6	0.52

	S <sub>2</sub> -Natyashala	0.09	4.6	1.04
	S <sub>3</sub> -Hathi Khol/Pol	0.12	4.4	0.39
	S <sub>4</sub> -Beside Khol/Pol	0.16	4.8	0.26
	S <sub>5</sub> -Ramgarh Mandir Road-1	0.07	4.2	0.19
	S <sub>6</sub> -Ramgarh Mandir Road-2	0.06	4.3	0.86
<b>Village- Amera</b>	S <sub>1</sub> -2 km from coal Field	0.14	4.5	0.77
	S <sub>2</sub> -3 km from coal Field	0.08	4.3	1.10
	S <sub>3</sub> -4 km from coal Field	0.06	3.9	0.69
	S <sub>4</sub> -5 km from coal Field	0.07	4.5	0.80
	S <sub>5</sub> - beside NH	0.19	4.3	1.15
<b>Village- (Navapara) Latori</b>	S <sub>1</sub> -Coal Dust	0.12	3.8	0.00
	S <sub>2</sub> - Coal Dust	0.24	4.4	0.00
	S <sub>3</sub> -500 m from Coal Field	0.06	3.5	0.80
	S <sub>4</sub> -1000 m from Coal Field	0.07	3.4	0.98
	S <sub>5</sub> -1500m from Coal Field Road Side	0.08	3.7	1.09
<b>Inside the Amera Coal Field</b>	S <sub>1</sub> -Gate no.1	0.33	4.7	1.21
	S <sub>2</sub> -500m from gate no.-1	0.16	5.4	0.69
	S <sub>3</sub> -Dumping Yard	0.17	5.3	1.03
	S <sub>4</sub> -Main Coal Mines	1.38	4.5	0.00
	S <sub>5</sub> -B-Grade Coal Mines	1.22	4.6	0.00
	S <sub>6</sub> -View Point Road Dust	1.20	4.5	0.00
	S <sub>7</sub> -1000m from Main Coal Mines	0.35	4.8	2.01

**Table-2: Site-Wise Average Soil Parameters of the Selected Sampling Locations.**

Site Name	No. of Sample	Average (EC)	Average pH	Average (OC)
<b>Village-Parsa</b>	5	0.166	5.86	0.776
<b>Village-RamgarhSitabengara</b>	6	0.137	4.32	0.543
<b>Village- Amera</b>	5	0.108	4.30	0.902
<b>Village- Latori (Nava Para)</b>	5	0.114	3.76	0.574
<b>Inside the Amera Coal Field</b>	7	0.687	4.83	0.706

#### 4.4 Statistical and Derived Parameter Analysis

The measured values of Electrical Conductivity (EC), pH, and Organic Carbon (OC) were statistically analyzed to evaluate variations among the selected sampling locations. Basic statistical parameters such as mean, standard deviation (SD), and coefficient of variation (CV) were calculated to assess the distribution and variability of the soil properties. In addition, Soil Organic Matter (SOM) was estimated from the measured Organic Carbon values using a standard conversion factor. These analyses provide a quantitative understanding of soil characteristics and support the interpretation of environmental conditions within the study area. [1], [3].

##### Mean (Average)

The mean value of each parameter was calculated using:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \dots \dots \dots (1)$$

Where  $\bar{x}$  is the mean value,  $x_i$  represents an individual observation, and n is the total number of observations.

##### Standard Deviation (SD)

$$SD = \sqrt{\sum_{i=1}^n \frac{(x_i - \bar{x})^2}{n-1}} \dots \dots \dots (2)$$

Where SD represents the dispersion of data around the mean value.

##### Coefficient of Variation (CV)

$$CV(\%) = \frac{SD}{\bar{x}} \times 100 \dots \dots \dots (3)$$

The coefficient of variation was used to compare the relative variability among different soil parameters.

##### Soil Organic Matter (SOM)

Soil Organic Matter was estimated from Organic Carbon using the Van Bemmelen conversion factor [1],[2]:

$$SOM = 1.724 \times OC \dots \dots \dots (2)$$

Where SOM is Soil Organic Matter (%) and OC is Organic Carbon (%).

**Table-3: Statistical Summary and Derived Soil Parameters of the Selected Study Sites.**

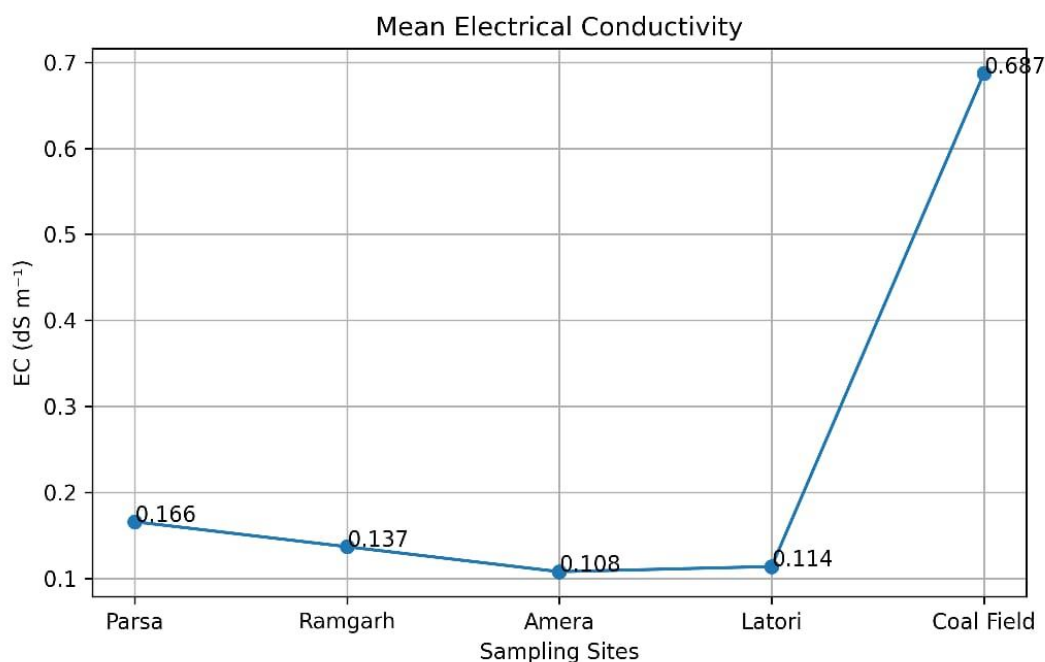
Study Site	Mean EC	SD (EC)	CV (%) EC	Mean pH	SD (pH)	CV (%) pH	Mean OC (%)	Estimated SOM (%)
Village-Parsa	0.166	0.080	48.5	5.86	0.647	11.0	0.776	1.338
Village-RamgarhSitabengara	0.137	0.097	70.9	4.32	0.412	9.5	0.543	0.936
Village- Amera	0.108	0.055	51.3	4.30	0.245	5.7	0.902	1.555
Village- Latori (Nava Para)	0.114	0.074	64.9	3.76	0.391	10.4	0.574	0.989
Inside the Amera Coal Field	0.687	0.550	80.0	4.83	0.373	7.7	0.706	1.217

Table 3 presents the statistical summary and derived soil parameters for the selected study sites. The highest mean Electrical Conductivity ( $0.687\text{dSm}^{-1}$ ) was observed inside the Amera Coal Field, indicating the influence of mining activities on soil electrical properties. The coefficient of variation for EC ranged from 48.5% TO 80.0%, showing considerable spatial variability. The pH values indicated predominantly acidic soil conditions throughout the study area, while Organic Carbon content varied among locations. The estimated Soil Organic Matter ranged from 0.936% to 1.555%, with the highest value recorded at Village Amera. These variations reflect differences in environmental conditions, organic matter accumulation, and mining influence across the study area.

## 6. RESULT AND DISCUSSION

### 6.1 Electrical Conductivity Analysis

The Electrical Conductivity (EC) values obtained from the collected soil samples showed considerable variations among the selected sampling sites. Comparatively higher EC values were observed in the Amera Coal Field region, whereas lower values were recorded in the surrounding village locations. The highest conductivity values were associated with active mining and coal dust affected areas. The observed increase in EC within the coalfield region may be attributed to the presence of coal particles, mineral deposits, and mining-related activities. Continuous deposition of coal dust and associated materials can alter the electrical characteristics of the soil environment. In contrast, soils collected from surrounding villages exhibited relatively lower conductivity, indicating lesser influence of mining operations. Since Electrical Conductivity represents the ability of soil to conduct electrical current, variations in EC are important for understanding the interaction between soil and electromagnetic waves. Higher Conductivity conditions may increase electromagnetic energy losses and thereby influence microwave propagation characteristics.



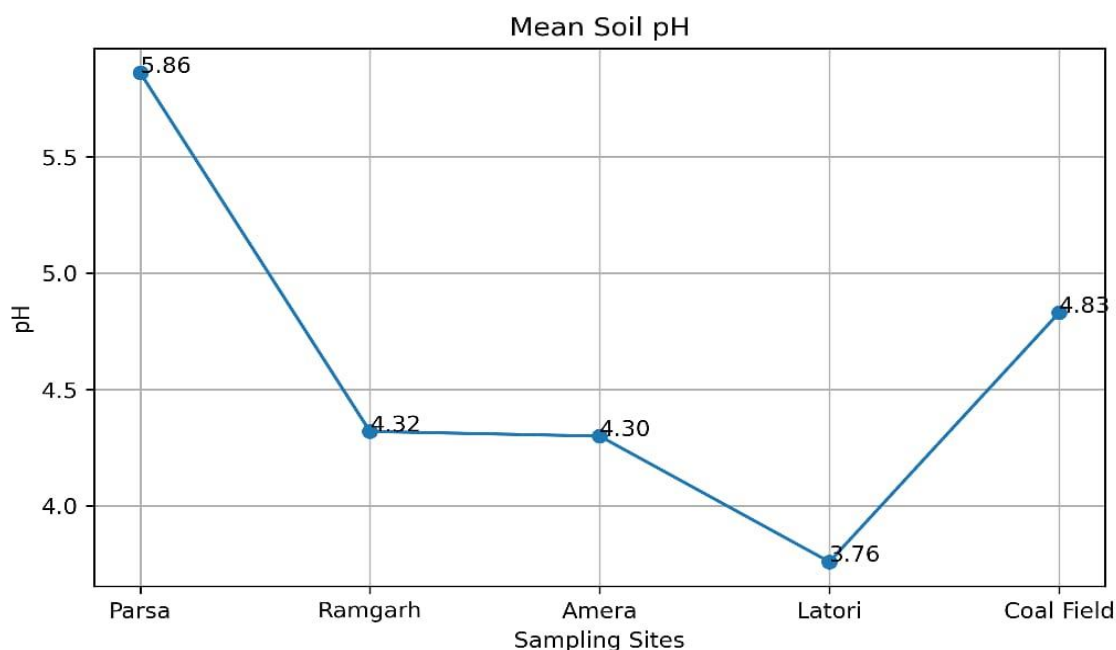
**Figure-2: Mean electrical conductivity (EC) values at different sampling sites in the coalfield region foSurguja District, Chhattisgarh.**

**Discussion:** The mean electrical conductivity (EC) values varied considerably among the selected sampling sites. The highest EC value was observed inside the Amera Coal Field (0.687 dS m<sup>-1</sup>), whereas comparatively lower values were recorded at Parsa (0.166 dS m<sup>-1</sup>), Ramgarh (0.137 dS m<sup>-1</sup>), Amera Village (0.108 dS m<sup>-1</sup>), and Latori (0.114 dS m<sup>-1</sup>). The elevated EC within the coalfield may be attributed to mining- related activities, coal dust deposition, and the accumulation of soluble ionic constituents in the soil. In contrast, the surrounding villages exhibited relatively lower conductivity, indicating lesser anthropogenic disturbance. The results suggest that mining operations may influence soil salinity and ionic concentration in the study area.

## 6.2 pH Analysis

The measured pH values indicated noticeable variation among the selected sampling locations. Most soil samples were found to be acidic in nature, although the degree of acidity varied from site to site. The acidic character of the soil may be related to local geological conditions, mineral composition, and environmental process occurring within the study area. Differences in pH valued suggest variations in soil chemistry and environmental conditions across the selected locations. Although pH is not a direct measure of microwave attenuation, it reflects the chemical condition of the soil environment. Therefore, pH can

provide useful information regarding the environmental characteristics of the study area and their possible influence on soil behavior.



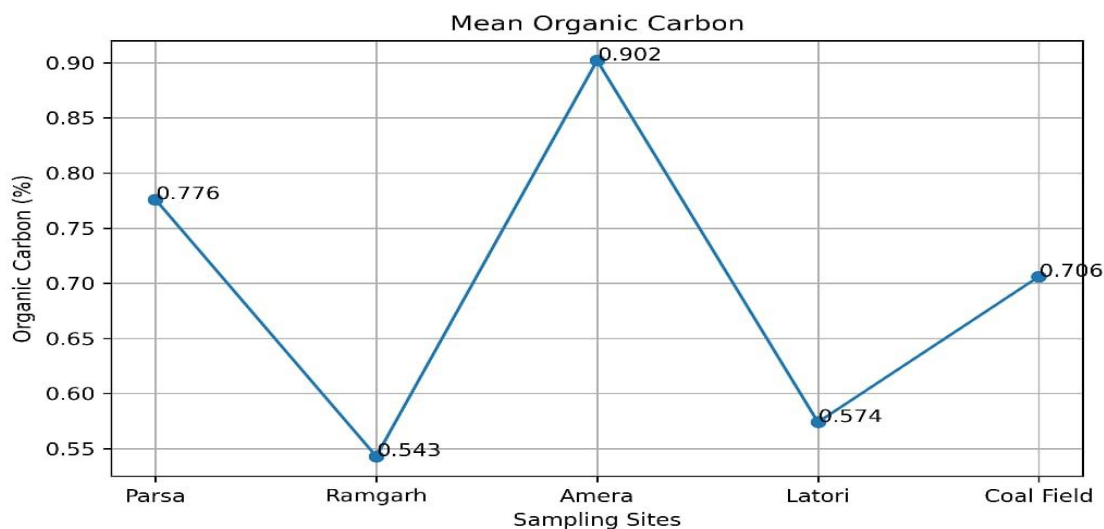
**Figure-3: Mean pH values at different sampling sites in the coalfield region foSurguja District, Chhattisgarh.**

**Discussion:** The mean soil pH values indicate that the soils of the study area are predominantly acidic in nature. The highest pH value was recorded at Parsa (5.86), while the lowest value was observed at Latori (3.76). Intermediate values were recorded at Ramgarh (4.32), Amara Village (4.30), and inside the Amara Coal Field (4.83). The acidic soil conditions may result from intensive leaching, weathering processes, and decomposition of organic matter under humid environmental conditions. The observed variations in pH among the sampling sites reflects differences in local soil characteristics and environmental influences. Soil acidity plays an important role in controlling nutrient availability, microbial activity, and overall soil fertility.

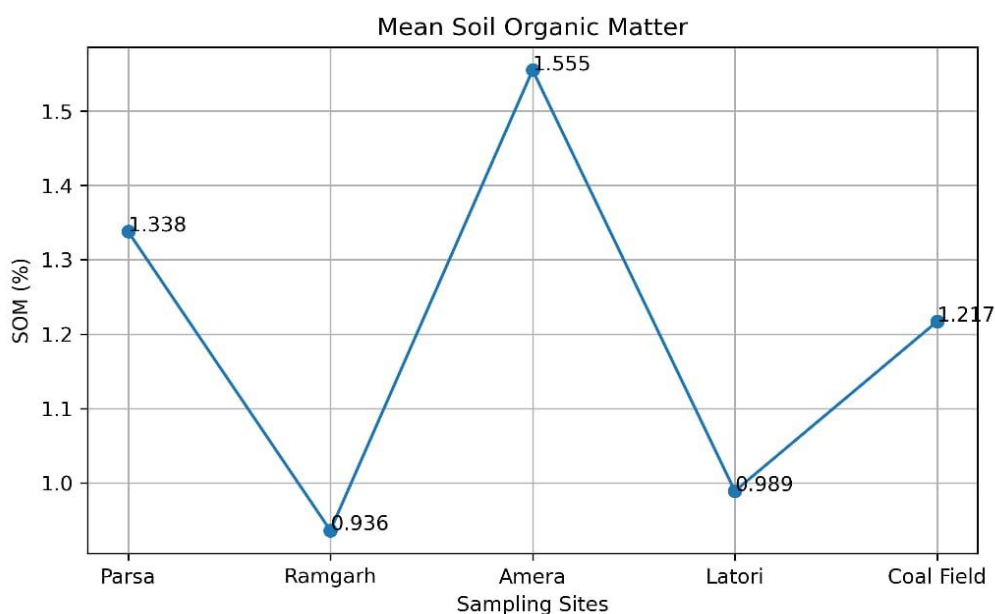
### 6.3 Organic Carbon Analysis

Organic Carbon (OC) values showed significant variation among the sampling sites. Some locations exhibited relatively high Organic Carbon content, whereas others showed comparatively lower values. The variation in OC content may be associated with difference in vegetation cover, organic matter accumulation, and local environmental conditions. Areas with greater organic matter generally possess improved soil quality and different physical

characteristics compared with locations having lower organic content. Organic Carbon is an important indicator of soil condition and environmental quality. Variations in OC may influence soil properties and consequently affect the interaction between electromagnetic waves and the surrounding environment.



**Figur-4: Mean organic carbon (OC) values at different sampling sites in the coalfield region foSurguja District, Chhattisgarh.**

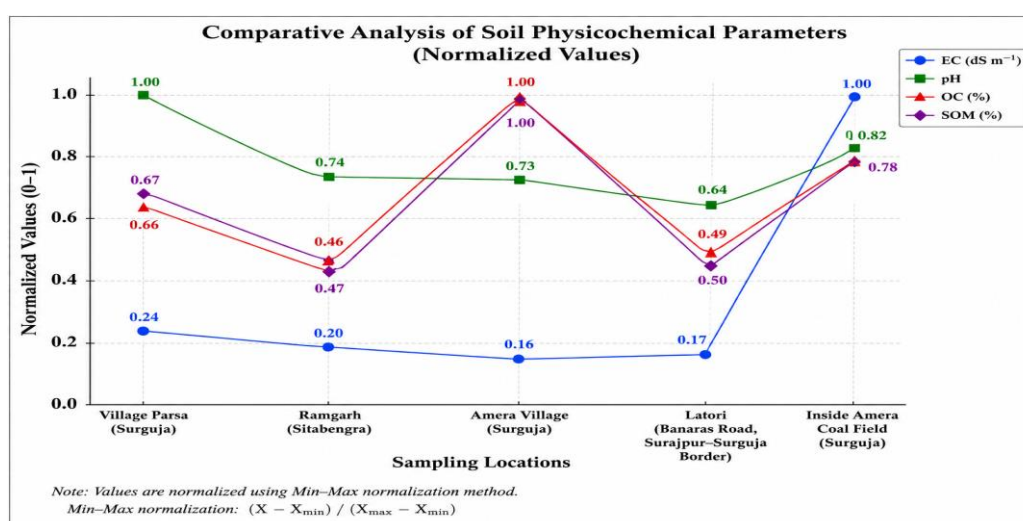


**Figur-5: Mean soil organic matter (SOM) values at different sampling sites in the coalfield region fo Surguja District, Chhattisgarh.**

**Discussion:** The organic carbon content showed noticeable variation among the sampling locations. The highest mean OC value was recorded at Amera Village (0.902%), followed by Parsa (0.776%), Inside the Amera Coal Field (0.706%), Latori (0.574%), and Ramgarh (0.543%). The corresponding SOM values ranged from 0.936% to 1.555%, with Amera Village exhibiting the highest estimated SOM content. Higher organic carbon and SOM values generally indicate greater organic matter accumulation, improved soil structure, and enhanced nutrient retention capacity. The relatively lower values observed at Ramgarh and Latori may be associated with reduced vegetation cover, organic residue input, or differences in land-use practices. These findings suggest that organic matter distribution varies considerably across the study area and contributes significantly to soil quality.

### 6.4 Comparative Analysis of Soil Parameters

A comparative evaluation of Electrical Conductivity, pH, and Organic Carbon revealed distinct differences among the selected sampling sites. Among the investigated parameters, Electrical Conductivity exhibited the most noticeable variation between coalfield and non-coalfield locations. The observed differences indicate that mining activities and local environmental conditions have influenced the physical and chemical characteristics of the soil. The combined analysis of EC, pH, and OC provides a comprehensive understanding of the environmental variability present within the study area. The results suggest that soil properties are not uniform across the region and vary according to local environmental and mining-related factors.



**Figure 6: Comparative analysis of soil physicochemical parameters (EC, pH, OC and SOM) across different sampling locations in the Amera Coalfield region, Surguja District, Chhattisgarh.**

**Discussion:** The comparative analysis indicates significant spatial variation in soil physicochemical properties across the study area. The Amera Coal Field site exhibited the highest EC value, suggesting greater ionic concentration and possible mining influence. Amera Village recorded the highest OC and SOM contents, indicating better organic matter accumulation and soil quality. Parsa showed the highest pH value, while Latori was the most acidic site. Overall, the results demonstrate that both mining activities and local environmental conditions contribute to the observed variability in soil characteristics within the Amera Coalfield region.

#### **6.5 Relation With X-band Microwave Attenuation:**

The measured soil parameters provide valuable information for understanding environmental conditions that may influence X-band microwave propagation in local mining regions. Among the investigated parameters, Electrical Conductivity appears to be most significant because it is directly related to the electrical behavior of the medium. The comparatively higher EC values observed in coalfield locations indicate a greater potential for electromagnetic energy dissipation than in surroundings village areas. Organic Carbon and pH may also contribute indirectly by influencing the overall environmental and chemical characteristics of the soil. Based on the observed results, it can be inferred that variations in Electrical Conductivity, pH, and Organic Carbon create differences in soil conditions that behavior. Therefore, these parameters can be considered useful environmental indicators for assessing the potential attenuation of X-band microwave signals in coalfield regions of Surguja district under dust storm conditions.

### **7 CONCLUSION**

The present study was conducted to evaluate the spatial variation of selected soil physicochemical properties in and around the Amera Coal Field region of Surguja District, Chhattisgarh. Soil samples collected from five representative locations were analysed for electrical conductivity (EC), pH, organic carbon (OC), and soil organic matter (SOM) to assess soil quality and its potential relevance to microwave and millimeter-wave propagation studies. The results demonstrated considerable variability in soil properties across the investigated sites. The highest mean electrical conductivity ( $0.687 \text{ dS m}^{-1}$ ) was recorded inside the Amera Coal Field, indicating a greater concentration of soluble ions and a possible influence of mining-related activities. In comparison, the surrounding village sites exhibited relatively lower EC values. Soil pH analysis revealed that the soils of the study area are

predominantly acidic in nature, with values ranging from 3.76 to 5.86. The lowest pH was observed at Latori, while Parsa exhibited comparatively less acidic conditions. Organic carbon and soil organic matter also showed significant spatial variation among the sampling locations. The highest organic carbon content (0.902%) and estimated SOM value (1.555%) were recorded at Amera Village, indicating comparatively better organic matter accumulation and improved soil quality. The variability observed in OC and SOM suggests differences in vegetation cover, organic residue inputs, and local environmental conditions. Statistical analyses based on mean, standard deviation, and coefficient of variation confirmed the heterogeneous nature of soil properties throughout the study area. The findings indicate that both natural environmental factors and mining-related activities contribute to variations in soil characteristics within the coalfield region. Changes in EC, pH, OC, and SOM can influence soil dielectric behaviour, moisture retention capacity, ionic conductivity, and electromagnetic interactions. Therefore, these parameters are important for understanding the propagation characteristics of microwave and millimeter-wave signals in mining-affected environments. Although the present study focused on soil quality assessment, the generated database provides valuable baseline information for future investigations related to electromagnetic wave propagation. The analyzed soil parameters can serve as important inputs for dielectric modelling, attenuation estimation, and propagation studies in the X-band and other microwave frequency ranges. Overall, the study highlights the significance of soil physicochemical properties in the coalfield region and establishes a foundation for integrating soil science with microwave and millimeter-wave propagation research. Future investigations should include soil moisture measurements, dielectric constant analysis, electromagnetic modelling, and direct attenuation studies to quantify the influence of soil characteristics on signal propagation under coalfield and dust-affected environmental conditions.

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