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# Determination of Petroleum Contamination of Soil Using Dielectric Method

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***Abstract*: -**As the amounts of petroleum hydrocarbon usage increased, the soil contamination with these compounds have been one of the environmental problems worldwide. This study assessed the feasibility and efficiency whether dielectric method be able to be used to detect petroleum contamination that can leach through the soil particles due to the spreading of petroleum compounds. For this reason, dielectric measurements, in the frequency range from 100 kHz to1000 kHz, were carried out in sand soil samples, partially filled or saturated with solutions of petroleum compounds, at different concentrations. The results suggest that we can detect soil contamination by petroleum contamination using dielectric method and have a different trend between saturated and unsaturated soil.

***Keywords:*** *Petroleum Contamination, Dielectric, Electromagnetic, Hydrocarbon, Soil.*

## 1. Introduction

Unfortunately, soil contamination by different petroleum compounds has rapidly expanded worldwide due to excessive use of these compounds [1-3]. The extraction, transportation, and storage of petroleum compounds regularly be as a source of spills and leaks to the soil, posing serious threats to environmental pollution which effects on human health [4-8]. Soil contamination causes destruction of its original chemical composition and also inferior properties such as high hydrophobicity, high sorption capacity and low volatility [9]. These negative effects pose a great risk to human health and environmental safety [10]. In other hand due to hydrophobic properties of soil petroleum compounds had adverse effects in agriculture such as inhibition of seed germination and plant growth [11,12], which results from the clogging of water infiltration by petroleum compounds more over the effects on soil aeration [13,14].The unsaturated zone of the soil where the infrastructure's foundations are normally placed, is the first zone will be polluted by petroleum compounds spills. It is also possible these compounds leakthrough the soil up to the groundwater zone. Therefore, petroleum compounds spills can contaminate groundwater then can be transported to the surrounding areas contaminating the soil [15] The quality and protection of the soil environment is necessary for sustaining the rapid development of agriculture, civilization and the economy and protecting human being health [16,17]. Soil is a multi-functional medium. It is a vital for life and provides a wide range of services, which are mostly taken for granted. To characterize the soil pollution, the most commonly used methods involve collecting representative soil samples and analyzing them in the laboratory. This method of characterizing the pollutants of a soil in general is the best one suitable to regulatory agencies [18]. On the other hand, soil sample collection and analysis in the laboratory take more time and more money, the samples may harsh when moving them, the samples will not be continuous with time, more over the samples may be polluted during collecting, carrying, and analysis in the lab. Therefore, many geophysical techniques have been developed that utilizes the contrast caused by the contaminant on physical properties of the soil [1920].Dielectric and electromagnetic methods prove high potential for soil [21-25].And these methods give accurate results for measuring soil pollution with petroleum compounds [26-30]. In addition, many dielectric and electromagnetic sensors were developed using these methods; depending on the availability of information about the dielectric properties of the polluted soil. Development of such information regarding the detection of soil polluted with petroleum compounds using geophysical methods has created a spotlight of research by many researchers around the world over several years [19, 31-33].Abidin [34] investigated the feasibility of using dielectric measurement of soil materials to find out the soil porosity, a linear relationship between the dielectric constant and porosity of soil-water mixtures was observed.In this paper, dielectric measurements have been directed towards the development of a sensor for a polluted soil test. The specific areas of concern are detection of benzene in soil matter and determination of pollution level of this pollutant. It is expected to produce equipment that helps the practicing civil engineer. Moreover, this work is directed towards succeeding in the understanding of the electromagnetic method involved in such a complex material.In this paper, dielectric measurements have been directed towards the development of reliable quality assurance tests for soil. The particular areas of interest are detection of hydrocarbon in soil material and determination of the contents of this contaminates. It is hoped to produce equipment, which will provide assistance to the practicing civil engineer. The current work is directed towards achieving the understanding for electromagnetic mechanisms involved in such a complex material.

**Dielectric Properties of Soil:** Dielectric permittivity ($\varepsilon^*$) of soil material can be defined as a Complex permittivity of its components which represents the interaction between electromagnetic signal and the soil media. It is also control the propagation of the signal in that media. Complex function with real and imaginary components as given in eqn (1).

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \qquad (1)$$

Where$j$ is the square root of -1. $\varepsilon'$ is the real part (dielectric constant) and it represent the amount of energy stored in the soil from the electric signals that applied to the material. $\varepsilon''$ is the imaginary part (loss factor) and it represents the energy loss as conductive current. The real part results from the polarization of material, while the imaginary part is due to ohmic and polarization losses. By dividing equation 1 by the permittivity of a vacuum ($\varepsilon_o$), the complex permittivity of soil become unit less representing the dielectric constant and loss factor of soil with respect to air.

## Experimental Program

**Materials and Sample Preparation:**In this research quartz sand with porosity (N=0.4, according to the procedure described in AASHTO manual was used after dried at 105oC for twenty-four hours. Fourteen soil samples of 500 g each have been prepared from the dried sample at constant deionized water content and at five different concentrations of benzene as a type of petroleum compound (supplied by Al Manaseer petrol station with density 0.89). By adding the required concentration of water and benzene to the dry sample, five soil samples sets are taken and recognized by the benzene concentration level. The soil samples were mixed well then kept for four hours in covered container to avoid any evaporation. The average values for three impedances were obtained at each frequency.Five samples were prepared to study the effect of benzene on saturated sandy soil. The whole liquid (water and benzene) was 40% by volume in order to saturate the sandy soil with porosity 0.4. Five different benzene contents were used in order to pollute the sandy soil. Table 1 shows the details of these five samples.

**Table 1. Samples of Benzene Polluted Soil – Saturated Samples.**

| Sample Code | Weight (g) | | | | Volume Fraction | | | |
|---|---|---|---|---|---|---|---|---|
| | Soil | Water | Benzene | Air | Soil | Water | Benzene | Air |
| B0WS | 500 | 126.26 | 0.00 | 00.0 | 0.600 | 0.400 | 0.000 | 0.00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| B1WS | 500 | 114.72 | 10.27 | 00.0 | 0.600 | 0.3635 | 0.0365 | 0.00 |
| B2WS | 500 | 103.18 | 20.54 | 00.0 | 0.600 | 0.3270 | 0.0730 | 0.00 |
| B3WS | 500 | 91.64 | 30.81 | 00.0 | 0.600 | 0.2905 | 0.1095 | 0.00 |
| B4WS | 500 | 80.10 | 41.08 | 00.0 | 0.600 | 0.2540 | 0.1460 | 0.00 |

The effect of benzene content on the electromagnetic properties of unsaturated soil has also been studied. Using the Inscribed central composite (ICC) design to prepare 9 soil samples with 9 different combinations of moisture and benzene content (see Figure 1).

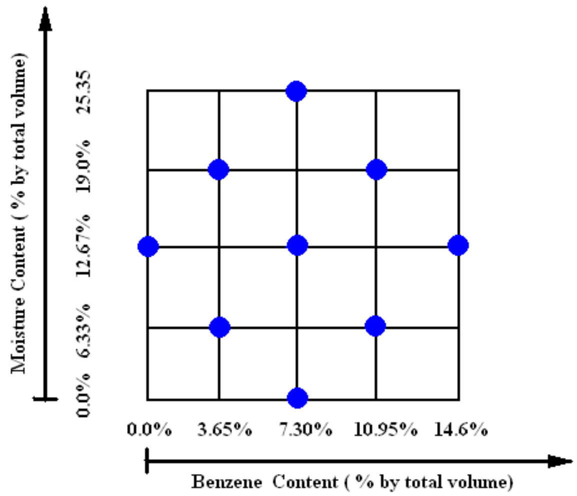



**Figure 1 Combination of Moisture and Benzene Content Using ICC Design**

Table 2 shows the details of these nine soil benzene polluted samples with different moisture content (from dried zero percent moisture content to saturated 40% moisture content).

**Table 2. Samples of Benzene Polluted Soil- Unsaturated Samples**

| Sample Code | Weight (g) | | | | Volume Fraction | | | |
|---|---|---|---|---|---|---|---|---|
| | Soil | Water | Benzene | Air | Soil | Water | Benzene | Air |
| B0W2 | 500 | 40.0 | 0.00 | 00.0 | 0.600 | 0.1267 | 0.0000 | 0.273 |
| B1W1 | 500 | 20.0 | 10.27 | 00.0 | 0.600 | 0.0633 | 0.0365 | 0.300 |
| B1W3 | 500 | 60.0 | 10.27 | 00.0 | 0.600 | 0.1900 | 0.0365 | 0.174 |
| B2W0 | 500 | 0.00 | 20.54 | 00.0 | 0.600 | 0.000 | 0.0730 | 0.327 |
| B2W2 | 500 | 40.0 | 20.54 | 00.0 | 0.600 | 0.1267 | 0.0730 | 0.200 |
| B2W4 | 500 | 80.0 | 20.54 | 00.0 | 0.600 | 0.2535 | 0.0730 | 0.074 |
| B3W1 | 500 | 20.0 | 30.81 | 00.0 | 0.600 | 0.0633 | 0.1095 | 0.227 |
| B3W3 | 500 | 60.0 | 30.81 | 00.0 | 0.600 | 0.1900 | 0.1095 | 0.101 |
| B4W2 | 500 | 40.0 | 41.08 | 00.0 | 0.600 | 0.1267 | 0.1460 | 0.127 |

**Electromagnetic Measurements and Test Cells:** The test cells were of internal dimensions 80×80×40mm. Copper electrodes with dimensions of 80×80×2 mm were attached to two opposite faces of the cell. Copper connections were passed through the cell walls and connected to the electrodes. All impedance measurements were acquired using the LCR meter, operating in voltage-drive mode, with the signal voltage being 1000 mV. A linear sweep over the frequency range of 1 kHz to 1000 kHz was used with the data, recorded at 21 frequency points within this range.

The connection to the LCR meter was by means of short, individually screened coaxial cables to the voltage (V), high/low and current (I) output/input terminals. Cable impedance, plate impedance and fringing impedance were determined using an appropriate model circuits. From the measurements, the impedances of soil sample were calculated and all data is logged by a PC. The complex permittivity's (real part dielectric constant and imaginary part loss factor) of soil samples were deduced from the impedance of the soil. The setup of the system is shown in Figure 2.

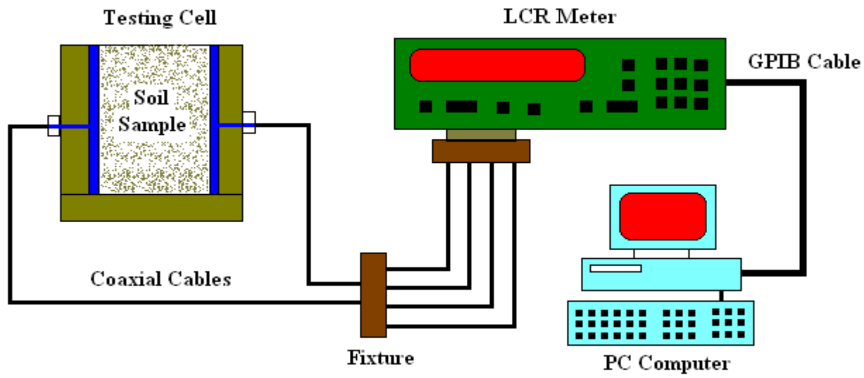
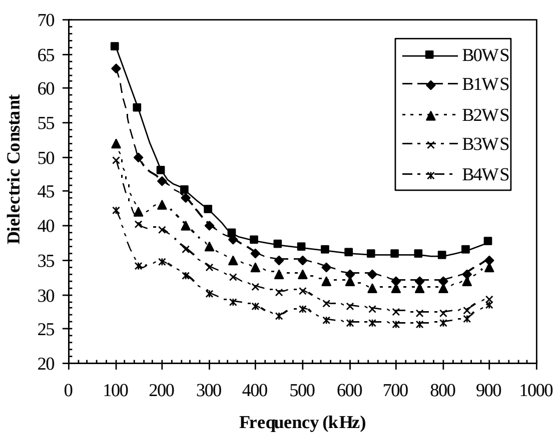



**Figure 2 Schematic Diagram of the Dielectric Measurement System**

## 2. Resultsand Discussion

The effect of benzene content on the measured electromagnetic properties of saturated soil material has been evaluated. Five levels of benzene content were used to contaminate saturated sand soil. These five levels of benzene were evaluated at frequency range of 100 to 1000 kHz.The results of dielectric constant and loss factor of saturated and unsaturated soil polluted with deferent level of benzene versus frequency are shown in Figure 3 and 4 respectively while the relations between the dielectric properties loss factor of saturated and unsaturated soil with benzene content are shown in Figure 5 and 6 respectively.



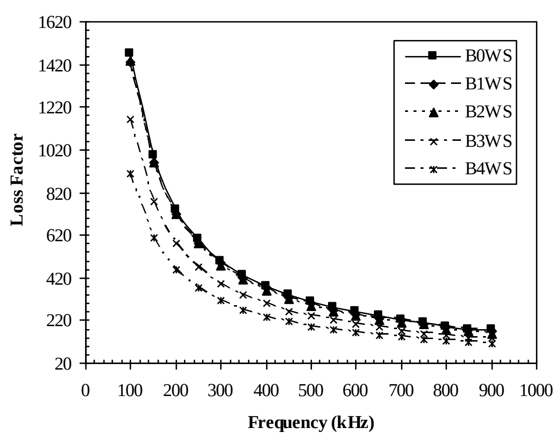




**Figure 3 Dielectric Constant and Loss Factor of Saturated Benzene Polluted Soil at Various Frequency.**

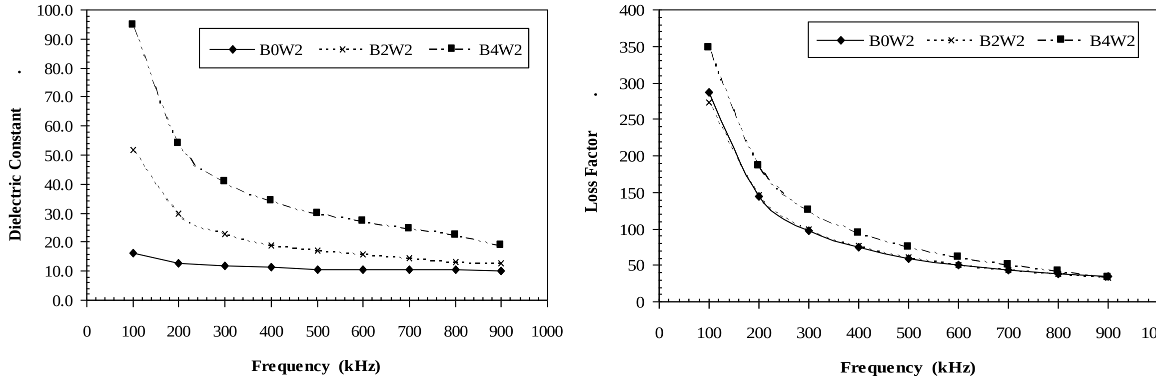



**Figure 4 Dielectric Constant of Unsaturated Benzene Polluted Soil at Various Frequency.**

The dielectric constants and loss factors decrease by increasing the frequency at all benzene content as shown in Figures 3 and 4, at low frequency it clears that has a rapid decreasing in dielectric constant.

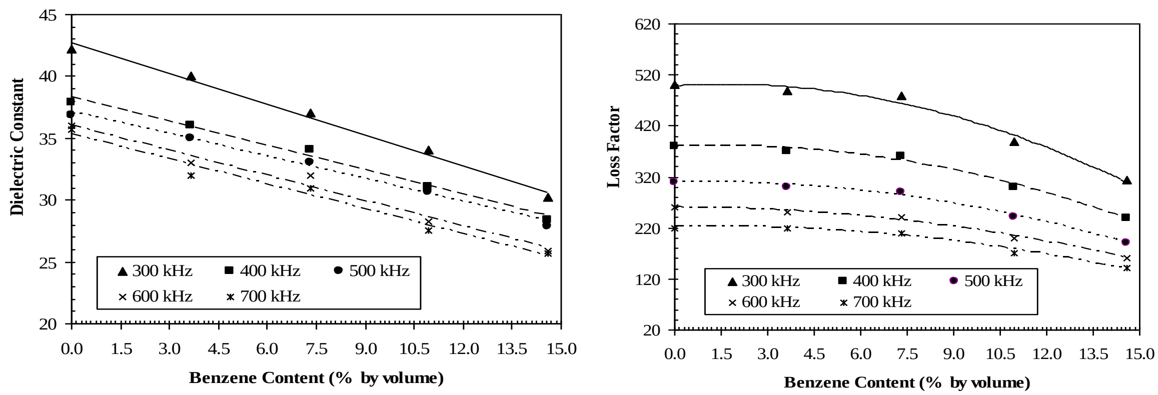



**Figure 5 Effect of Benzene Concentration on Dielectric Constant and Loss Factor of Saturated Polluted Soil.**

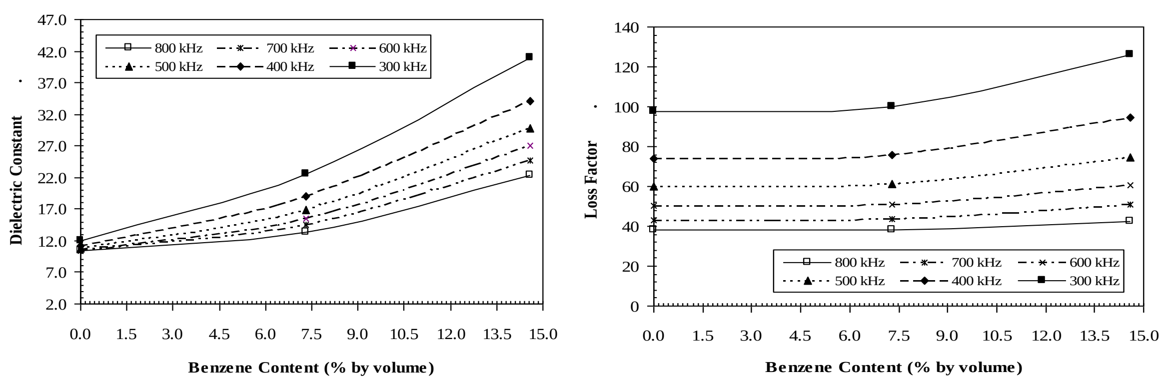



**Figure 6 Effect of Benzene Concentration on Dielectric Constant and Loss Factor of Unsaturated Polluted Soil.**

It is clear from the figure 5 for benzene-polluted soil at saturation condition that both dielectric constant and loss factors of soil are decreased with increasing benzene content. The dielectric constant shows linear decrease with increasing benzene content while loss factor shows high rate of decrease with increasing benzene content.The variations of dielectric constant and loss factor of unsaturated polluted soil with benzenecontent are shown in Figure 6. The results show an opposite trend of saturated soil. In general, the dielectric constant (real part of permeativitty) and loss factor (imaginary part of permeativitty) increased with increasing benzenecontent. hence, the result indicates that the electromagnetic properties of soil are dependent on the interaction of the various phases (water, benzene and air) in the voids of unsaturated soil. In addition, these results may be attributing to the conducting channels forms in the pore space of soil.

## 3. Conclusions

The dielectric constant (real part of permeativitty) and loss factor (imaginary part of permeativitty) were studied in the frequency range of 100 to 1000 kHz for benzene polluted sandy soil. And the experiments confirmed both dielectric constant and loss factors of soil samples decrease with increasing frequency. In saturated benzene polluted soil and over all frequency range of 100 to 1000kHz both dielectric constant and Loss factors of soil samples decrease with increasing benzene-polluted content. This can be attributing to the decrease of conductivity of the soil when the high conducting water is replaced by very low conductivity benzene. While in unsaturated benzene polluted soil exhibit different trend when adding benzene to the unsaturated polluted soil help to form more conducting channels by water phase from the large amount of water available in the unconnected channel in the pore structures of soil. This phenomenon can be used to explain the continuous decrease of resistivity of soil with increasing benzene content as a result of increasing the conductivity of soil by water.

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