IOP Conference Series: Materials Science and Engineering

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IOP Conf. Series: Materials Science and Engineering **298** (2018) 012003 doi:10.1088/1757-899X/298/1/012003

Investigation of dielectric constant variations for Malaysians soil species towards its natural background dose

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Abstract. The correlation of natural background gamma radiation and real part of the complex relative permittivity (dielectric constant) for various species Malaysian soils was investigated in this research. The sampling sites were chosen randomly according to soils groups that consist of sedentary, alluvial and miscellaneous soil which covered the area of Batu Pahat, Kluang and Johor Bahru, Johor state of Malaysia. There are 11 types of Malaysian soil species that have been studied; namely Peat, Linau-Sedu, Selangor-Kangkong, Kranji, Telemong-Akob-Local Alluvium, Holyrood-Lunas, Batu Anam-Melaka- Tavy, Harimau Tampoi, Kulai-Yong Peng, Rengam-Jerangau, and Steepland soils. In-situ exposure rates of each soil species were measured by using portable gamma survey meter and ex-situ analysis of real part of relative permittivity was performed by using DAK (Dielectric Assessment Kit assist by network analyser). Results revealed that the highest and the lowest background dose rate were 94 ±26.28 μR hr^{-1} and 7 ±0.67 μR hr^{-1} contributed by Rengam Jerangau and Peat soil species respectively. Meanwhile, dielectric constant measurement, it was performed in the range of frequency between 100 MHz to 3 GHz. The measurements of each soils species dielectric constant are in the range of 1 to 3. At the lower frequencies in the range of 100 MHz to 600 MHz, it was observed that the dielectric constant for each soil species fluctuated and inconsistent. But it remained consistent in plateau form of signal at higher frequency at range above 600 MHz. From the comparison of dielectric properties of each soil at above 600 MHz of frequency, it was found that Rengam-Jerangau soil species give the highest reading and followed by Selangor-Kangkong species. The average dielectric measurement for both Selangor-Kangkong and Rengam-Jerangau soil species are 2.34 and 2.35 respectively. Meanwhile, peat soil species exhibits the lowest dielectric measurement of 1.83. It can be clearly seen that the pattern of dielectric measurement for every soil at the frequency above 600 MHz demonstrated a specific distribution which can be classified into two main regions which are higher and lower between the ranges of 1.83 to 2.35. Pearson correlation analysis between the frequency of 100 MHz and 2.6 GHz with respect to exposure rate for every soil species was r = 0.38 and r = 0.51, respectively. This indicates that there was no strong correlation between both parameter, natural background dose and soils dielectric for each soils sample. This factor could be contributed by major and minor elements contained in each soils sample species, especially Ferum, Fe and Silica, Si.

1. Introduction

Studies of natural radioactivity from the environment have become important issues around the world. The dose of radioactive received by human population is mainly contributes by radionuclides primordial and cosmic rays, thoron, radon and their progeny through food and drinks [1]. Moreover, the radiation exposure from the natural background is mainly depending on geographical features at a certain location [2,3]. In Malaysia, granite and sedimentary residual cover, most of the lands except the coastal areas of soft clay predominate in the area [4].

Naturally, the gamma radiation were emitted from radioisotopes, such as Uranium, ^{238}U and Thorium, ^{232}Th which exist at level in all grounds formations. However, many researchers have confirmed that the radiation dose is influence by the geological features and also together with the concentration of parent radionuclide, Uranium and Thorium in the soil [3,5–7]. The decay of both parent radionuclides (U and Th) in rocks or soils will lead to the emitting of gamma radiation to the environment and its concentrations in rocks and soils could lead external irradiation to human.

One of the soil properties that needs to be considered is its dielectric properties. Soil dielectric is one of the significant parameters in soil science and its influence with natural background is unclear. Many soil dielectric study had been claimed that the moisture content of vigorously influenced the soil dielectric properties due to the presence of water [8–11]. The study of these variables was conducted at microwave frequencies and many different measurement can be used for dielectric permittivity measurement [12]. Permittivity measurement consists of real part permittivity and imaginary part of permittivity. Real part relative permittivity was the ability of material to store electromagnetic energy [13] while imaginary part was represent the loss factor and attenuation of energy in the material [14]. Meanwhile, real part relative permittivity also called dielectric constant were focussed in this study. Dielectric permittivity was also related to polarization of the material to adapt the electric field when it is applied [15–17].

Even though many studies have been conducted in the soil science area, information regarding natural radiation is still lacking. Therefore, to contribute new knowledge to this area, the current study on the effect of soil dielectric toward natural background radiation is carried out. In soil science field of study, the dielectric properties cover several parameters such as resistivity, permittivity and dielectric constant [18]. In additions, most studies on the dielectric are associated with the elemental measurement of water content in the soil. As a result, the study of soil dielectric effects in the direction of natural background radiation was very significant to expose the cause other than geological formation in the study of natural radiation.

2. Material method

2.1. Soil sampling at study area

The soil sampling was conducted in several districts in Johor, Malaysia which are Batu Pahat, Kluang and Johor Bahru. Eleven species of soil have been identified and all the soil sample was measured its gamma radiation levels at the sampling site and then several kilograms of soil are used as samples to be transported to the laboratory for the next process. Each soil species sampling site was determined its background radiation reading from the portable gamma ray survey meter. Gamma radiation measurement was taken at three point for each point in order to achieve good statistics. Each sampling location was identified based its soil group as shown in table 1. The coordinate points for each sampling location were determined using a Garmin GPSMAP model 62s to record the latitude and longitude of each location.

The best exposure rate soil samples were put into container, identified with the label species and brought into laboratory for sample preparation before analysis began. Subsequent, the soil samples were dried in oven for overnight in a temperature-controlled oven at 110℃. After that, the sample were grinded into powdered and sieved through mesh size 200 µm. From that, the clay and minerals particles can be regulated to powder size. Table 1 shows the various soil species were collected according to its coordinates based on the Soil of Map [19].

Table 1. The list of several soil species with the GPS coordinate and FAO/UNESCO Legend [20][21].

Soil Names (local name)	Soil Type [22]	Soil Group	Sampling location	GPS coordinate	FAO/UNESCO Legend
Kranji	silt	Alluvial soil	Minyak Beku, Batu Pahat	1°47'50.8"N , 102°53'50.2"E	Thionic Fluvisols
Selangor-Kangkong	silty clay	Alluvial soil	Kg. Parit Selangor, Pontian	1°29'34.0"N , 103°24'07.0"E	Vertic Cambisols-eutric Gleysols
Harimau-Tampoi	sandy clay	Alluvial soil	Kg Cahaya Masai, Pasir Gudang	1°33'24.6"N 103°54'39.4"E	Ferric Acrisols
Telemong Akob	silty clay	Alluvial soil	Sungai Machap, Machap	1°52'27.0"N 103°16'40.3"E	Dystric Fluvisols-Dystric Gleysol
Gambut (Peat)	peat	Alluvial soil	Kg Parit Nipah Laut, Batu Pahat	1°49'59.4"N 103°09'48.8"E	Thionic Fluvisols
Linau Sedu	silt	Alluvial soil	Kg Parit Jelutong, Batu Pahat	1°50'46.2"N 103°04'46.9"E	Thionic Fluvisols
Holyrood Lunas	sand	Alluvial soil	Kg Baru, Sri Gading	1°50'39.9"N 103°02'28.2"E	Xanthic Ferralsol-Dystric Gleysols
Rengam-Jerangau	sandy clay	Sedentary soil	Simpang Rengam	1°51'42.2"N 103°21'93.9"E	Dystric Nitosols-Orthic Ferralsols
Kulai-Yong Peng	sand	Sedentary soil	Gelang Patah, Nusajaya	1°25'91.7"N 103°35'35.7"E	Rhodic Nitosols-Ferric Acrisols
Batu Anam-Melaka-Tavy	silty clay	Sedentary soil	Taman Perdana, Ayer Hitam	1°55'23.1"N 103°10'38.7"E	Orthic Acrisols-Plinthic Ferralsols
Steepland	sandy clay	Highland soil	Bukit Perdana, Batu Pahat	1°50'50.1"N 102°57'38.6"E	Steepland

From table 1, it can be seen that types of soil differ according to its specific location. For example, alluvial soil can be found near the riverine area or coastal areas. However, sedentary soils can be found mostly at the idled area. Alluvial and sedentary represents the group of the soil which located nearby the riverine area or and coastal area while sedentary soil formed in the midland of the Peninsular area which consists of wide range of rocks [23]. Each soil species were classified based on FAO Legend which represent the lateral cross section layer of each soil [20][24] and the soil texture was claimed by [22].

2.2. Dielectric Measurement Setup

In this current study, the real part permittivity of every soil species was measured in the range of 100 MHz to 3 GHz EM wave using Dielectric Assessment Kit (DAK). The open-ended coaxial probe technique as a base technique is used in this system and its probe was manufactured for fast and precision purposes. Furthermore, its offers a high-dielectric measurement of complex permittivity, conductivity and also loss tangent. DAK will be interfaced with vector network analyser (VNA) to measure the scattering parameter in the open-ended probe. It was assisted to DAK as a computer system that calculate the dielectric constant of samples. DAK was also a technique measurement for dielectric suitable for liquids, solids, and semi –solids [25][26].

Prior to dielectric measurement, the sample need to be process into fine powder to and passes through a 2 mm sieve to exclude present larger particle that are less reactive [27]. The dielectric probe will be put in the corresponding container to the size of the probe to prevent from the disturbance during the measurement. Prior the measurement were conducted, this equipment will be undergoing calibration procedure that involves the measurement of air (open), a coaxial cable connection (short) and deionized water measurement needed for storing the standard material reference.

3. Discussion of results

All the discussion of the results were based on exposure rate of gamma survey meter and dielectric constant measurement for every each of soil species. All data are presented in table 2 and figure 1 - 3

3.1. Exposure rate of various soil species

The background reading was taken at four to five points for each of soil species location and the highest exposure rate was taken as a sample. A sampling location was determined by using GPS based on the Reconnaissance Soil Map released by the Department of Agriculture, Malaysia [19] and recorded in table 2 below.

Table 2. A detail of soil type, GPS coordinate and survey meter reading

Soil Types	GPS	Survey Meter Reading μR hr $^{-1}$
Kranji	1°47'50.8"N, 102°53'50.2"E	15 ± 0.58
Selangor-Kangkong	1°29'34.0"N, 103°24'07.0"E	14 ± 1.45
Harimau-Tampoi	1°33'24.6"N, 103°54'39.4"E	20 ± 2.84
Telemong Akob	1°52'27.0"N, 103°16'40.3"E	16 ± 0.57
Holyrood Lunas	1°50'39.9"N, 103°02'28.2"E	16 ± 1.20
Peat	1°49'59.4"N, 103°09'48.8"E	7 ± 0.67
Linau Sedu	1°50'46.2"N, 103°04'46.9"E	16 ± 3.12
Rengam-Jerangau	1°51'42.2"N, 103°21'93.9"E	94 ± 26.28
Kulai-Yong Peng	1°25'91.7"N, 103°35'35.7"E	16 ± 2.97
Batu Anam-Melaka-Tavy	1°55'23.1"N, 103°10'38.7"E	24 ± 3.05
Steepland	1°50'50.1"N, 102°57'38.6"E	56 ± 3.33

All the sampling location were determined at Batu Pahat, Kluang and Simpang Rengam and Johor Bahru. Roughly the range of the survey meter reading for all soil sample were in range of 7 μR hr $^{-1}$ to 94 μR hr $^{-1}$. Based on the table 2, it is clearly seen that the highest readings are 94 ± 26.28 μR hr $^{-1}$ for Rengam Jerangau soil types followed by the second highest is Steepland, 56 ± 3.33 μR hr $^{-1}$ while for the lowest readings are 7 ± 0.67 μR hr $^{-1}$ which is Peat that collected in the area of oil palm plantation at Parit Nipah Laut, Batu Pahat. Significant differences are seen between the highest reading and lowest reading around 87 μR hr $^{-1}$. In addition, there are four types of soil, Telemong Akob, Holyrood Lunas, Linau Sedu and Kulai -Yong Peng exhibit the similar reading volume of 16 μR hr $^{-1}$ but in the different sampling location. Nevertheless, the parent material that exists in every each soil species also influences the radioactivity level [20]. For example, the originality of soil that come from granite will decay higher radioactivity level compared to other family of rocks and according to Badawy [28] effective dose rate of clay soil were higher compared to sandy soils due to compositions of ^{226}Ra, ^{232}Th and ^{40}K. This results agree to peat soil that the compose from partially decay plant have a lower radioactivity [20,29]. It can be conclude that the Rengam Jerangau have contain a large scale of granite compared to other soil types.

3.2. Dielectric constant measurement for each soil species

Dielectric constant measurement are present in this subtopic were based on wide range measurement frequency 100 MHz to 3 GHz, comparison between certain frequency (100 MHz, 600 MHz and 3 GHz) and correlation between exposure rates and dielectric constant for every soil species.

3.2.1. Dielectric Constant at Wide Range of Frequency from 100 MHz to 3 GHz. The dielectric constant for every soil species were performed in this research by using vector network analyser (VNA) and assisted by DAK probe and its software for signal processing. Figure 1 shows the polynomial dielectric constant graph for each soil type in the wide range frequency from 100 MHz to 3 GHz. The dielectric constant of different soils are different due to the composition of the soil. As shown in the graph, the dielectric constant was found to be linear in between 100 MHz to 600 MHz. In the present discovery, there is good agreement with [30] which discussing ground state at low frequency is the occurrence of frequency distortion due to oriental polarizations. These mechanisms were referred to the positive and negative ion were aligned to the electric field applied to the material. After entering the 600 MHz value, the results produced by all soil types are in the relaxation process. This stated that the dipole moment in the particle were completely aligned the direction of the applied electric field and its dominant frequency by the ionic conduction in that frequency range [31]. The graph depict that the results generated by this tool have resulted in two different areas at the top (2.2-2.5) and the bottom (1.6-2.1). At 3 GHz, the above group consists of Steepland, Kranji, Rengam Jerangau, Harimau Tampoi Selangor Kangkong, while the other are Peat, Linau Sedu, Telemong Akob, Holyrood Lunas and Batu Anam Melaka Tavy. In addition, the below area was produced when the value entered 600 MHz frequency readings. Finally, from 600 MHz to 3 GHz it can be clearly seen that the range of dielectric constant was stable.

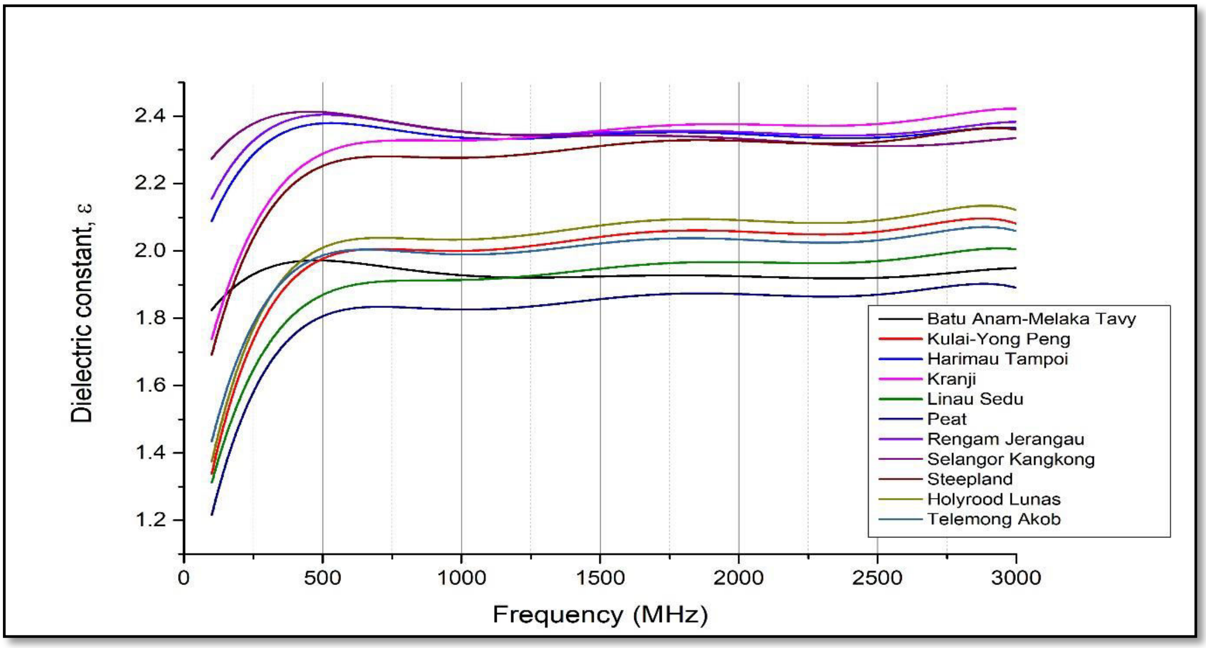


Figure 1. The wide range frequency of the dielectric constant for every soil species.

3.2.2. The comparison the value of dielectric constant at frequency 100 MHz, 600 MHz and 3 GHz. In this section, the comparison value of dielectric constant of each soil at frequency of 100 MHz, 600 MHz and 3 GHz will be discussed as follow. These three frequencies are emphasized because they show importance in this study, where the 100 MHz frequency is a low initial setting and the situation was strong in relation to polarization of particles caused by positive and negative ions in soils. While the results start to show stability at 600 MHz until 3 GHz. At 3 GHz, was the highest frequency value produced by VNA and roughly the results of all three are different. At 100 MHz, the dielectric constant of the type of Selangor Kangkong land of 2.50 was highest. The lowest was Kulai-Yong Peng, 0.99. Next, to the 600 MHz frequency, the results for each land showed that Harimau Tampoi explained that it was the highest reading value of 2.33 and the lowest was Peat 1.79. At the highest frequency value of 3 GHz, it appears an oddity occurs where the Kranji soil type dielectric constant was the highest at 2.44. The questioned was that the exposure rate for Kranji is the lowest in table 1 and it have a high value of dielectric constant at frequency 3 GHz. For Peat soil, the results for all three frequency values were the lowest. This also influence by the factor that affecting in soil dielectric constant measurement which is the soil composition in the soil beside moisture content [32]. It specifies the soil compositions in the soil contain a diversity of elements such as iron, calcium and etc. That could influence the measurement of dielectric constant [33][34]

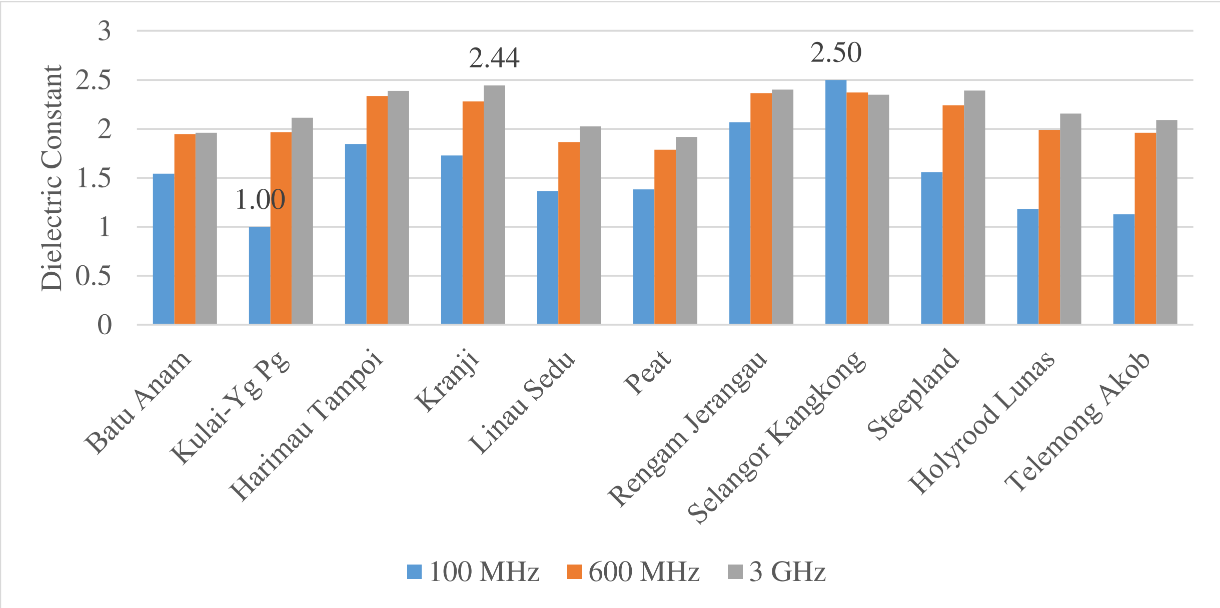
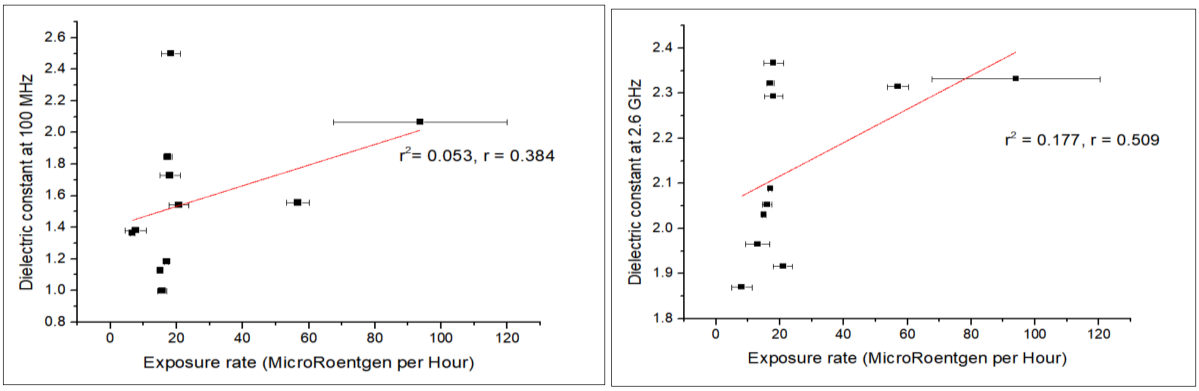


Figure 2. The dielectric constant comparison between 100 MHz, 600 MHz and 3 GHz for every soil species

3.2.3 The correlation between natural background radiation and dielectric constant of various soil species. The effects natural background radiation and dielectric constant were analysed through linear correlations and obtained results are presented in figure 3 (a-b). The linear correlation shows a statistical result of either the association between the two variables by yielding in the -1 to 1 [35]. Figure 3a, displays the correlation natural background radiation and the dielectric constant at 100 MHz are weak when observed from the correlation results, $r = 0.38$. Although for 2.6 GHz frequency (Fig. 3b), the correlation results are moderate, $r = 0.51$. From a statistical point of view, the relationship between the two variables is very weak because strong correlation must have a value greater than 0.8 [35]. This obtain that the occurrence of anomalies between radiation levels and dielectric constant of soil cannot be assume that the high level exposure rate also have a high value dielectric constant. Moreover, there were many factors that can influence the measurement of dielectric constant such as temperature ,samples, humidity and size of sample [36] .



(a) (b)

Figure 3 (a-b). Correlation analysis between dielectric constant and gamma exposure rate for frequency 100 MHz and 2.6 GHz

4. Conclusion

Study on the correlation between the natural background radiation and dielectric constant for various species of soil was conducted.

- The highest dose readings recorded was soil series Rengam Jerangau, 94 ± 26.28 µR hr^{-1} and lowest was Peat 7 ± 0.67 µR hr^{-1}.
- Good dielectric constant reading does not affect exposure dose rate readings for each soil. For example, the Rengam Jerangau soil series that has high exposure dose rate readings but the reading value of the dielectric constant is the opposite.
- The results of correlation between value dielectric constant and gamma exposure rate was not solid enough to prove it if they have correlations because of some other factor such as moisture content, soil compositions and temperature also influence the dielectric constant measurement.

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Acknowledgments
This paper was funded by the Centre for Graduate Studies, University Tun Hussein Onn Malaysia. The authors also acknowledge for the Research centre of Applied Electromagnetic (EMCenter, UTHM) for assistance with DAK for dielectric constant measurement and Research centre for Soft Soil (RECESS, UTHM) for soil work process