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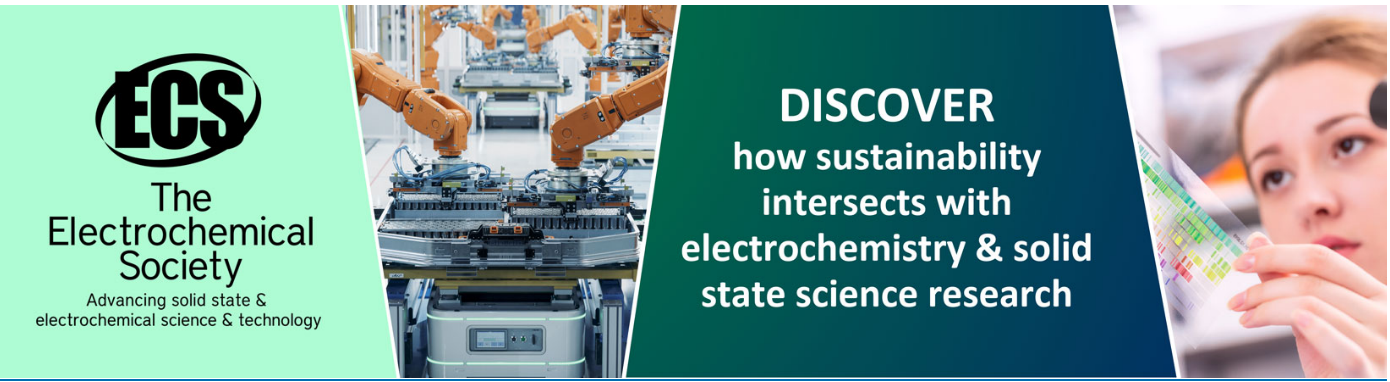

Assessment of background radiation in some parts of Canaanland Ogun state, southwestern Nigeria using integrated geophysical techniques

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Abstract. Radioactivity in soil occurs naturally due to the presence of ^{238}U, ^{232}Th and ^{40}K. Undue exposure of humans to these radiations can result in some serious health problems. There is need to have adequate information on the level of radiation that is available around us in order to take adequate measures for protection. Electrical resistivity and radiometric methods were used in this study. The results by the radiometric method revealed the activity concentrations of U, Th and K to vary from 12.658 Bq kg^{-1} - 42.299 Bq kg^{-1}, 44.9645 Bq kg^{-1} - 128.702 Bq kg^{-1} and 31.3Bq kg^{-1} - 453.85 Bq kg^{-1}, respectively. The result of the electrical resistivity method varied between 75 and 2025 Ωm. Finally, it was observed that region of high resistivity was prone to higher level of radiation, which could be as a result of some radioactive geological features in the subsurface.

Keywords: Radioactivity, exposure, resistivity, geological features

1. Introduction

Our environment is constantly dominated with naturally occurring radionuclides to which man is regularly exposed. This is because these radioactive substances are present in soil and air around us [1]. Most prominent among these radionuclides are 238U (226Ra), 232Th and 40K which can pose serious hazard to man if their presence around us is more than the world recommended standard [2-4]. Although, naturally occurring radionuclides have natural origin, but their concentrations can be influenced by the activities of man. Such activities may include industrial processes such as cement production, coal mining, oil and gas exploration, fertilizer production (phosphate) and fertilizer application and so on [5-6].

Radiation has some useful applications in different areas including agriculture, medicine, mining, geology, archaeology, biology, etc. But there is a minimum permissible level of this radiation that man should be exposed to. The intensity of radiation depends on the amount of naturally occurring radioactive minerals (NORM) present in the soil and the time of exposure [7-8]. Food crops grown on the soil with high level of radionuclide content can pose serious health hazard such as the destruction of the gene pool [9-10]. Long term exposure can cause radiation sicknesses such as diarrhea, fever, nausea, vomiting, dizziness and disorientation, hair loss, blood stools, fatigue, infections, poor wound healing, low blood pressure.

Since these radionuclides originate in nature, it implies that there is no place in the world that is totally free from the influence of radioactive materials. Therefore, it is important to assess the level of radiation that people are exposed to from time to time so as to ascertain that the level of these radionuclide concentration is not beyond the world recommended safe limit.

2. Geology of the Study Area

The area of study is in the Eastern part of Dahomey Basin (Fig. 1), extending from the Volta Delta (Southeastern Ghana) to the Western flank of the Niger Delta in Nigeria [11]. The basin is separated from the Niger Delta in the Eastern section by the Benin Hinge Line and Okitipupa Ridge and marks the continental extension of the chain fracture zone [12-13]. The stratigraphy of the basin consists of six formations which comprises of Abeokuta, Ewekoro, Akinbo, Oshosun, Ilaro and Benin Formations. The Abeokuta Formation is Cretaceous. The Abeokuta formation is mainly made up of large grained sand that spreads over the whole basin. It also contains mudstones, siltstones and shale-clay with slim limestone beds formed due to marine transgression [14-15]. It is poorly sorted with a sequence of continental grits and pebbly sands. Overlying the Abeokuta formation is the Ewekoro formation. It is predominantly comprised of shallow marine limestone as a result of the contamination of the marine transgression. The Ewekoro limestone is Palacocene in age. Overlying the Ewekoro Formation is the Akinbo formation. It is dominated by shale and it is of Late Palaeocene to Early Eocene. The Akinbo Formation is overlain by the Oshosun Formation. It is composed of Eocene shale. The Oshosun formation is overlain by the Ilaro formation. It is predominantly a sequence of coarse sandy estuarine, deltaic, and continental beds. The Ilaro Formation displays rapid lateral facies changes. Overlying the Ilaro Formation is the Benin Formation. It is predominantly composed of coastal plain sands and tertiary alluvium deposits [16]. Canaanland, the site of the study is in Ogun state, southwestern Nigeria. This site is the seat of Faith Tabernacle, the world acclaimed largest church auditorium in the world, where over 400,000 people worship every Sunday.

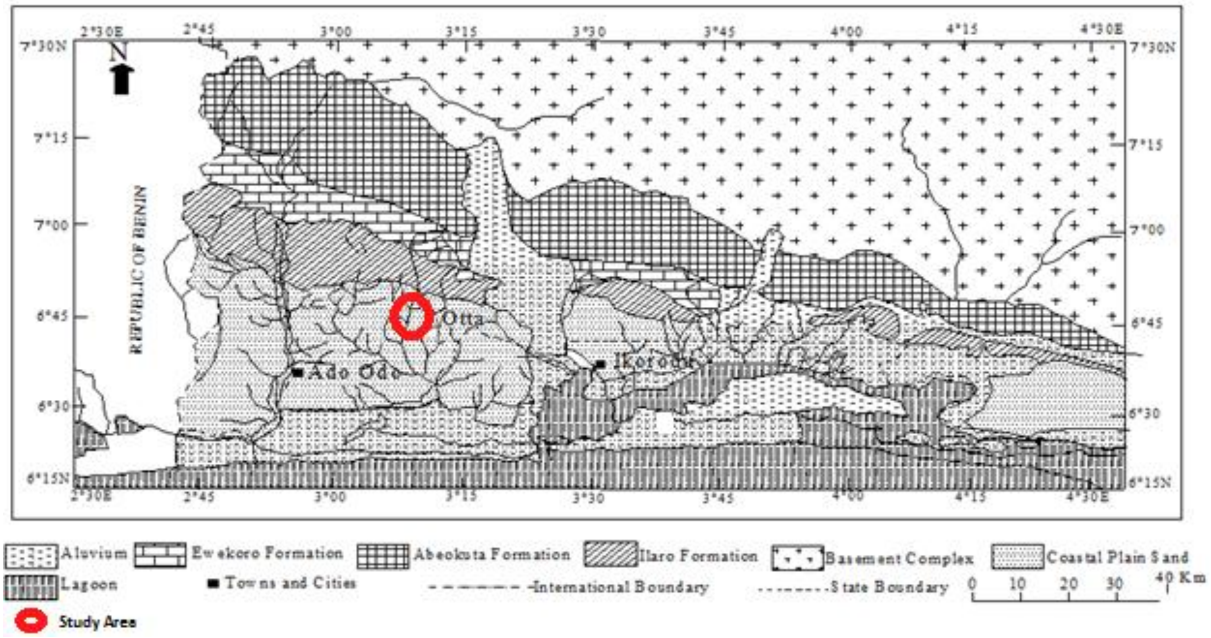

Figure 1. Geological Map of the Study Area

3. Materials and Methods

In this study, electrical resistivity was integrated with radiometric method. The resistivity method was used to determine both vertical and lateral variation in the resistivity of the study area. For this study, an ABEM Terrameter 1000/4000 (SAS) was engaged. Wenner electrode configuration was used. The length of each profile was 100 m and an electrode spacing of 5 m was used. The measurement was conducted by arranging the four electrodes such that the two outer electrodes are for injecting current into the subsurface while the two internal electrodes are required to estimate the potential difference. The value of the resistance is measured from the application of ohms law [17-18]. In order to determine the resistivity, the value of the resistance is multiplied with the geometric factor of this electrode arrangement. The four electrodes move laterally along the profile, maintaining constant distance, from one end to the other. Similarly, radiometric method was used in this study to determine the background radiation of the study area. A hand held gamma spectrometry was used in this study. This equipment detect gamma rays emitted from the earth. The gamma rays are estimated by counting the number of times each gamma ray of particular energy intersects the spectrometer. In this survey the radionuclides detected were 238U, 232Th and 40K present in the soil. The background radiation measurement was carried out along the same profile along which the resistivity measurement was done (Figure 2).

The electrical resistivity data collected were formatted in a manner that could be fed into DIPRO software in order to produce a 2-D image of the area surveyed. Information on the local geology and hand dug well available at the time of survey was of great assistance in interpreting the 2-D images [17] [19]. In a similar manner, the data obtained from gamma spectrometry were used to calculate some important radiological parameters required to achieve the aim of this study.

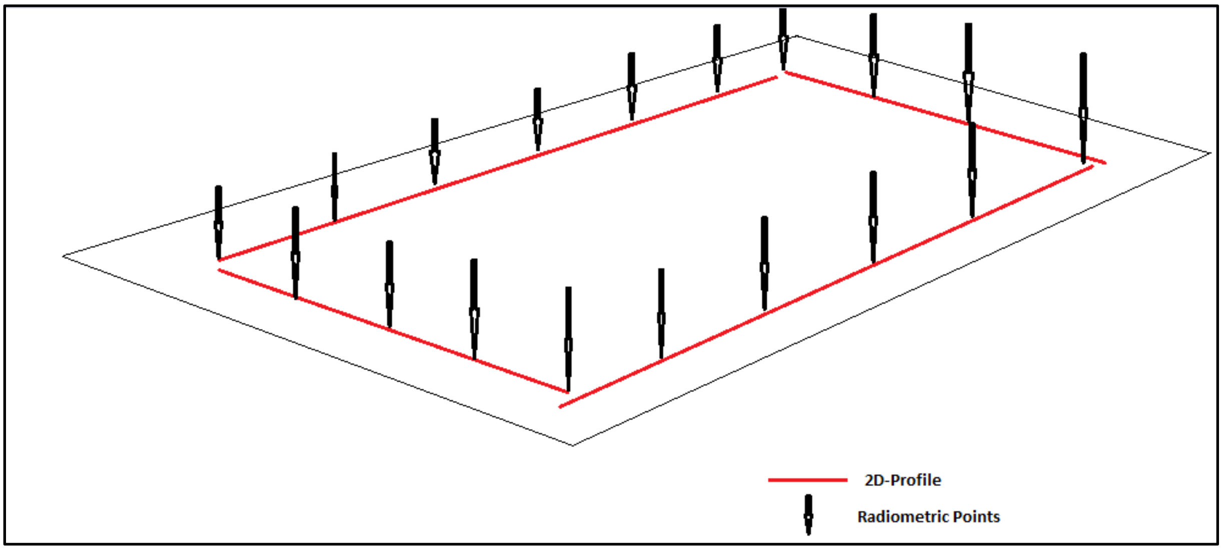

Figure 2. Base map of the study area

4. Results and Discussion

4.1. Radioactivity Concentrations

The detected naturally occurring radionuclides (226Ra, 232Th and 40K) of 14 locations within the study site are presented in Table 1. The activity concentrations ranged between 14.52 and 35.82, 44.96 and 128.70 and 31.30 and 453.85 Bq kg^{-1} in Radium, Thorium and Potassium respectively. It was also observed that the variations between the minimum and maximum values were reported between locations 1 and 6 for ^{226}Ra, locations 1 and 13 for ^{232}Th and between locations 2, 5, 8 and 13 for ^{40}K. The rampant re-occurrence of locations 1 and 13 could be as a result of the underlying geological features in which Uranium and Potassium are more dominant.

4.2. Radium Equivalent Activity (Raeq)

The radium equivalent activity represents a weighted sum of activities of ^{238}U, ^{232}Th and ^{40}K. It is based on the fact that 370 Bq kg^{-1} of ^{238}U, 259 Bq kg^{-1} of ^{232}Th, and 4810 Bqkg^{-1} of ^{40}K produce the same gamma radiation dose rate. This is calculated by using equation (1) [20][3].

$$\text{Raeq (Bgkg}^{-1}\text{)} = C_U + 1.43C_{Th} + 0.077C_K \tag{1}$$

4.3. External Absorbed Dose Rate (D)

This is the estimation of the amount of radiation energy absorbed or deposited per unit mass of substance [10]. The absorbed gamma dose rates due to gamma radiations in air at 1 m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) were calculated using equation (2).

$$D(nGyh^{-1}) = 0.462C_U + 0.604C_{Th} + 0.041C_K \tag{2}$$

The results obtained as shown in Table 1 revealed that the variation in the estimated values varied between locations 1 and 13, with location 1 having the lowest value. The results ranged between 40.52 and 115.35 nGy h^{-1}. The very high value noticed in location 13 could be as a result of some embedded geological features which are more pronounced in location 13.

4.4. Annual Effective Dose (AED)

The annual effective dose rate (AEDR) in mSvy^{-1} resulting from the absorbed dose values (D) was calculated using equation (3) [21-22].

$$EDE\ (mSvy^{-1}) = D(nGyh^{-1}) \times O_c \times F_c \times 8760 \times 10^{-6} \tag{3}$$

From the table of results, it could be seen that the minimum value of 0.049 mSv y^{-1} was noticed in location 1, while the highest value of 0.142 mSv y^{-1} was observed in location 13.

4.5. External Hazard Index (Hex)

The external hazard index (Hex) can then be estimated using equation (4)

$$H_{ex} = \frac{C_U}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \tag{4}$$

This index must be less than unity (1) for the radiation hazard to be considered insignificant. In all the readings, the external hazard index was far less than 1, therefore, external hazard index may be regarded as non-significant in the area of study.

Table 1: Shows the estimated radiological parameters from the study area

S/N	^{226}Ra Bg kg^{-1}	^{232}Th Bq kg^{-1}	^{40}K Bq kg^{-1}	Ra_{eq} Bq kg^{-1}	D(out) nGy h^{-1}	AED (mSv y^{-1})	H_{ex}
1	14.51	44.96	93.90	86.04	40.02	0.049	0.232
2	21.00	46.89	31.30	90.46	41.36	0.051	0.244
3	27.79	55.83	86.08	114.25	52.54	0.064	0.309
4	28.41	55.32	70.43	112.93	51.79	0.064	0.305
5	23.47	58.87	31.30	110.06	50.34	0.062	0.297
6	35.82	58.36	54.78	123.49	56.30	0.069	0.334
7	19.74	86.58	242.58	162.23	76.22	0.094	0.438
8	21.00	45.37	31.30	88.29	40.35	0.050	0.238
9	22.54	50.85	39.13	98.27	44.98	0.055	0.265
10	17.60	53.19	101.68	101.48	47.12	0.058	0.274

11	12.66	73.49	211.23	134.01	63.19	0.078	0.362
12	21.30	104.65	406.75	202.27	95.94	0.118	0.546
13	24.70	128.70	453.85	243.69	115.35	0.142	0.658
14	23.77	50.34	273.88	116.85	55.31	0.068	0.316

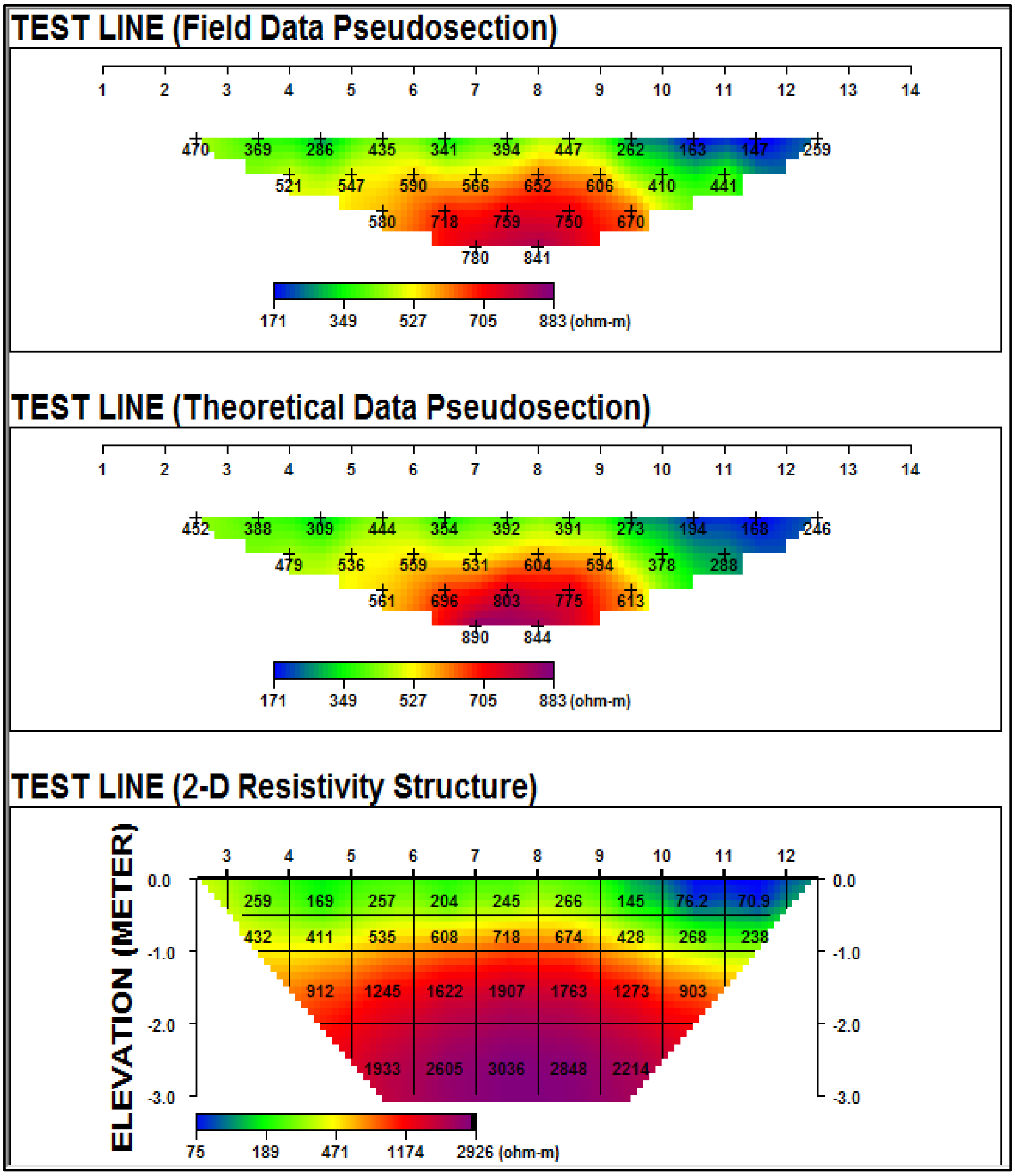

Figure 3: 2-D resistivity image of the surveyed profile in the area of study

Within the depth of investigation, two distinct layers were delineated by the electrical resistivity method. The first layer or the top soil is composed of sandy clay, this is characterized by an unconsolidated material of low resistivity ranging between 75 and 432 Ωm. The thickness of the top soil is about 1.5 m in the area of study. The second layer is characterized by a geologic formation of relatively high resistivity ranging between 903 and 2926 Ωm. This layer is described as a sandy mud stone, as observed in Figure 3. The variation in the resistivity within this lithological unit could be as a result of the age of deposition or the level of compaction of the unit [23]. The thickness of the second layer could be above 1.5 m captured by the 2-D image due to the depth of investigation.

It could be seen from the above that the variation in the activity concentration measured in this study, especially at location 13, could be the influence of highly resistive geologic formation that dominated the second geologic layer in the study area. There are no obvious activities carried out in the study area that could trigger undue increase in the background radiation in the area of study.

5. Conclusion

Integration of electrical resistivity and radiometric methods were employed to assess the background radiation of some parts of Canaanland and also to delineate the geological features that are contributing to this radiation. The results by the radiometric method revealed the activity concentrations of U, Th and K to vary from 12.658 Bq kg^{-1} - 42.299 Bq kg^{-1}, 44.9645 Bq kg^{-1} - 128.702 Bq kg^{-1} and 31.3Bq kg^{-1} - 453.85 Bq kg^{-1}, respectively. The results of the Radium equivalent activity varied between 86.04 and 243.69 Bq kg^{-1}. Furthermore, the result of the external absorbed dose rate varied between 40.02 and 115.35 nGy h^{-1}. However, the result of the electrical resistivity method varied between 75 and 1025 Ωm. Finally, it was observed that region of high resistivity was prone to higher level of radiation, which could be as a result of some radioactive geological features in the subsurface.

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