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Ground radiometric survey for assessment of environmental radioactivity in a fertilized farmland: a case history in southwestern Nigeria

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Abstract. Soils in their natural state contain radionuclides and heavy metals at different concentrations which may be increased by the use of fertilizers. When the concentrations of radionuclides and in soils are higher in value than the recommended limits, this may pose health concern. In this study, absorbed dose rate was measured in-situ at thirty-five station points in the farmland using a caesium Iodide-based GammaRAE II R full range dosimeter held at gonald height above the surface.Results of the in-situ absorbed dose rate in air are presented and the potential risks to the farmers and near-by residents are equally assessed.The results revealed that the measured absorbed dose rate (ADRA) in the farm is high which is likely to be connected to the use of fertilizer in the farmland. It is highly recommended that the management of the farm should reduce the use of fertilizer but rather use natural organic manure that is less toxic. Also, a routine check on environmental radioactivity of the farmland should be done regularly for adequate monitoring.

Keywords: *Environmental radioactivity, Agriculture, Fertilized farmland, Radiometric survey*

1. Introduction

All organisms on earth are permanently exposed to ionizing radiation (emitted by radionuclides) coming from natural and artificial sources. Radionuclides are contained in human apartments where we live, air that we breathe, the water use for domestic and industrial purposes, in the earth subsurface and also in the outer space. New experimental procedure in radiobiology using the mechanisms of cells concluded the low dose rate of an ionizing radiation is capable of stimulating the human defence mechanism [1-2].

Radiobiological experiments with cells and cell mechanisms seem to conclude that ionizing radiation in small amounts and with a low dose rate stimulate humans defence mechanisms [1-2]. When ionizing radiation passes through matter they impact the material (or system or compound) with their energy through direct and indirect effects of radiation.The extent of damage done in this process depends largely on both the amount of energy involved and the quantity of the material through which they impacted. The level of this radiation damage goes up with respect to the amount of their energy

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involved, but reduced with increase in the quantity of the materials [3-5]. Natural radionuclides is not the same for different places as it depends on the doses from external gamma radiation [6-12].

Many investigations have been carried out by researchers on the presence of radionuclides in fertilizers and on the implications of fertilizer usage on the environment. [13]used gamma ray spectrometric method to measure level of^{226}Ra, ^{232}Th and ^{40}K radionuclides in different kinds of fertilizers in Nigeria and reported that ^{40}K, was exceptionally high across all the brands. [14] considered several types of fertilizers used in Saudi Arabia and employed sodium iodide detector to measure the ^{40}K, ^{226}Ra and ^{232}Th radionuclides activity concentration in them. The result showed that the highest value of ^{40}K (4227.2Bq/kg), ^{226}Ra (120.7Bq/kg) and ^{232}Th (56.81Bq/kg) were found in chemical fertilizers and lowest values of ^{40}K (115.2Bq/kg), ^{226}Ra (21.00Bq/kg) and ^{232}Th (3.2Bq/kg) in organic fertilizers [15].It is known from the works of [14 – 17] that application of fertilizer in soils used for growing forages is one of the ways of contaminating the soil with radionuclides.

2. Methodology

2.1 Study Area

The area of study is a farmland situated within the latitude 07^0 08.627'N - 07^0 08.949'N and longitude 003^{0}10.214'E - 003^0 10.893'EinAbeokuta North local government area (LGA) of Ogun state, southwestern Nigeria (Figure 1).The area is found in a sub-humid tropical region within Southwest Nigeria. The average annual precipitation of Abeokuta is 1,270 mm and its temperature is about 28 degree Celsius.The average yearly evaporation within this area is about 1,100 mm. The city is drained mainly by River Ogunin a generaldendriticpattern. Abeokuta covers a geographical area of 1,256 square kilometre.Figure 2 shows that the area lies geologically within the Eastern section of the Dahomeybasin with east-westward trend sediments deposition and six lithostratigraphic units comprising Benin, Ilaro, Oshosun, Akinbo, Ewekoro and Abeokuta Formations from youngest to the oldest geological formation. Abeokuta Formation denoted as Cretaceous has been classified as a Group divided into Araromi, Afowo and Ise Formations. Abeokuta Formation is of sequence of poorly sorted grits and pebbly sands with intercallations of siltstones, mudstones and shaly clay. Ewekoro Formation is known to be a Paleocene shallow marine deposit of non-crystalline and non-fossiliferous limestone strata. Akinbo shale units is of late Paleocene to Early Eocene overlaid by Eocene Shale of Oshosun Formation. Coarse sequence of estuarine, deltaic and continental sandy unit of Ilaro Formation overlie Oshosun Formation. Benin Formation is the youngest overlying the Ilaro Formation.

2.2 Ground Radiometric Survey

A high performance gamma radiation detector GammaRAE II R full range dosimeter was used for data acquisition because it intrinsically excludes the contribution from cosmic radiation in its operation works. Ambient dose equivalent rate from radionuclides at the thirty-five station points within the farmland was measured randomly and the coordinates of each sampling point were taken with a GPS (Global Positioning System) (Table 1). The dosimeter was turned on by pressing and hold the MODE button for about 3 seconds. The GammaRae II R was initially put on search mode for background calibration reading countdown for about 36 seconds after which the continuous data logging mechanism is enabled. Throughout the survey, the dosimeter was made to operate in normal mode where it detects gamma radiation and accumulates radiation dosage data. The GammaRae II R dosimeter was mounted on a tripod stand about 1 metre above each station point before measurements were taking. This particular gamma radiation detector was chosen for this research because is intrinsically safe and possesses highly sensitive scintillator sensors to detect low-level radiation according to Otwoma et al [19]. Also, this dosimeter can operate for six hundred hours on 2AA batteries and can rely on internal re-chargeable batteries that is manufactured waterproof to IP-67 standards.

Figure. 1: Map showing the farmland within the Abeokuta.

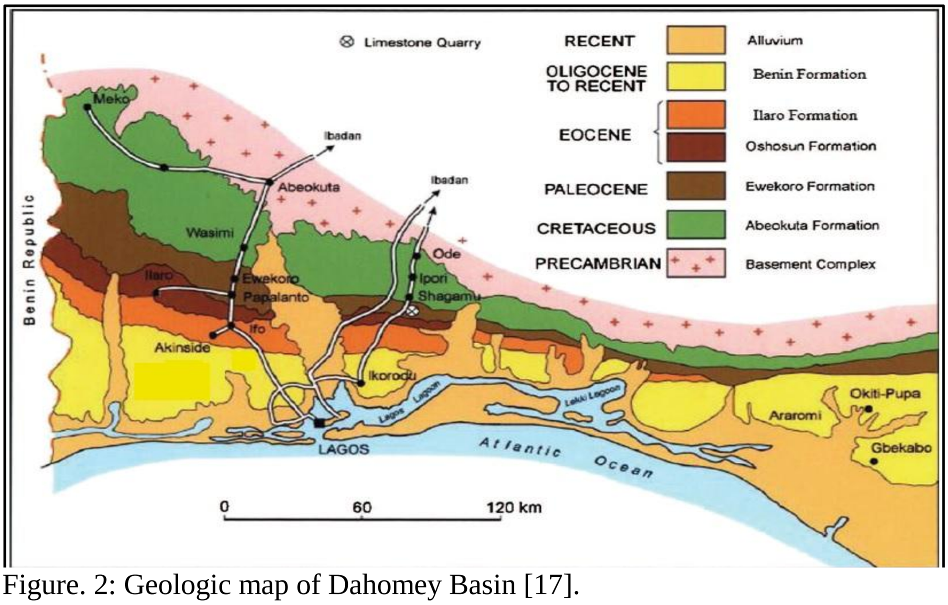

Figure. 2: Geologic map of Dahomey Basin [17].

3. Results and Discussion

The results of the in-situ measurement of mean absorbed dose rate in air (ADRA) at the sampling points in the farmland studied alongside the corresponding annual effective dose equivalent (AEDE) estimated using equation (1) are presented in form of charts (Figure 3). The chart shows the in-situ mean absorbed dose rate in air (ADRA) to be 72.24 nGy/h (0.05 μSv/h) while the range is from 42.86

Figure 3: Charts showing the measured absorbed dose rate (ADRA) in nGy/h and µSv/h, and estimated annual effective dose rate (AEDE) (mSv/y) in the farmland

Table 1: The station points and their geographical coordinates

StationPoint	*Latitude*	*Longitude*
L1	N 070 08.627’	E 003010.433’
L2	N 070 08.708’	E 003010.454’
L3	N 070 08.733’	E 003010.414’
L4	N 070 08.723’	E 003010.416’
L5	N 070 08.711’	E 003010.422’
L6	N 070 08.736’	E 003010.400’
L7	N 070 08.732’	E0030 10.390’
L8	N 070 08.725’	E0030 10.393
L9	N 070 08.721’	E0030 10.382’
L10	N 070 08.732’	E0030 10.399’
L11	N 070 08.917’	E0030 10.269’
L12	N 070 08.929’	E0030 10.277’
L13	N 070 08.914’	E0030 10.290’
L14	N070 08.898’	E0030 10.295’
L15	N070 08.905’	E0030 10.214’
L16	N070 08.884’	E0030 10.269’
L17	N070 08.899’	E0030 10.302’
L18	N070 08.876’	E 0030 10.293’
L19	N070 08.872’	E0030 10.291’
L20	N070 08.870’	E0030 10.294’
L21	N070 08.871’	E0030 10.284’
L22	N070 08.892’	E0030 10.284’
L23	N070 08.876’	E0030 10.270’
L24	N070 08.887’	E0030 10.276’
L25	N070 08.888’	E0030 10.279’
L26	N070 08.849’	E0030 9.854’
L27	N070 08.935’	E0030 9.862’
L28	N070 08.942’	E0030 09.876’
L29	N070 08.946’	E0030 9.886’
L30	N070 08.949’	E0030 9.893’
L31	N070 08.937’	E0030 9.848’
L32	N070 08.931’	E0030 9.844’
L33	N070 08.942’	E0030 9.842
L34	N070 08.953’	E0030 9.840’
L35	N070 08.927’	E0030 9.827’

nGy/h (0.03 μSv/h) to 100 nGy/h (0.07 μSv/h). The calculated in-situ mean AEDE is 0.19 mSv/y with range 0.11 – 0.26 mSv/y. Some values of the ADRA in many station points in the farm and the mean in-situ ADRA value were discovered to be more than the weighted mean dose rate of 59 nGy/h as given by the United State Scientific Committee on the effects of Atomic radiations (UNSCEAR) [20]. These high ADRA values are likely connected to the use of fertilizers in the farmland. However, the AEDE values are observed to be lessthanInternational Commission on Radiological Protection (ICRP) publication[21]threshold dose limit for members of public which is 1 mSv/y.

$$AEDE\,(mSv) = ADRA \times DCF \times OOF \times T \qquad (1)$$

Where ADRA is the in-situ measured absorbed dose rate in air and DCF is the dose conversion factor, which is $0.7SvGy^{-1}$ $x10^{-6}$, the outdoor Occupancy factor (OOF) is 0.42 and T is the time factor (8766 hours) according to UNSCEAR [20].

4. Conclusions

The study has examined the in-situ absorbed dose rate in air and annual effective dose equivalent in thirty-five station points in a farmland in part of Abeokuta, Nigeria. The results revealed that the measured mean absorbed dose rate are well above the UNSCEAR threshold limit whereas the annual effective dose equivalent values are lower than the ICRP standard limit for members of the public. It is recommended that the management of the farm should use more of organic manure that is less environmentally toxic. Also, a routine check on environmental radioactivity of the farmland should be done regularly for adequate monitoring. It is also recommended that soil samples from the farmland should be collected and the investigation of natural radioactivity due to the radionuclide concentration in them should be carried out. This is important so as to ascertain whether the source of the high absorbed dose rate is the fertilizers that are being used in the farm.

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