

**GAMMA DOSE RATE, ANNUAL EFFECTIVE DOSE AND COLLECTIVE  
EFFECTIVE DOSE OF FOOD  
CROP PRODUCING REGION OF ONDO STATE, NIGERIA**

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**ABSTRACT:** *The activity concentrations of natural gamma-emitting radionuclides  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in soils from 7 sampling sites in Ondo State, southwestern Nigeria have been measured by using a well calibrated high resolution gamma ray spectrometer. The mean activity concentration values of  $39.24 \pm 1.12$ ,  $52.86 \pm 1.40$  and  $445.02 \pm 12.24$  Bq kg<sup>-1</sup> for  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  respectively were obtained for the State. Absorbed dose rates in outdoor air were calculated to be in the range of  $12.35 \pm 0.65$  and  $179.59 \pm 4.1$  nGy h<sup>-1</sup> with an overall mean value of  $67.50 \pm 1.86$  nGy h<sup>-1</sup>. The corresponding outdoor annual effective dose rates were estimated to be between 22.7 and 330.6  $\mu\text{Sv y}^{-1}$  for the area assuming 30% occupancy factors. The average outdoor annual effective dose rate for most of the towns is  $64882.95 \mu\text{Sv y}^{-1}$  representing 92.65% of the world average value ( $70000 \mu\text{Sv y}^{-1}$ ) given by UNSCEAR. The value of the collective effective dose as calculated from the outdoor annual effective dose rates was found to be 540858 person-Sv.*

**KEYWORDS:** Dose, Gamma, Radionuclide, Radiation, Outdoor

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## **INTRODUCTION**

Ecological risk assessment of natural radiation is evolving and has become an objective of several organizations (including the international atomic energy association) (ICRP1991), the reason being the possible exposure to ionizing radiation arising from naturally occurring radionuclide such as  $^{40}\text{K}$ ,  $^{232}\text{Th}$  and  $^{238}\text{U}$ . These radionuclides contribute over 20% of the average annual dose to man from all radiation sources. Naturally occurring radioactive materials are present in air, food water and rocks as well as the ground from which man settlements are built (Anne 1994). Natural radioactivity is composed of the cosmogenic and primordial radionuclide. Cosmogenic radionuclide, such as  $^3\text{H}$ ,  $^7\text{Be}$ ,  $^{14}\text{C}$  and  $^{22}\text{Na}$  are produced by the interaction of cosmic ray particle (mainly high-energetic proton) in the earth's atmosphere. Primordial radionuclide (also called terrestrial background radiation) is formed by the process of nucleosynthesis in stars.

Radionuclide in man's environment are also derived from various artificial sources which include nuclear and non-nuclear industries and environmental matrix such as air, soil, food, water, vegetation and sediments. In some cases however, radionuclides may be derived

from sources such as nuclear power generation, fallout from nuclear explosions and medical sources (Ebong et al. 1992). In most cases, they find their way into the environment via accidents, transport, routine releases, incorrect disposal and misuse.

The passage of radiation through solid liquid and gas has the same general effect in the sense that it causes ionization. Ionization of the molecules of living cells constitutes biological hazard and must certainly occur when  $\alpha, \beta, \gamma$ , or x-rays pass through living tissue. All living cells consist of an active nucleus surrounded by a fluid called the cytoplasm and within the nucleus are found the chromosomes which carry all the hereditary factors. When penetrating radiations pass through cells it is reasonable to suppose that ionization takes place just as it does in an inanimate liquid.

The consequences of the ionization of protein molecules are not fully on the molecular scale. They are, however, well known in so far as they affect the health of the whole body. The normal chemical action of various proteins is often totally destroyed, and even the whole cell can be destroyed. Some cells have the biological property of self-repair whereas others are irreparably damaged (Ebong et al.1992). Chromosomes are especially sensitive to ionizing radiations at the moment of cell division and the gene arrangement in the chromosomes can be seriously modified. The normal gene mutation rate can be increased by extra doses of ionizing radiations, so producing abnormalities in the succeeding generation. The biological effects of ionizing radiations can be superficial, affecting skin and hair or deep within the body including blood disorders, tumours and damage to the bone marrow (Ebong et al .1992).

## **MATERIALS AND METHOD**

Soil samples were collected from Oba, Ugbe, Ogbagi, Owo, Ikare, Ogbese and Irun (Ondo State, Nigeria) at depth of 6-10 cm. The area represents where most of the food crops are produced in the state. The samples were processed according to the recommended procedure by the International Atomic Energy Agency (IAEA). The samples were first sun-dried for 12 hours, then oven-dried at 110<sup>0</sup>C to constant weight. The soil samples were pulverized using mole grinding machine and sieved using 2 mm mesh screen to obtain fine texture. The sieved soil samples were packed in 250 g lots into clean airtight cellophane bags. The packaged soil samples were kept for about 4 weeks to allow for secular equilibrium between parent radionuclides and their respective progenies before gamma analysis was carried out.

Gamma spectrometry measurements were carried out with coaxial-type high purity germanium (HpGe) detector with relative efficiency of 50% and having a resolution of 2.4 keV at 1.33 MeV of <sup>60</sup>Co. The detector was properly shielded in lead castles. The detector was calibrated using certified reference standard samples for various radionuclides. Spectra analyses were performed with the Genie2k spectrometry software, version 2.1 (Camberra

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Industries Inc.). Each sample was counted for 86,400 seconds to achieve minimum counting error. Specific activity of each radionuclide in the soil samples was determined. The absorbed dose rates in air at about 1m (average gonadal height) above the ground was calculated from the specific activity concentration of the radionuclides using the method of Beck et al. (1972) as

$$D = 0.042S_K + 0.429S_U + 0.666S_{Th} \quad (1)$$

where  $D$  is the absorbed dose rate in air ( $\text{nGy h}^{-1}$ ), and

$S_K, S_U, S_{Th}$  are the soil specific activity concentrations ( $\text{Bq kg}^{-1}$ ) of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  respectively taking  $^{214}\text{Bi}$  and  $^{208}\text{Tl}$  as indicators for  $^{238}\text{U}$  and  $^{232}\text{Th}$  respectively.

The annual outdoor effective dose equivalent was estimated using outdoor occupancy factor of 0.3 and conversion factor of  $0.7 \text{ Sv Gy}^{-1}$  (UNCEAR, 2000) in the following relation

$$E(\chi) = D(\gamma) \times N(h) \times O_f \times K_f \quad (2)$$

where  $E(\chi)$  is annual outdoor effective dose ( $\mu\text{Sv y}^{-1}$ ),

$D(\gamma)$  is the absorbed dose rate in air ( $\text{nGy h}^{-1}$ ),

$N(h)$  is number of hours in a year ( $24 \times 365.25$ ),

$O_f$  is the outdoor occupancy factor and

$K_f$  is the conversion factor ( $\text{Sv Gy}^{-1}$ ).

The collective effective dose equivalent was estimated using the following expression (ICRP, 1991).

$$S_E = \sum_i N_i H_{Ei} \quad (3)$$

where  $S_E$  is the collective effective dose equivalent (person-Sv),

$N_i$  is the number of individuals exposed to radiation (Africa Atlases, 2002) and

$H_{Ei}$  is the mean outdoor effective dose equivalent ( $\mu\text{Sv y}^{-1}$ )

**RESULTS AND DISCUSSION**Table 1a: Radionuclide concentration (Bq kg<sup>-1</sup>)

Location	<sup>40</sup> K	<sup>137</sup> Cs	<sup>208</sup> Tl	<sup>210</sup> Pb	<sup>212</sup> Bi	<sup>212</sup> Pb	<sup>214</sup> Bi	<sup>214</sup> Pb
Oba	1358.60± 28.54	3.95 ±0.87	150.76 ±3.19	140.92±10. 97	520.11± 19.37	465.34± 10.66	86.86 ±2.29	94.10±3.3 4
Ugbe	292.49 ±11.13	1.18 ±0.58	50.46 ±1.56	36/16± 10.86	184.87± 11.1	170.73± 8.36	ND	39.81±
Ogbagi	449.46 ±13.22	0.32 ±0.15	27.20 ±0.87	13.58± 12.91	98.22±6.41	91.60 ±4.54	22.92± 0.85	25.97±1.4 8
Owo	102.33 ±4.18	0.33 ±0.16	5.35± 0.34	ND	18.44±3.52	19.35± 0.75	8.63± 0.48	9.11±0.61
Ikare	323.76± 9.57	1.48 ±0.26	91.05± 2.14	8.57±11.79	302.80± 13.94	327.43± 6.74	96.21 ±2.05	112.45± 2.79
Ogbese	282.22± 9.91	0.28 ±0.33	17.87± 0.83	49.89±15.3 6	56.33±6.59	68.79 ±2.08	33.39 ±1.22	37.25±1.6 6
Irun	306.30 ±9.16	0.29 ±0.31	27.34 ±0.84	37.65±3.82	98.28±6.22	90.57± 2.02	26.66 ±0.94	29.48±0.8 8
Average	445.02 ±12.24	1.12 ±0.38	52.86 ± 1.40	40.9 ± 9.39	182.72±9.6 8	176.26±5.0 2	39.24±1.1 2	42.6±1.72

Table 1b: Radionuclide concentration (Bq kg<sup>-1</sup>)

Location	<sup>224</sup> Ra	<sup>226</sup> Ra	<sup>228</sup> Ac	<sup>228</sup> Th	<sup>234m</sup> Pa	<sup>234</sup> Th	<sup>235</sup> U
Oba	402.51± 18.45	198.05±1 3.79	429.93±1 2.10	598.12±4 0.26	111.66±5 8.82	141.11± 6.76	12.15± 0.83
Ugbe	ND	9.18±11.7 3	146.84±6. 44	ND	ND	92.33±6. 09	4.86±0. 72
Ogbagi	ND	57.86±6.8 6	73.74±3.3 5	131.56±1 3.08	ND	33.41±3. 60	3.55±0. 42
Owo	ND	12.09±3.3 5	ND	160.59±1 4.14	ND	20.53±1. 87	0.74±0. 21
Ikare	ND	71.76±25. 76	253.61±6. 67	92.35±7.0 5	117.05±4 1.10	206.10± 9.27	7.97±1. 39
Ogbese	ND	85.34±8.9 5	47.57±2.0 9	ND	ND	40.76±3. 32	5.24±0 54
Irun	69.23±5. 28	76.35±63. 77	77.52±23. 16	12.48±9.6 7	ND	50.26±2. 65	46.85± 0.39
Average	67.39±3.3 9	82.95- ±19.17	147.04±7. 69	142.16±1 2.03	32.67±14. 27	83.5±4.7 9	11.62± 0.4

ND: below detectable limit

Table 2: Absorbed Gamma Dose rates (nGy h<sup>-1</sup>)

Location	Contribution of <sup>40</sup> K	Contribution of ( <sup>232</sup> Th)	Contribution of ( <sup>238</sup> U)	Absorbed Gamma dose rates
Oba	57.06 ±1.20	64.68 ±1.37	57.85 ±1.53	179.59±4.1
Ugbe	12.29 ±0.47	21.65 ±0.67	ND	33.94±1.14
Ogbagi	18.88 ±0.56	11.67 ±0.37	15.27± 0.57	45.82±1.5
Owo	4.30 ±0.18	2.30 ±0.15	5.75 ±0.32	12.35±0.65
Ikare	13.60± 0.40	39.06 ±0.92	64.08 ±1.37	116.74±2.69
Ogbese	11.85± 0.41	7.67 ±0.38	22.24 ±0.81	41.76±1.58
Irun	12.87± 0.39	11.7±3 0.36	17.76± 0.63	42.36±1.38
Total	130.85±3.61	158.76±4.2	182.95±5.23	472.56 ±13.04

Table 3: Outdoor Annual Effective Dose (μSv y<sup>-1</sup>)

Location	Absorbed dose nGy h <sup>-1</sup>	Outdoor Annual Effective dose μSv y <sup>-1</sup>
Oba	179.53	330600.04
Ugbe	33.94	62478.79
Ogbagi	45.82	84348.21
Owo	12.35	22734.62
Ikare	116.74	214902.00
Ogbese	41.76	76874.31
Irun	42.36	77978.83

Table 4: Collective Effective Dose (person-Sv)

State	Average Effective dose μSv y <sup>-1</sup>	Population Person	Collective Effective dose person-Sv
Ondo	124273.83	4352150	540858

In estimating the health risk associated with exposure to radiation from radioactivity in the soil, it is necessary to convert the activity concentration shown in Tables 1a and 1b to absorbed gamma dose rates in air at 1m above the ground surface. This was calculated from concentrations of nuclides of <sup>232</sup>Th and <sup>238</sup>U series, and of <sup>40</sup>K using the relation given by Beck et al. (1972) as shown in equation 1. The result is shown in Table 2, with the values ranging from 12.35±0.65 in Owo to 179.59±4.1 nGy h<sup>-1</sup> in Oba (average of 67.51±.86 nGy h<sup>-1</sup>). The relative contribution to dose due to <sup>238</sup>U is 38.7%, followed by

contribution due to  $^{232}\text{Th}$  and  $^{40}\text{K}$  (33.6% and 27.7% respectively). However, these values are comparable. In order to make a rough estimate of the annual effective dose outdoor, there is need to take into account the conversion coefficient from absorbed dose in air to effective dose and the outdoor occupancy factor. In the UNCEAR recent reports (1993, 2000) as shown in equation 2, the committee used  $0.7\text{SvGy}^{-1}$  for the conversion coefficient from absorbed dose and 0.3 for the outdoor occupancy factor for rural area (meaning that an average person stays about 7 hours outside daily). Table 3 gives the effective dose assessment for the study area (rural area).

The average annual outdoor effective dose for towns with the exception of Oba and Ikare is  $64882.95\mu\text{Sv y}^{-1}$  representing 92.6% of the world value ( $70000\mu\text{Sv y}^{-1}$ ) given by UNCEAR (2000) and 66.1% of Nigeria value ( $98000\mu\text{Sv y}^{-1}$ ) given by Jibiri (1998). The overall average effective dose of all the towns (Oba and Ikare inclusive) is  $124273.83\mu\text{Sv y}^{-1}$ . This high value is as a result of the high dose rate obtained for rocky towns like Oba and Ikare. The value is almost three times the value estimated for the cities in Lagos state in a similar work (Ojo, 2010). Hence, the result shows the effect of rock and duration of exposure to dose in air by an individual.

The collective effective dose equivalent to a population, which is a measure of the collective detrimental effects and the percentage of people at risk of incurring radiation-induced diseases, was estimated in this work using the expression in equation 3 as given by ICRP 1991. This quantity was estimated for each of the sampled area using population figure of 4352150 (Africa Atlases, 2002). The result is represented in Table 4. The value obtained is 540858 person-Sv . The result shows that about 12.4% of the population of the area are at risk of incurring radiation-induced diseases.

## CONCLUSION

The result shows that there is usually a high value of dose rate associated with rocky area as reported by other research work. In addition, more than 10% of the entire population of the area under study have the possibility of incurring radiation induced ailments.

## REFERENCES

- Africa Atlases. Nigeria. Paris: Les Editions ; 2002: 84.
- Anne A (1994) Radium and your Drinking water. (A Home owner's guide). U. Environmental Protection Agency. 5-6
- Beck. H. L., De Campo, J. A., and Gogolak, C. V. (1972). "In situ Ge(Li) and NaI (TI) Gamma-Ray Spectrometry", Report HASL-258 U. S. Atomic Energy Commission, New York.
- Ebong. A and Algoa K. D. (1992). Estimate of gamma rays background exposure at a fertilizer plant. *Discovery and innovation*: Vol 4, page 4 – 10.

IAEA (1991). International Atomic Energy Agency, measurement of radionuclides in food and the Environment. A Guidebook on Technical Report series No 295 (IAEA, Vienna).

ICRP (1991). “International Commission on Radiological Protection” 1990 recommendations of the International Commission on Radiological Protection. New York: *Elsivier*; ICRP Publication 60, Ann. ICRP 21(1-3)

Fasasi, M. K., Tchokossa, P., Ojo, J. O., and Balogun F. A. (1999). “Occurrence of natural radionuclides and fallout Cesium-137 in dry-season agricultural land of South Western Nigeria”. *Journal of Radioanalytical and Nuclear Chemistry* 24(1) 94-95.

UNCEAR, 2000. Sources and Effects of Ionizing Radiation. Report to General Assembly, with Scientific Annexes, United Nations, New York.