Gamma Dose Rate, Annual Effective dose and Collective Effective dose of Food Crops Producing region of Ondo State, Nigeria

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Abstract

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

Keyword: radionuclide, radiation, gamma, dose, exposure

1. Introduction

Ecological risk assessment of natural radiation is gaining importance and is being objectively studied by several organizations, including the international atomic energy association [1], the reason being the possible exposure to ionizing radiation arising from naturally occurring radionuclide such as ^{40}K, ^{232}Th and ^{238}U. These radionuclides contribute over 20%, from all radiation sources, of the average annual dose to humans.

Naturally occurring radioactive materials are present in air, food water, rocks and the ground on which human settlements are built [2]. Natural radioactivity is composed of the cosmogenic and primordial radionuclide. Cosmogenic radionuclide, such as ^{3}H,^{7}Be,^{14}C and ^{22}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) are formed by the process of nude synthesis 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 [3]. In most cases, they are released into the environment via accidents, transport, routine releases, incorrect disposal and misuse.

The passage of radiation through solid liquid and gas, causes ionization, having the same general effect. Ionization of the molecules of living cells constitutes biological hazard and occur when α,β,γ, 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, carrying all the hereditary factors. When penetrating radiations pass through cells it is presupposed 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 [3].

Chromosomes are especially sensitive to ionizing radiations at the phase of cell division and the gene arrangement in the chromosomes. The normal gene mutation rate can be increased by extra doses of ionizing radiations, thereby producing abnormalities in the subsequent generations. The biological effects of ionizing radiations when superficial affect skin and hair, while deep within the body produces blood disorders, tumours and damage to the bone marrow [3].

2. Materials and Method

Soil samples were collected from the predominantly food growing areas of Oba, Ugbe, Ogbagi, Owo, Ikare, Ogbese and Irun (Ondo State, Nigeria) at depth of 6-10 cm. The samples were processed according to the recommended procedure [4]. The samples were first sun-dried for 12 hours, then oven-dried at $110^{0}C$ to a constant weight. The soil samples were pulverized using mole grind-

ing 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 60 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 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 [5] as

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

where D is the absorbed dose rate in air (nGy h^{-1}), and S_K, S_U, S_{Th} are the soil specific activity concentrations (Bq kg^{-1}) of ^{40}K, ^{238}U and ^{232}Te respectively taking ^{214}Bi and ^{208}Tl as indicators for ^{238}U and ^{232}Th respectively.

The annual atmospheric effective dose equivalent was estimated using outdoor occupancy factor of 0.3 and conversion factor of 0.7 Sv Gy^{-1} [9] in the following relation

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

where, is annual outdoor effective dose (mSv y^{-1}),

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

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

O_f is the outdoor occupancy factor and

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

The collective effective dose equivalent was estimated using the following expression [1].

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

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

N_i is the number of individuals exposed to radiation [6] and

H_{Ei} is the mean outdoor effective dose equivalent (mSv y^{-1})

3. Results and Discussion

Table 1. (*a). Radionuclide concentration (Bq kg^{-1})*

Location	^{40}K	^{137}Cs	^{208}Tl	^{210}Pb	^{212}Bi	^{212}Pb	^{214}Bi	^{214}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±3.34
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±1.48
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±15.36	56.33±6.59	68.79 ±2.08	33.39 ±1.22	37.25±1.66
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±0.88
Average	445.02 ±12.24	1.12 ±0.38	52.86 ± 1.40	40.9 ± 9.39	182.72±9.68	176.26±5.02	39.24±1.12	42.6±1.72

Table 1.(b) *Radionuclide concentration (Bq kg^{-1})*

Location	^{224}Ra	^{226}Ra	^{228}Ac	^{228}TH	^{234M} Pa	^{234}Th	^{235}U
Oba	402.51± 18.45	198.05±13.79	429.93±12.10	598.12±40.26	111.66±58.82	141.11±6.76	12.15±0.83
Ugbe	ND	9.18±11.73	146.84±6.44	ND	ND	92.33±6.09	4.86±0.72
Ogbagi	ND	57.86±6.86	73.74±3.35	131.56±13.08	ND	33.41±3.60	3.55±0.42
Owo	ND	12.09±3.35	ND	160.59±14.14	ND	20.53±1.87	0.74±0.21
Ikare	ND	71.76±25.76	253.61±6.67	92.35±7.05	117.05±41.10	206.10±9.27	7.97±1.39
Ogbese	ND	85.34±8.95	47.57±2.09	ND	ND	40.76±3.32	5.24±054
Irun	69.23±5.28	76.35±63.77	77.52±23.16	12.48±9.67	ND	50.26±2.65	46.85±0.39
Average	67.39±3.39	82.95±19.17	147.04±7.69	142.16±12.03	32.67±14.27	83.5±4.79	11.62±0.4

ND: below detectable limit

Table 2. *Absorbed Gamma Dose rates (nGy h^{-1})*

Location	Contribution of ^{40}K	Contribution of (^{232}Th)	Contribution of (^{238}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^{-1})*

Location	Absorbed dose nGy h^{-1}	Outdoor Annual Effective dose μSv y^{-1}
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^{-1}	Population Person	Collective Effective dose person-Sv
Ondo	124273.83	4352150	540858

In estimating the heath 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 ^{232}Th and ^{238}U series, and of ^{40}K using the relation [5] as shown in equation 1. The result is shown in Table 2, with the values ranging from12.35±0.65 in Owo to 179.59±4.1 nGy h^{-1} in Oba (average of 67.51±.86 nGy h^{-1}). The relative contribution to dose due to ^{238}U is 38.7%, followed by contribution due to ^{232}Th and ^{40}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 (2000) as shown in equation 2, the committee used 0.7 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 64882.95mSv y^{-1} representing

92.6% of the world value is 70000mSv y^{-1} [9] and 66.1% of Nigeria value is 98000mSv y^{-1} [7]. The overall average effective dose of all the towns (Oba and Ikare inclusive) is 124273.83mSv 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 [8]. 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 [1]. This quantity was estimated for each of the sampled area using population figure of 4352150 [6]. 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.

4. 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 have the possibility of incurring radiation induced ailments.

5. References

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