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INDOOR AND OUTDOOR AMBIENT RADIATION LEVELS IN KEFFI, NIGERIA

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Abstract. *This research paper investigates and presents the ambient radiation levels (in mSv/yr) in Keffi, Nigeria. A halogen-quenched GM detector (Inspector Alert Nuclear Radiation Monitor SN: 3544) was used for the purpose of the study. Some areas were found to have a relatively higher indoor dose, while others had a higher outdoor dose equivalent rate ranging from 0.81 to 1.27mSv/yr and 0.21 to 0.28mSv/yr for the outdoor and the indoor radiation levels respectively. The mean outdoor and indoor radiation levels were found to be 0.25 and 1.08mSv/yr respectively, and are in good approximation with the internationally approved annual dose limits for members of the public (1mSv/yr). The outdoor and indoor ratio was computed to be 23.1%.*

Key words: *equivalent dose rate, radon, indoor, outdoor*

INTRODUCTION

Man is by the very nature of his environment exposed to varying amounts of ambient radiation with or without his consent. The ambient radiation encompasses both the natural and artificial radioactivity in his environment (Farai and Vincent; 2006). One of the radionuclides around man's environment that contributes high amounts of potentially lethal dose is radon; which causes the majority of deaths resulting from lung cancer (Maria et al; 2010).

Figures in the ICRP (November, 2009) statement imply that the risk of death from exposure to radon at work and at home could be greater than the one observed for travelling by car and the estimated risk of lung cancer from exposure to radon could be greater than the observed risk of lung cancer from all the remaining causes. Does this include smoking? The statement did not differentiate between a smoker and a non-smoker (Don, 2010). Maria et al (2010) reported that smoking does not serve as a measure confounder in accounting for lung cancer risk in German Uranium Miners.

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COSMOGENIC RADIONUCLIDE

The interactions of cosmic-ray particles in the atmosphere produce a number of radionuclides, including 3H, 7Be, 14C, and 22Na. These and other radioactive nuclides have half-lives greater than 1 day. Essentially all nuclear species lighter than the target nuclei (primarily nitrogen, oxygen and argon) are produced by high-energy spallation interactions. Production is greatest in the upper stratosphere, but some energetic cosmic-ray neutrons and protons survive in the lower atmosphere, producing cosmogenic radionuclides there as well. Production is not only altitude- but also latitude-dependent and varies as well with the 11-year solar cycle that modulates cosmic-ray penetration through the earth's magnetic field. NCRP (2000) assessed the annual effective doses from cosmogenic radionuclides to be 12μSv from 14C, 0.15μSv from 22Na, and 0.01μSv from 3H.

TERRESTRIAL RADIATION

Naturally occurring radionuclides of terrestrial origin (also called primordial radionuclides) are present in various degrees in all media in the environment, including the human body itself. Only those radionuclides with half-lives comparable to the age of the earth, and their decay byproducts exist in significant quantities in these materials. Irradiation of the human body from external sources is mainly by gamma radiation from radionuclides in the 238U and 232Th series and from 40K. These radionuclides are also present in the body and irradiate the various organs with alpha and beta particles, as well as gamma rays. Some other terrestrial radionuclides, including those of the 235Useries, 87Rb, 138La, 147Sm, and 176Lu, exist in nature but at such low levels that their contributions to the dose in humans are small.

EXTERNAL EXPOSURES

External exposures arise from terrestrial radionuclides present at trace levels in all soils. The specific levels are related to the types of rock from which the soils originate. Higher radiation levels are associated with igneous rocks, such as granite, and lower levels with sedimentary rocks. There are exceptions, however, as some shells and phosphate rocks have a relatively high content of radionuclides. There have been many surveys to determine the background levels of radionuclides in soils, which can in turn be related to the absorbed rates in the air. The latter can easily be measured directly, and these results provide an even more extensive evaluation of the background exposure levels in different countries. All of these spectrometric measurements indicate that the three components of the external radiation field, namely from the gamma-emitting radionuclides in the 238U and 232Th series and 40K, make approximately equal contributions to the externally incident gamma radiation dose to individuals in typical situations both outdoors and indoors. The radionuclides in the uranium and thorium decay chains cannot be assumed to be in a radioactive equilibrium. Isotopes 238U and 234U are in approximate equilibrium, as they are separated by two much shorter-lived nuclides, 234Th and 234Pa. The decay process itself may, however, allow some dissociation of the decay radionuclide from the source material, facilitating subsequent environmental transfer. Thus, 234U may be somewhat deficient relative to 238U in soils and enhanced in rivers and the sea. The 226Ra radionuclide in this chain may have slightly different concentrations than the 238U, because separation may occur between its parent 230Th and uranium and because radium has greater mobility in the environment. The decay products of 226Ra include the gaseous element radon, which diffuses out of the soil, reducing the exposure rate from the 238U series. The radon radionuclide in this series, 222Rn, has a half-life of only a few days, but it has two longer-lived decay products, 210Pb and 210Po, which are important in dose evaluations. For the 232Th series, similar considerations apply. The radionuclide 228Ra has a sufficiently long half-life that may allow some separation from its parent, 232Th. The gaseous element of the chain, 220Rn, has a very short half-life and no long-lived decay byproducts (NCRP, 2000).

INTERNAL EXPOSURES OTHER THAN RADON

Internal exposures arise from the intake of terrestrial radionuclides by inhalation and ingestion. Doses that are inhaled result from the presence of dust particles containing radionuclides of the 238Uand232Th decay chains in air. The dominant component of inhalation exposure is the short-lived decay byproducts of radon. Doses that are ingested are mainly due to 40K and to the 238U and 232Th series radionuclides present in food and drinking water. The dose rate of 40K can be determined directly and accurately from external measurements of its concentration in the body. The analysis of the content of uranium- and thorium-series radionuclides in the body requires more difficult chemical analyses of tissues, and fewer data are available. The analysis of the radionuclide content of food and water, along with bioassay data and knowledge of the metabolic behaviour of the radionuclides, provides an alternative basis for dose estimation. The samples are more readily obtained, and they can reflect widely different locations. With these data, dose estimates for children as well as adults can be derived.

Natural sources of radiation include; extraterrestrial cosmic radiation (consisting of 87% proton, 12% α-particles and 1% heavier nuclei) (Ghoshal, 2007) and terrestrial radiation form primordial elements in the earth. In the same vein, building materials in use today contain various concentrations of naturally occurring radionuclides which decay to yield radon as one of their progenies. These building materials contribute to the indoor ambient radiation level. Exposure to ionizing radiation pose a high health risk and this risk may include cancer induction, radiation catractogenesis, indirect chromosomal transformation because of the health risk, the practice being to keep one's exposure to ionizing radiation as low as reasonably possible, known as the ALARA principle (Norman, 2008).

DEFINITION OF TERMS AND LITERATURE REVIEW

Radiation doses depend on the intensity and energy of radiation, exposure time, the area exposed and the depth of energy deposition. Quantities, such as the absorbed dose, the effective dose and the equivalent dose have been introduced to specify the dose received and the biological effectiveness of that dose (Akpa, 2010).

The absorbed dose (D): specifies the amount of radiation absorbed per unit mass of material. The S.I unit of absorbed dose is gray. And $1Gy = 1Jkg^{-1}$. In Dosimetry, it is important to define the absorbed dose rate; it is the rate at which an absorbed dose is received. The units are GyS^{-1}, $mGyhr^{-1}$, etc. It is important to mention that the biological effects depend not only on the total dose the tissue is exposed to, but also on the rate at which the dose was received.

The equivalent Dose (H): The absorbed dose does not give an accurate indication of the harm that radiation can do. Equal absorbed doses do not necessarily have the same biological effects. An absorbed dose of 0.1Gy of alpha radiation is more harmful than an absorbed dose of 0.1Gy of beta or gamma radiation. To reflect the damage done in biological systems from different types of radiation, the equivalent dose is used. It is defined in terms of the absorbed dose weighted by a factor which depends on the type of radiation. The S.I unit is Sievert (Sv).

Farai and Vincent (2006) measured the outdoor radiation level in Abeokuta, Nigeria using Thermoluminescent Dosimetry and reported that the human equivalent dose due to outdoor exposure in the city ranges between 0.19 to 1.64 mSv/yr with a mean of 0.45 mSv/yr and the mean dose of extraterrestrial radiation estimated to be 0.18mSv/yr in the city.

A nationwide survey conducted by Farai and Jibri (2000) of terrestrial radiation using the technique of in-situ gamma spectrometry reported that the annual mean effective dose equivalent is 0.27mSv/yr. Another nationwide study on the assessment of natural radioactivity in Taiwan by Yu-ming et al (1996) reported that the adult effective dose in Taiwan is 1.56mSv, which is safe.

Keffi is a local government Area in Nasarawa State, Niger. It has an area of $138km^2$ and a population of about 92,664 according to 2006 census. The geographical coordinate of Keffi is $9^0 29'0''N$, $8^0 53'0''E$ (www.maplandia.com/Nigeria/keffi-abo-google-earth.html). It houses the prominent Maloney Hill which, today, is one of the sources of granite rocks used for building and construction around the state.

MATERIALS AND METHODS

The indoor and outdoor radiation levels of 24 areas in Keffi town were inspected using a halogen-quenched GM detector (U.S made Inspector Alert Nuclear Radiation monitor SN: 35440). Six hundred data were collected for each (indoor and outdoor) measurements around these areas. For outdoor measurement, open fields like football pitches, parks, farms and gardens were used, whereas houses, churches and mosques were used in indoor inspection. The monitor was held one meter (1m) above the terrestrial level throughout the study. Readings were also taken at the excavation and processing sites of Maloney Hill for comparisons. The equivalent dose reading (in μSv/hr) is what we measure in all the areas investigated in this study.

THEORY AND CALCULATIONS

UNSCEAR, 1988 recommended indoor and outdoor occupancy factors of 0.8 and 0.2 respectively. This occupancy factor (OF) is the proportion of the total time during which an individual is exposed to a radiation field. Eight thousand seven hundred and sixty hours per year (8760hr/yr) were used.

To convert the dose rate in μSv/hr into an equivalent dose rate in mSv/yr, the equations below were used:

Indoor: (X)μSv/hr multiplied by 8760hr/yr multiplied by 0.8 =IAEDR (mSv/yr) (1.0)

Outdoor: (Y)μSv/hr multiplied by 8760hr/yr multiplied by 0.2 =O AEDR (mSv/yr) (2.0)

Where X and Y are the meter's readings indoor and outdoor respectively.

RESULTS AND DISCUSSION

Table 1. Table of Readings

Area code	Name of area	Mean X(μSv/hr)	Mean Y(μSv/hr)	IAEDR (mSv/yr)	OAEDR (mSv/yr)
A1	G.S.S Yalwa	0.149±0.02	0.135±0.02	1.40±0.14	0.24±0.04
A2	Angwan Tofa	0.154±0.03	0.148±0.03	1.08±0.20	0.26±0.06
A3	Tudun wada	0.142±0.04	0.144±0.02	0.99±0.28	0.25±0.05
A4	Gangaren Tudu	0.147±0.02	0.134±0.02	1.03±0.14	0.21±0.04
A5	Yaran Maji	0.160±0.02	0.142±0.03	1.12±0.14	0.25±0.05
A6	Yaran Zana	0.142±0.02	0.132±0.02	0.99±0.14	0.23±0.04
A7	Sabon Kasuwa	0.145±0.02	0.134±0.02	0.89±0.14	0.21±0.04
A8	Makwalla	0.156±0.01	0.132±0.02	1.09±0.07	0.26±0.04
A9	Sabon Gareji	0.147±0.02	0.135±0.02	1.03±0.14	0.24±0.04
A10	Kofan Goriya	0.149±0.02	0.130±0.02	1.05±0.07	0.23±0.04
A11	Tudun Amama	0.147±0.02	0.128±0.02	1.03±0.14	0.22±0.04
A12	Angwan Kwara	0.128±0.04	0.134±0.02	0.89±0.28	0.21±0.04
A13	G.R.A	0.152±0.01	0.143±0.03	1.07±0.07	0.25±0.04
A14	Kadarako	0.181±0.03	0.126±0.02	1.27±0.21	0.22±0.04
A15	Pada	0.141±0.02	0.134±0.02	0.99±0.14	0.21±0.04
A16	Angwan Nufawa	0.143±0.01	0.127±0.02	1.00±0.07	0.22±0.04
A17	Gangaren Tudu	0.140±0.02	0.138±0.02	0.98±0.14	0.24±0.04
A18	Kofan Pada	0.142±0.02	0.135±0.02	0.99±0.14	0.24±0.04
A19	Tsohon Kasuwa	0.161±0.03	0.160±0.03	1.13±0.21	0.28±0.05
A20	Angwan Kwara	0.139±0.02	0.140±0.02	0.97±0.14	0.25±0.04
A21	Karofi	0.144±0.01	0.144±0.02	1.01±0.14	0.25±0.05
A22	Makera	0.156±0.03	0.160±0.03	1.09±0.21	0.28±0.04
A23	Gagaren Aboki	0.133±0.02	0.134±0.02	0.81±0.14	0.21±0.04
A24	Kauran Sarki	0.163±0.02	0.140±0.02	1.14±0.14	0.25±0.04
			Average	1.08±0.15	0.25±0.04

IAEDR is the indoor annual effective dose rate and **OAEDR** is the outdoor annual effective dose rate.

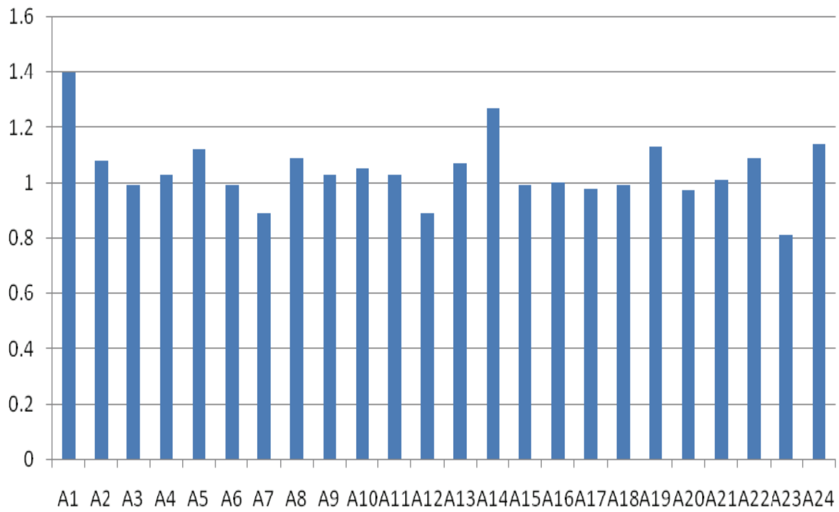

Fig.1. A plot of indoor annual equivalent dose rate for each area.

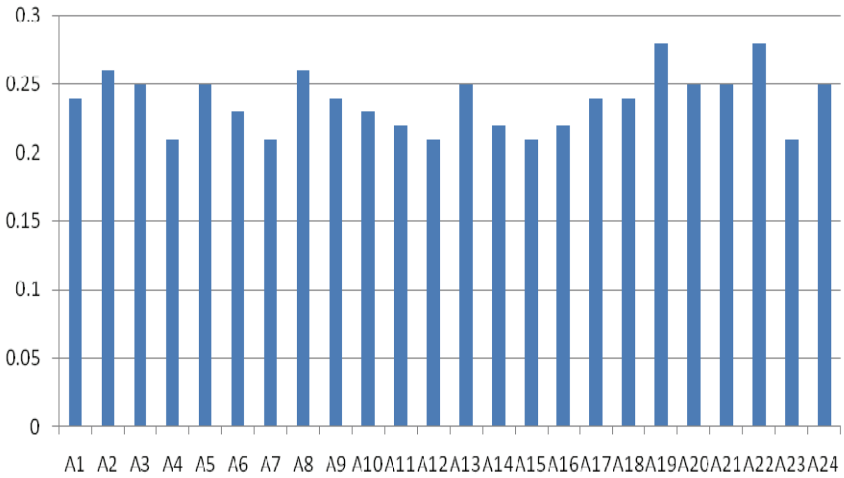

Fig. 2. A plot of outdoor annual equivalent dose rate for each area.

DISCUSSION

Table 1 presents the meter mean readings and the annual equivalent dose readings (obtained by using equations (1) and (2) of both indoor and outdoor measurements.

The mean indoor and outdoor annual equivalent dose rates were computed as 1.08±0.15 and 0.25±0.04mSv/yr respectively. Fig.1 shows that A1 (G.S.S Yalwa) and A14 (Kadarko) and A24 (Kauran Sarki) have higher indoor radiation dose rates in that order. Since an Assembly Hall and Mosques were used during the inspection, the building materials (granite in tiles), the altitude and the geology (which was not the primary focus of the study) of these areas might be contributing factors to the radiation level in these areas. In Kadarko, houses are closely built without organized building plans. In addition, there are no access roads for delivery trucks into theses area. Both Kadarko and Kauran sarki are closer to Maloneys Hill and are on the same level of geographical terrain.

A23 (Gangaren Aboki) has the lowest indoor radiation level of 0.81±0.14mSv/yr. This area is relatively far in distance from Maloney Hill, and is located at alower altitude (if compared to A1, A14 and A24), houses in this area are not closely built like in A14 (kadarKo).

Fig.2 shows that A19 (Tsohon Kasuwa) and A22 (Makera) have teh highest outdoor radiation. These two areas are closer to Maloney Hill, in comparison to A4 (Gangaren Tudu), A7 (Sabon Kasuwa) and A12 (Angwan Kwara) which have the least outdoor radiation levels.

CONCLUSION

Measurements at both the excavation and processing points in Maloney Hill in the Keffi town quarry show a mean Annual equivalent dose rate of 0.29±0.04 and 0.35±0.05mSv/yr respectively. And these are quite beyond our annual mean equivalent dose rate for both indoor and outdoor measurements in Keffi. This is in agreement with the data of Agba et al. (2006) and confirms that higher radiation levels are associated with igneous rocks such as granite (NCRP, 2000).

The average equivalent dose rates for both indoor and outdoor radiation exposure in Keffi have been measured using a halogen-quenched GM detector. These results provide the essential baseline information for the assessment of any environmental radioactive contamination of the area in foreseeable future.

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NIVOI RADIJACIJE U ZATVORENOM I NA OTVORENON PROSTORU U MESTU KEFFI, NIGERIJA

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Ovo istraživanje ima za cilj da predstavi nivoe radijacije u okruženju (mSv/yr) u mestu Keffi, Nigerija. GM halogeni detektor (Inspector Alert Nuclear Radiation Monitor SN: 3544) je korišćen u ovom istraživanju. U nekim delovima su utvrđeni relativno visoke vrednosti u zatvorenim prostorima, dok sun a drugim mestima doze bili u rasponu od 0.81 do 1.27mSv/yr i od 0.21 do 0.28mSv/yr za nivo radijacije na otvorenom i u zatvorenom prostoru, tim redosledom. Srednja vrednost nivoa radijacije u zatvorenom prostoru i na otvorenom bila je 0.25 i 1.08mSv/yr tim redosledom, što je u skladu sa međunarodno prihvaćenim godišnjim vrednostima za stanovništvo (1mSv/yr). Odnos na otvorenom i u zatvorenom prostoru bio je 23.1%.

Ključne reči: *odnos ekvivalentnih doza, Radon, zatvoreni prostor, otvoreni prostor*