Journal of the Nigerian Association of Mathematical Physics
Volume **24 (July, 2013), pp 129 – 136**
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Indoor measurement of background gamma radiation with height and ambient temperature within Edo State secretariat building, Benin City, Nigeria.

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Abstract

Indoor measurement of background gamma radiation with height and ambient temperature has been conducted within Edo State secretariat building. In this study a calibrated digilert 50 nuclear radiation monitor was used to determine the indoor background gamma radiation. Starting from the ground floor and moving up to the last floor (eighth floor) the background gamma radiation in counts per minute (cpm) was determined at 10 minutes interval close to the window and at distances 25.3 and 3.15 m from the windows. Simultaneously the ambient temperature was measured by means of an electronic thermo–hygrometer, model THC–20, manufactured by Optilab Mumbai, Maharashtra, India. The results obtained show that the background gamma radiation ranged from a minimum of 4 cpm to a maximum of 20 cpm. The ambient temperature was found to range from a minimum of 26.2 °C to a maximum of 29.6 °C. The calculated mean count rate in cpm converted to annual dose equivalent in millisievert per year ranged from 0.34 ± 0.09 to 0.57 ± 0.15 mSvyr $^{-1}$. These values are lower than the dose limit of 1 mSvyr $^{-1}$ in a normal environment set by the European Council for Nuclear Research (CERN) for all persons, other than those occupationally exposed. This study further shows that for a low–rise building such as the secretariat building where this study was carried out, the variations in indoor background gamma radiation does not show a steady increase or decrease with the height of the building.

Keywords: Background radiation, counts per minute, ambient temperature, secretariat building, annual dose equivalent.

1.0 Introduction

All living organisms are exposed to ionizing radiation on a continuous and daily basis. This type of exposure is referred to as background radiation. The sources of background radiation include radioactive materials and their decay products in the natural environment (referred to as terrestrial), in building materials and from outer space (referred to as cosmic radiation). There is considerable variation in the background radiation levels throughout the world. The worldwide average background dose for a human being is about 2.4 millisievert (mSv) per year. The interest in the study of background radiation has increased tremendously of recent, and this has led to extensive research in many countries. The result of such researches can be useful for both assessment of public dose rate and the performance of epidemiological studies as well as reference data to check possible changes in background radiation in the environment [1, 2].

The background radiation experience indoor is usually the sum of both natural and artificial radiation sources, some of the sources are cosmic rays and radon gas released by the earth crust, radiation from outer space and small percentage comes from man-made items such as luminous dials, nuclear weapon test, burning fossil fuel, nuclear medicine, building materials and household electrical appliance. The radioactive elements and their radiations are an indispensable part of nature. Their influence on living organisms is very important to studies since the potential hazard of radiation exposures to radon gas and its daughter products from natural background has been highlighted in the world of scientific press [3 - 5].

Some of the essential elements that make up the human body, mainly potassium and carbon, have radioactive isotopes that add significantly to our background radiation dose. An average human contains about 30 milligrams of potassium- 40 (^{40}K) and about 10 nanograms (10^{-8} g) of carbon-14 (^{14}C), which has a decay half-life of 5,730 years. Excluding internal contamination by external radioactive material, the largest component of internal radiation exposure from biologically functional components of the human body is from potassium- 40. The decay of about 4,000 nuclei of ^{40}K per second makes

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potassium the largest source of radiation in terms of number of decaying atoms. The energy of beta particles produced by ^{40}K is also about 10 times more powerful than the beta particles from ^{14}C decay. ^{14}C is present in the human body at a level of 3700 Bq with a biological half-life of 40 days. There are about 1,200 beta particles per second produced by the decay of ^{14}C. However, a ^{14}C atom is in the genetic information of about half the cells, while potassium is not a component of DNA. The decay of a ^{14}C atom inside DNA in one person happens about 50 times per second, changing a carbon atom to one of nitrogen [6].

The level of natural background radiation varies depending on location, and in some areas the level is significantly higher than average. Such areas include Ramsar in Iran, Guarapari in Brazil, Kerala in India, the northern Flinders Ranges in Australia and Yangjiang in China [1, 6 ,7].The highest levels of natural background radiation recorded in the world is from areas around Ramsar, particularly at Talesh-Mahalleh which is a very high background radiation area (VHBRA) having an effective dose equivalent several times in excess of ICRP-recommended radiation dose limits for radiation workers and up to 200 times greater than normal background levels. Most of the radiation in the area is due to dissolved radium-226 in water of hot springs along with smaller amounts of uranium and thorium due to travertine deposits. This high level of radiation does not seem to have caused ill effects on the residents of the area and even possibly has made them slightly more radioresistant, which is puzzling and has been called radiation paradox. It has also been reported that residents have healthier and longer lives. On the basis of this and other evidence including the fact that life had originated in a much more irradiated environment, some scientists have questioned the validity of linear no-threshold model, on which all radiation regulations currently depend [8, 9]. Others point out that some level of radiation might actually be good for health and have a positive effect on population based on the controversial radiation hormesis model, by jump starting DNA repair mechanisms inside the cell [10, 11].

Airflight involves a change in the exposure to ionizing radiation. As altitude increases during flight, there is an initial lowering of the exposure due to the reduction of the terrestrial (Earth-based) component of background radiation. As altitude increases further, the cosmic radiation component increases and can exceed the initial radiation exposure at ground level. The important part of a flight from an overall cosmic radiation exposure perspective is the cruising phase of jet airflight. This typically involves altitudes between 7000 and 12000 m. In addition to altitude, latitude – the distance from the equator – also has an influence on the exposure level. Exposures increase the farther that the flight path is away from the equator. The groups with the most significant occupational exposure to cosmic radiation are cabin crew, pilots and flight engineers. Measurements and modeling of aircrew exposures have indicated an additional dose from commercial air flight of around 1.8 mSv per year for those involved in domestic routes, and around 4 mSv per year for those involved in international flight routes [12].

Radiation levels at the wrecked Fukushima I power plant were observed to have varied, spiking up to 1,000 mSv/h (millisievert per hour) which is a level that can cause radiation sickness to occur at a later time following a one hour exposure[13] .Significant release in emissions of radioactive particles took place following hydrogen explosions in three reactors, as technicians tried to pump in seawater to keep the uranium fuel rods cool, and bled radioactive gas from the reactors in order to make room for the seawater. Concerns about the possibility of a large scale radiation leak resulted in 20 km exclusion zone being set up around the power plant and people within the 20–30 km zone being advised to stay indoors. Later, the UK, France and some other countries told their nationals to consider leaving Tokyo, in response to fears of spreading nuclear contamination [14]. New Scientist has reported that emissions of radioactive iodine and cesium from the crippled Fukushima I nuclear plant have approached levels evident after the Chernobyl disaster in 1986 [15].

Ionizing radiation causes biological effects by directly damaging cells, tissues, components of cells and enzymes. Damage to important parts of the cell such as the DNA – the genetic material – can occur by ionizing radiation directly breaking chemical bonds or by interacting with cellular chemicals that create agents that will break chemical bonds, or by mechanisms that change how cell divide, communicate or die. Damage to the DNA is felt to be an important step with regards to the risk of cancer and the risk of heritable defects, although human cells do have an enormous capacity to repair such damage.

Because the biological effects of radiation depend not only on dose but also on the type of radiation, the dosimetric quantity relevant to radiation protection is the dose equivalent H defined mathematically as:

$$H = DQ \qquad (1.1)$$

where D is the absorbed dose and Q is the quality factor for the radiation.

Whole body exposures are rarely uniform. For a given exposure received, internally or externally, dose equivalents for various tissues may differ markedly. Also tissues vary in sensitivity to radiation–induced effects. To take into account these non uniform irradiation situations the concept of effective dose equivalent (H_E) has been adopted by the ICRP. The effective dose equivalent (H_E) is defined as the sum of the weighted dose equivalents for irradiated tissues or organs. Mathematically, we have:

$$H_E = \sum W_T H_T \qquad (1.2)$$

where W_T is the weighting factor of tissue T and H_T is the mean dose equivalent received by tissue T.

Radiation exposure limits or standards were introduced as early as the start of the twentieth century when the potential hazards of radiation were realized. One of the first standard setting bodies was the International Commission on Radiological Protection (ICRP) which continues its function through its series of publications. These reports form the basis for many national protection guidelines. In the United States, the National Council on Radiation Protection and Measurement (NCRP) has functioned as a primary standard–setting body through its separate publications. In Nigeria we have Nigeria Institute of Radiation Protection (NIRP) and Nigerian Nuclear Regulatory Agency (NNRA) which have been mandated to regulate and provide certain laws on radiation protection and control of nuclear radiation in Nigeria. The guidelines and recommended actions are in general agreement, although they differ in detail. The material distributed in radiation update is intended to provide information needed to help understand issues and to provide a compilation of the relevant facts for those individuals interested in the potential health effects of environmental radiation.

2.0 Materials and Method

Indoor measurement of background gamma radiation with height and ambient temperature was carried out within Edo State secretariat building (Fig. 1) along Sapele road, Benin City. In this study a calibrated digilert 50 nuclear radiation monitor (Fig. 2) was used to determine the indoor background gamma radiation. Starting with the ground floor and moving up to the eighth floor the background gamma radiation in counts per minute (cpm) was determined at 10 minutes interval close to the window and at distances 25.3 and 3.15 m from the windows. Simultaneously the ambient temperature was measured by means of an electronic thermo–hygrometer (Fig.3), model THC–20 manufactured by Optilab Mumbai, Maharashtra, India. The nuclear radiation monitor and the electronic thermo–hygrometer were placed atop a stool of about 1.5 m high. To convert the mean count rate to annual dose equivalent, (Eq. 2.1) is used [16].

$$1\text{cpm} = 0.0438\ \text{mSVyr}^{-1} \qquad (2.1)$$

Figure 1: Secretariat building Sapele road, Benin City, Edo State, Nigeria.

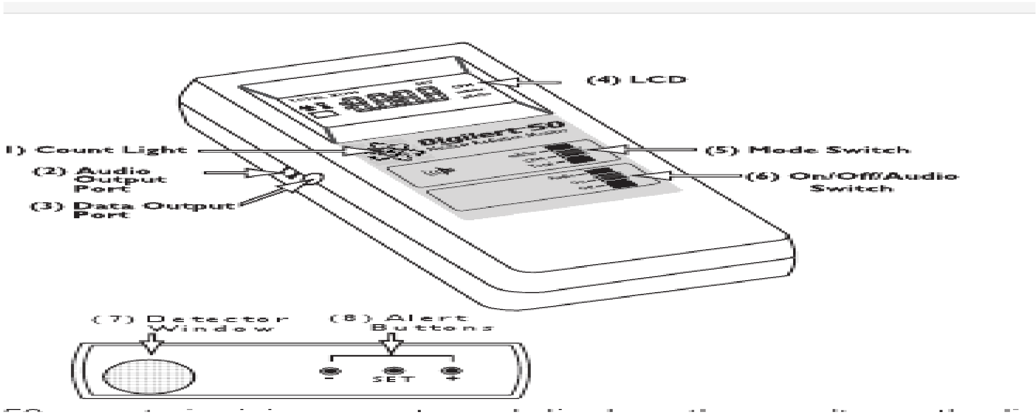

Figure 2: Digilert 50 nuclear radiation monitor.

Figure 3: Electronic Thermo - Hygrometer**.**

3.0 Results and Discussion

Studies of background radiation are of great importance because of its variability in space and time [17]. Little wonder then that such studies have become the focus of scientific research in most countries in recent past [18 – 23]. The aim of this study is to measure indoor background gamma radiation with height and ambient temperature within Edo State secretariat building in order to determine the pattern of variation. The results obtained in this study are shown in Tables 1, 2, 3 and Fig. 4 for close to the window and far from the window measurements.

The results show that radioactivity is actually a random process as the measured background radiation in count per minute from the sources in and around the building is not a function of the ambient temperature. However, the variation in the values obtained could be attributed to human activities in and around the building, the building materials and the number of people in the building at the different floors. The results further show that the mean count rates (cpm) obtained in this study close to the window in each floor with the exception of the seventh floor were slightly higher than the standard background radiation of 11 cpm recommended by the U.S. Nuclear Regulatory Commission [24] whereas, that of the far from the window were less than the recommended value except for the first and third floors. On the average however, a value of 11.28 ± 1.51 cpm was obtained as the indoor background radiation for the secretariat building. This value converted to annual dose equivalent is 0.49 ± 0.07 mSvy^{-1}. As shown in (Fig. 4) it can be seen that for a low–rise building such as the secretariat building where this study was carried out, the variations in indoor background gamma radiation does not show a steady increase or decrease with the height of the building rather the values obtained fluctuate around the standard background radiation value.

To estimate annual effective dose, the conversion coefficient must be taken into account from the absorbed dose in air to the effective dose. Gamma radiation is less absorbed in children and infants resulting in a higher dose conversion coefficient (adults: 0.7, children: 0.8 and infants: 0.9) [25, 26]. Then the annual average effective dose for adults in the secretariat building would be $0.49 \times 0.7 = 0.34$ mSvy^{-1}. This value is within the average radiation exposure from medical tests, which ranges from 0.04 to 1.00 mSvy^{-1} [26] that is allowed for members of the public.

4.0 Conclusion

In the next three decades, the world population is expected to increase from 6.1 to 8.1 billion with much of this growth concentrated in tall buildings in urban areas located in less developed countries. It is thought that with the realization of this dream of tall buildings people will be less expose to radon which is a terrestrial source of ionizing radiation that is of particular concern because, although on average it is very rare, this intensely radioactive element can be found in high concentrations in many areas of the world, where it represent a significant health hazard. However, to build a building that is 7000 to 12000 m tall where a steady change in background radiation could be observed is not only inconceivable but is also not realizable. According to [27] tall buildings are those higher than 91 m. Buildings taller than 305 m are commonly referred to as super tall. Yeang provides a definition for skyscrapers as essentially a tall building with a small footprint and small roof area with tall facades [28]. His definition distinguishes between skyscrapers, medium–rise and low–rise buildings. On the basis of this definition the secretariat building where this study was carried out falls into the category of low–rise buildings and hence the stochastic pattern of variation with estimated height (Fig. 4) of indoor background gamma radiation observed in this study. Based on this present study it could be concluded that the annual effective dose of 0.49 mSvy^{-1} obtained may not pose any serious health threat to the people working in and around the secretariat building.

Table 1: Location, time, count per minute, mean count rate, dose equivalent, ambient temperature and mean temperature for measurements close to the window.

Location	**Time (Minutes)**	**Count Per Minute (cpm)**	**Mean count rate (cpm)**	**Dose equivalent (mSvyr $^{-1}$)**	**Ambient temperature (°C)**	**Mean temperature (°C)**
Ground floor	10	11	13.00 ± 3.03	0.57 ± 0.13	27.7	27.37 ± 0.18
	20	13			27.2	
	30	16			27.3	
	40	15			27.4	
	50	08			27.3	
	60	15			27.3	
First floor	10	14	11.33 ± 1.97	0.50 ± 0.09	27.8	27.33 ± 0.25
	20	09			27.4	
	30	12			27.2	
	40	12			27.1	
	50	12			27.2	
	60	09			27.3	
Second floor	10	13	12.67 ± 4.59	0.56 ± 0.20	28.2	27.52 ± 0.34
	20	19			27.4	
	30	12			27.3	
	40	12			27.3	
	50	05			27.5	
	60	15			27.4	
Third floor	10	15	13.00 ± 3.52	0.57 ± 0.15	26.6	26.37 ± 0.14
	20	07			26.4	
	30	16			26.3	
	40	16			26.2	
	50	11			26.3	
	60	13			26.4	
Fourth floor	10	10	13.00 ± 3.16	0.57 ± 0.14	27.1	27.05 ± 0.08
	20	09			27.1	
	30	16			27.0	
	40	17			26.9	
	50	13			27.1	
	60	13			27.1	
Fifth floor	10	10	12.83 ± 3.97	0.56 ± 0.17	28.8	28.40 ± 0.29
	20	14			28.7	
	30	15			28.4	
	40	19			28.1	
	50	11			28.2	
	60	08			28.2	
Sixth floor	10	12	12.50 ± 4.59	0.55 ± 0.20	28.8	28.95 ± 0.42
	20	15			28.6	
	30	12			28.5	
	40	20			28.9	
	50	07			29.3	
	60	09			29.6	
Seventh floor	10	09	10.50 ± 2.88	0.46 ± 0.13	27.7	27.38 ± 0.16
	20	10			27.4	
	30	16			27.3	
	40	09			27.3	
	50	08			27.3	
	60	11			27.3	
Eighth floor	10	10	11.50 ± 2.07	0.50 ± 0.09	27.1	27.27 ± 0.10
	20	15			27.3	
	30	10			27.3	
	40	10			27.2	
	50	11			27.4	
	60	13			27.3	

Table 2: Location, time, count per minute, mean count rate, dose equivalent, ambient temperature and mean temperature for measurements far from the window.

Location	**Time (Minutes)**	**Count Per Minute (cpm)**	**Mean count rate (cpm)**	**Dose equivalent (mSvyr^{-1})**	**Ambient temperature (°C)**	**Mean temperature (°C)**
Ground floor	10	05	8.83 ± 2.23	0.39 ± 0.10	28.1	27.12 ± 0.50
	20	11			27.2	
	30	09			26.9	
	40	08			26.8	
	50	09			26.9	
	60	11			26.8	
First floor	10	11	11.67 ± 4.03	0.51 ± 0.18	27.7	26.75 ± 0.52
	20	06			27.0	
	30	11			26.6	
	40	14			26.4	
	50	10			26.4	
	60	18			26.4	
Second floor	10	10	11.00 ± 2.10	0.48 ± 0.09	27.7	26.83 ± 0.46
	20	14			27.0	
	30	09			26.7	
	40	13			26.5	
	50	09			26.6	
	60	11			26.5	
Third floor	10	11	11.83 ± 3.06	0.52 ± 0.13	27.0	26.67 ± 0.23
	20	16			26.9	
	30	08			26.6	
	40	15			26.6	
	50	10			26.4	
	60	11			26.5	
Fourth floor	10	15	10.00 ± 4.05	0.44 ± 0.18	27.3	26.85 ± 0.24
	20	09			26.9	
	30	14			26.8	
	40	08			26.7	
	50	10			26.7	
	60	04			26.7	
Fifth floor	10	08	7.67 ± 1.97	0.34 ± 0.09	27.2	26.80 ± 0.45
	20	07			26.9	
	30	05			26.0	
	40	08			26.9	
	50	07			26.9	
	60	11			26.9	
Sixth floor	10	09	10.00 ± 4.94	0.44 ± 0.22	28.2	27.58 ± 0.33
	20	04			27.7	
	30	08			27.5	
	40	16			27.3	
	50	07			27.4	
	60	16			27.4	
Seventh floor	10	15	10.83 ± 2.23	0.47 ± 0.10	27.9	27.30 ± 0.32
	20	11			27.4	
	30	09			27.2	
	40	09			27.2	
	50	11			27.1	
	60	10			27.0	
Eighth floor	10	12	10.83 ± 3.71	0.47 ± 0.16	27.0	27.02 ± 0.08
	20	10			26.9	
	30	12			27.0	
	40	04			27.1	
	50	12			27.1	
	60	15			27.0	

Table 3: Location, height and mean count rate for close to the window and far from the window measurements.

Location	Estimated height (m) of measurement	Mean count rate (cpm)	
		Close to the window	Far from the window
Ground floor	1.50	13.00 ± 3.03	8.83 ± 2.23
First floor	4.75	11.33 ± 1.97	11.67 ± 4.03
Second floor	7.46	12.67 ± 4.59	11.00 ± 2.10
Third floor	10.17	13.00 ± 3.52	11.83 ± 3.06
Fourth floor	12.88	13.00 ± 3.16	10.00 ± 4.05
Fifth floor	15.59	12.83 ± 3.97	7.67 ± 1.97
Sixth floor	18.30	12.50 ± 4.59	10.00 ± 4.94
Seventh floor	21.01	10.50 ± 2.88	10.83 ± 2.23
Eighth floor	23.72	11.50 ± 2.07	10.83± 3.71

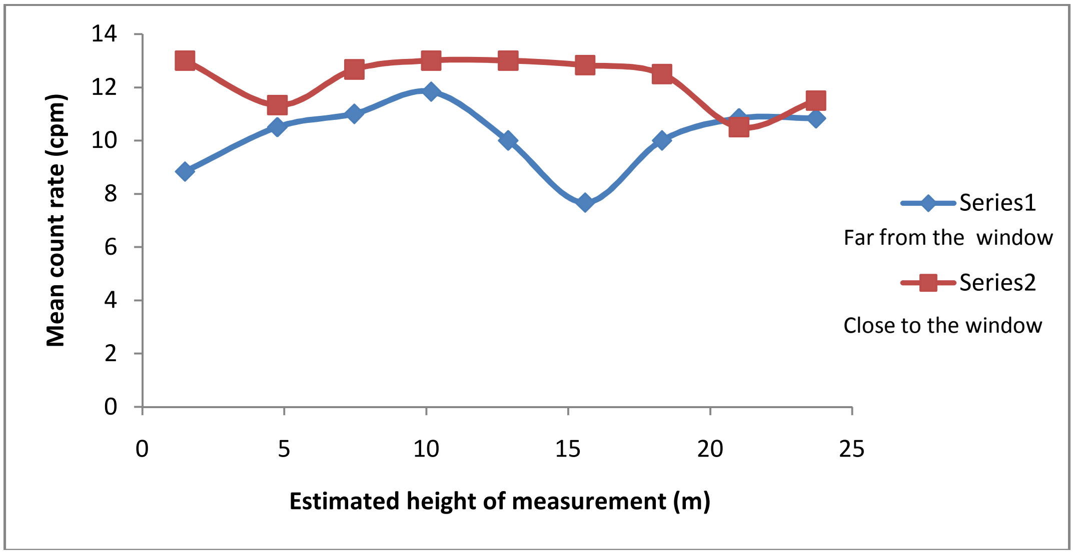

Figure 4: A graph of mean count rate versus estimated height of measurement depicting over the window and indoor measurements.

Acknowledgement

The author is grateful to the then Honorable Commissioner and other members of staff (between June – September 2011) of the Ministry of Lands, Surveys and Housing, Edo State, for allowing me to carry out this study in the secretariat building and their assistance to me while the study lasted.

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