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EVALUATION OF INDOOR BACKGROUND IONIZING RADIATION PROFILE OF A PHYSICS LABORATORY

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Abstract. *Certain types of building materials are known to be radioactive. And exposure to indoor ionizing radiation like exposure to any other type of ionizing radiation results in critical health challenges. We report here a survey of the background ionizing radiation profile within the Physics Laboratory of the Rivers State College of Education, Port Harcourt and its immediate neighbourhood. This laboratory also harbours a number of active radiation sources. Our survey shows that there is a higher level of dangerous radiation within the laboratory (0.871±0.03mSv/yr) than outside in the area immediately surrounding the laboratory (0.728±0.02mSv/yr).We have assessed the health implications of our results by comparing our data with accepted radiation dosage as recommended by responsible international agencies.*

Key Words: *Radon Gas, Indoor Ionizing Radiation, Background Ionizing Radiation, Count Rate, Dose Equivalent*

1. INTRODUCTION

In Nigeria, outdoor background ionizing radiation (BIR) profile has received much attention [1-5]. Conversely, indoor BIR appears to have been neglected even though it is also important as studies have established the presence of dangerous background ionizing radiation within buildings [6-11]. Indoor BIR investigation is important because:

1. Some of the materials used in the construction of buildings are known to be radioactive [4, 8, 10, 12].
2. Indoor air often contains the harmful radioactive gas, radon (^{222}Rn) [7,8,11]. And generally, indoor air has a higher concentration of radon than outdoor air [7].

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3. Due to changes in lifestyle, people spend more time indoors than outdoors [11]. Surveys undertaken by the World Health Organization (WHO) and the International Commission on Radiological Protection (ICRP) show that residents of temperate climes spend only about 20% of their time outdoors and 80% indoors (their homes, offices, schools, other buildings) [8]. The implication of this statistics is obvious – the probability of exposure to dangerous radiation is higher indoors than outdoors. Figures are not available for Nigeria; however, it is reasonable to expect that they could also be as high.

Indoor BIR profiles for a building are, therefore, crucial since they enable us to assess the level of risk of exposure to the regular users of such buildings and the general population. It has been established that chronic exposure to an even low dose and a low dose rate of nuclear radiations from an irradiated building has the potential to induce cytogenetic damage in human beings [6].

Of particular concern for indoor BIR is the incidence of the invisible, odorless, colorless radioactive gas ^{222}Rn which is a member of the Uranium radioactive series. Estimates show that of the 2.4mSv/yr annual exposure from all ionizing sources 40% is contributed by internal exposure to radon alone [13]. There is a strong correlation between radon exposure (inhalation) and the prevalence of lung cancer [7, 11].

^{222}Rn results from the radioactivity of ^{238}U and itself decays with a half life of 3.82 days. When it is inhaled it penetrates into the lung. It's most dangerous daughters are the α emitters ^{218}Po and ^{214}Po which emit α particles with energy of 6.0MeV and 7.69MeV, respectively. The continuous deposition and interaction of such high energy particles with the lung lead to its damage and the incidence of lung cancer. ^{222}Rn finds its way indoors through building materials, through diffusion and convection and through the soil under the building [7, 11].

In this work the BIR levels within the Physics Laboratory (College of Education, Rumuolumeni, Port Harcourt) and its immediate environs are assessed to enable us determine the level of risk to which staff and students are exposed. This is needful because aside the regular sources of indoor BIR mentioned earlier, the Physics Laboratory harbors a number of active radiation sources. Furthermore, the factory of the Eastern Bulkcem Cement Company, producers of the Eagle Cement brand is a close neighbor of the College of which the Physics Laboratory is a part. Cement and the raw materials for its production are known to contain radioactive substances so that cement factories influence the ionizing radiation levels of their immediate neighborhood [4]. This is especially so in cases as between the College and the cement factory where interconnecting surface and underground water systems exist to act as transport routes for the radioactive materials [4,7].

We will also compare the BIR level within and outside the laboratory to internationally accepted standards.

2. EXPERIMENTAL SET UP

In collecting the data, an assembly involving a G-M tube, an associated scalar counter and a stop-watch was used. The G-M tube is an exceptionally robust, non-energy dissipative instrument and has a mean dead time of 208 ± 40μs [14]. These make it an effective and sensitive instrument for radiation monitoring. Important environmental radiation surveys have used the G-M tube such as the survey of the BIR levels resulting from fertilizer production operations [3]; estimates of radiation profiles of sub-industrial areas of Port Harcourt, Nigeria [2] and the determination of BIR levels within the premises of a multinational company involved in oil and gas operations in the Niger Delta region, Nigeria [15].

Three target areas were delineated for this work. These are the Physics Laboratory (indoors) and two adjoining locations in the immediate vicinity of the laboratory which were chosen for comparative purposes. To adequately cover the designated target areas 20 readings were taken in each area.

We have used a conversion factor of 1cpm = 0.044mSv yr^{-1} based on calibration done by Sigalo and Briggs-Kamara [12].

3. RESULTS OF MONITORING

Table 1. Indoor count rate (R), dose equivalent (D), deviations from mean count rate (ΔR) and dose equivalent (ΔD) and percentage deviations from mean (ΔR%, ΔD%) (Physics Laboratory)

	Count rate, R_i (cpm)	ΔR_i (cpm)	% ΔR_i	Dose equivalent D_i (mSv/yr)	ΔD_i (mSv/yr)	% ΔD_i
1	19.25	-0.55	2.9	0.847	-0.024	2.8
2	19.75	-0.05	0.3	0.869	-0.002	0.2
3	17.25	-2.55	14.8	0.759	-0.112	14.8
4	21.75	1.95	9.0	0.957	0.086	9.0
5	24.25	4.45	18.4	1.067	0.196	18.3
6	18.75	-1.05	5.6	0.825	-0.046	5.6
7	20.25	0.45	2.2	0.891	0.020	2.3
8	17.75	-2.05	11.6	0.781	-0.090	11.5
9	18.00	-1.80	10.0	0.792	-0.079	10.0
10	17.50	-2.30	13.1	0.770	-0.101	13.1
11	16.00	-3.80	23.8	0.704	-0.167	23.7
12	15.75	-4.05	25.7	0.693	-0.178	25.7
13	21.75	1.95	9.0	0.957	0.086	9.0
14	24.50	4.70	19.2	1.078	0.207	19.2
15	19.50	-0.30	1.5	0.858	-0.013	1.5
16	22.75	2.95	13.0	1.001	0.130	13.0
17	19.50	-0.30	1.5	0.858	-0.013	1.5
18	19.50	-0.30	1.5	0.858	-0.013	1.5
19	18.50	-1.30	7.0	0.814	-0.057	7.0
20	23.75	3.95	16.6	1.045	0.174	16.7

Table 2. Outdoor count rate (R), dose equivalent (D), deviations from mean count rate (ΔR) and dose equivalent (ΔD) and percentage deviations from mean ($\Delta R\%$, $\Delta D\%$) (Downward Orientation of G-M tube)

	Count rate, R_i (cpm)	ΔR_i (cpm)	% ΔR_i	Dose equivalent D_i (mSv/yr)	ΔD_i (mSv/yr)	% ΔD_i
1	18.50	1.95	10.5	0.814	0.086	10.6
2	12.75	-3.80	29.8	0.561	-0.167	29.8
3	15.25	-1.30	8.5	0.671	-0.057	8.5
4	16.25	-0.30	1.9	0.715	-0.013	1.8
5	21.25	4.70	22.1	0.935	0.207	22.1
6	19.25	2.70	14.0	0.847	0.119	14.1
7	17.00	0.45	2.7	0.748	0.020	2.7
8	14.25	-2.30	16.1	0.627	-0.101	16.1
9	17.00	0.45	2.7	0.748	0.020	2.7
10	15.00	-1.55	10.3	0.660	-0.068	10.3
11	19.50	2.95	15.1	0.858	0.130	15.2
12	15.00	-1.55	10.3	0.660	-0.068	10.3
13	15.00	-1.55	10.3	0.660	-0.068	10.3
14	19.75	3.20	16.2	0.869	0.141	16.2
15	17.75	1.20	6.8	0.781	0.053	6.8
16	17.25	0.70	3.9	0.759	0.031	4.1
17	14.75	-1.80	12.2	0.649	-0.079	12.2
18	14.00	-2.55	18.2	0.616	-0.112	18.2
19	14.50	-2.05	14.1	0.638	-0.090	14.1
20	17.00	0.45	2.7	0.748	0.020	2.7

Table 3. Outdoor count rate (R), dose equivalent (D), deviations from mean count rate (ΔR) and dose equivalent (ΔD) and percentage deviations from mean ($\Delta R\%$, $\Delta D\%$) (Upward orientation of G-M tube)

	Count rate, R_i (cpm)	ΔR_i (cpm)	% ΔR_i	Dose equivalent D_i (mSv/yr)	ΔD_i (mSv/yr)	% ΔD_i
1	17.50	-0.19	1.1	0.77	-0.01	1.3
2	21.00	3.31	15.8	0.92	0.14	15.2
3	18.75	1.06	5.7	0.83	0.05	6.0
4	18.75	1.06	5.7	0.83	0.05	6.0
5	17.50	-0.19	1.1	0.77	-0.01	1.3
6	18.75	1.06	5.7	0.83	0.05	6.0
7	15.00	-2.69	17.9	0.66	-0.12	18.2
8	17.75	0.06	0.3	0.78	0.00	0.0
9	15.25	-2.44	16.0	0.67	-0.11	16.4
10	18.75	1.06	5.7	0.83	0.05	6.0
11	17.00	-0.69	4.1	0.75	-0.03	4.0
12	18.75	1.06	5.7	0.83	0.05	6.0
13	13.25	-4.44	33.5	0.58	-0.20	34.5
14	18.00	0.31	1.7	0.79	0.01	1.3
15	18.75	1.06	5.7	0.83	0.05	6.0
16	18.25	0.56	3.1	0.80	0.02	2.5
17	17.50	-0.19	1.1	0.77	-0.01	1.3
18	18.75	1.06	5.7	0.83	0.05	6.0
19	16.25	-1.44	8.9	0.72	-0.06	8.3
20	18.25	0.56	3.1	0.80	0.02	2.5

Table 4. Minimum and maximum values of count rate and dose equivalent

Indoor

R_{min} (cpm)	D_{min} (mSv/yr)	R_{max} (cpm)	D_{max} (mSv/yr)
15.75	0.693	24.50	1.078

Outdoor -1 (Downward orientation of G-M tube)

R_{min} (cpm)	D_{min} (mSv/yr)	R_{max} (cpm)	D_{max}(mSv/yr)
12.75	0.561	21.25	0.935

Outdoor - 2 (Upward orientation of G-M tube)

R_{min} (cpm)	D_{min} (mSv/yr)	R_{max} (cpm)	D_{max} (mSv/yr)
13.25	0.580	21.00	0.920

Table 5. Mean values(<R>, <D>), standard deviations and mean percentage deviation from mean (< %>)

Indoor

<R> (cpm)	σ_R	<D> (mSv/yr)	σ_D	< % >
19.80 ±0.56	2.52	0.871±0.03	0.11	10.3

Outdoor -1 (Downward orientation of G-M tube)

<R> (cpm)	σ_R	<D> (mSv/yr)	σ_D	< % >
16.55 ± 0.49	2.21	0.728 ± 0.02	0.1	11.4

Outdoor- 2 (Upward orientation of G-M tube)

<R> (cpm)	σ_R	<D> (mSv/yr)	σ_D	< % >
17.69 ± 0.37	1.66	0.780 ± 0.02	0.07	7.4

4. DISCUSSION

The results are presented in Tables 1-3. Data set 1 (Table 1) was collected indoors in the Physics Laboratory. Data set 2 (Table 2) was obtained outdoors with the G-M tube oriented vertically downwards towards the bare ground. Data set 3 (Table 3) was also obtained outdoors but with the G-M tube oriented vertically upwards, away from a macadamized surface. We show in these tables the count rate (R), deviations from mean count rate (ΔR), percentage deviation from mean count rate ($\%\Delta R$), the dose equivalent (D), deviation from mean dose equivalent (ΔD) and percentage deviation from mean dose equivalent ($\%\Delta D$). Table 4 gives a comparative analysis of the data showing the minimum and maximum values of count rate and dose equivalent for the indoor and outdoor profiles. The minimum dose equivalent, D_{min} within the laboratory is 0.693mSv/yr (or a minimum count rate, R_{min} of 15.75cpm) while the maximum dose equivalent, D_{max} is 1.078mSv/yr (24.50cpm). The outdoor BIR with the G-M tube oriented vertically downwards has a minimum dose equivalent of 0.561mSv/yr (12.75cpm) and a maximum dose equivalent of 0.935mSv/yr (21.25cpm). The second outdoor survey involving the vertical upward orientation of the G-M tube gives a minimum dose equivalent of 0.660mSv/yr (15.00cpm) and a maximum dose equivalent of 0.920mSv/yr (21.00cpm).

In Table 5, we present the mean values and the standard deviations for each profile. Within the Physics Laboratory, the mean dose equivalent, <D> is 0.871±0.03mSv/yr with a standard deviation, σ_D of 0.11(or a mean count rate, <R> of 19.80±0.56cpm and a standard deviation, σ_R of 2.52). For the outdoor profile involving the vertically downward G-M tube orientation we have a mean dose equivalent of 0.728±0.02mSv/yr and a standard deviation, σ_D of 0.1 (16.55±0.49cpm with a standard deviation, σ_R of 2.21) while we have 0.780±0.02mSv/yr and a standard deviation, σ_D of 0.07 (17.69 ± 0.37cpm with a standard deviation, σ_R of 1.66) for the outdoor profile in which the G-M tube is oriented vertically upwards.

The data for all three profiles show that for any given quantity, the value for the indoor profile is consistently higher than the corresponding value for the two outdoor profiles. There is therefore, a higher level of ionizing radiation indoors within the Physics Laboratory than outdoors in its immediate environment. There are four possible reasons for this, namely radioactive substances from the cement factory transported through the underground water system and which then settle on the soil beneath the laboratory; the presence of radon gas in the air within the laboratory; residual radioactivity of equipments in the laboratory and the building materials used in the construction of the laboratory; and the active radiation sources in the laboratory.

To determine the impact of the cement factory on our results there is the need to carry out a radioactivity profile for both the soil and water along the paths of the surface and underground water systems that connect the College to the cement plant. And to ascertain the presence of radon in the laboratory and hence its contribution to the observed elevated indoor BIR, there is the need to analyze the indoor air for radon. Until this is done and as a precautionary measure against unintended exposure to this dangerous radioactive gas, we recommend that whenever the laboratory is in use, proper ventilation should be ensured as this reduces radon concentration in the indoor air [7].

5. CONCLUSION

1. This work shows that there is a higher level of harmful ionizing radiation within the Physics Laboratory than outside, around its immediate environs. But further work in the areas of air, water and soil radioactivity profiles need to be undertaken to ascertain the impacts of both indoor radon and the nearby cement production plant on the present work. However, staff and students and others who use the Physics Laboratory and its immediate neighborhood are exposed to insignificant health risks as the values obtained in this work are consistently less than the 1.0mSv/yr recommended by the International Commission on Radiological Protection (ICRP). This not withstanding, the aggressive industrial activities around the College campus demands that regular and periodic monitoring of the BIR level be carried out to assess the health risks both staff and students may be exposed to in the future.

2. Alongside the outdoor BIR evaluations that have been done in various parts of the nation, we wish to recommend that indoor BIR profiles of buildings in different sectors of the society be undertaken to set national standards and assess health risks to which citizens are exposed. Such evaluations have been done in other countries, for example, for buildings in the textile industry in Taiwan [11]; for different types of structures in Lithuania [10] and in several countries of Europe and America [7].

3. In a subsequent work, we intend to survey the BIR profile for the entire main campus of the College.

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PROCENA PROFILA SOBNE POZADINSKE JONIZIRAJUĆE RADIJACIJE U JEDNOJ LABORATORIJI ZA FIZIKU

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Poznato je da su izvesni tipovi građevinskih materijala radioaktivni. Izlaganje sobnoj jonizirajućoj radijaciji, kao izlaganje bilo kom drugom tipu jonizirajuće radijacije, dovodi do kritičnih zdravstvenih promena. U ovom radu predstavljamo pregled profila sobne pozadinske jonizirajuće radijacije u Laboratoriji za fiziku Državnog obrazovnog koledža Rivers, u Port Harkortu i njenoj neposrednoj okolini. Ova laboratorija takođe skladišti i izvestan broj aktivnih izvora radijacije. Naš pregled pokazuje da postoji viši nivo opasne radijacije unutar laboratorije (0.871±0.03mSv/yr) od onog u oblasti koja neposredno okružuje laboratoriju (0.728±0.02mSv/yr). Procenili smo medicinske implikacije naših rezultat poređenjem naših podataka sa prihvatljivim dozama radijacije koje preporučuju odgovorne međunarodne agencije.

Ključne reči: *gas radon, sobna jonizirajuća radijacija, pozadinska jonizirajuća radijacija, stopa brojanja, ekvivalencija doze*