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1 (1) : 54 - 58 | Received: 31/07/2024 | Reviewed: 08/09/2024 | Accepted: 10/09/2024

Radiation Dosimetry and their Effects on Humans on the UNITECH Campus

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Abstract: Radiation effects on human are generally high in earthquake-prone areas like Papua New Guinea. In this context, radiation effects are studied in UNITECH campus by analyzing soil samples collected from different locations within the campus and analyzed in a gamma ray spectrometer. The calculated values of indoor and outdoor Annual Effective Dose were 229.91$\pm$48 and 57.48$\pm$12 μSv y^{-1} and the measured indoor and outdoor effective dose rates were found to be 520$\pm$66 and 130$\pm$16 μSv y^{-1} respectively which are less than the permissible limit of 1000 μSv y^{-1}. The average value of Radium equivalent is observed to be 101.43$\pm$20.97 $Bqkg^{-1}$ which is less than the permissible value of 370 $Bqkg^{-1}$. The internal and external Hazard Indices calculated are 0.028$\pm$0.06 and 0.36$\pm$0.9 which are within the safe limit of 1. The Excess Lifetime Cancer Risk (ELCR) was found to be 1.5$\pm$0.3X10^{-4} whereas the global average is 1.45X10^{-4}.

Keywords: Dose rate, Radium equivalent, Hazard indices, ELCR.

1. Introduction

The crust of the earth consists of natural elements as well as radioactive elements. The chief contributor of radioactivity is ^{238}U, ^{234}Th and ^{40}K [1]. The naturally occurring radioactive elements undergo decay process and release radiation. This radiation varies from location to location around the world due to change in the soil structure and texture. Terrestrial radiation is emitted from the soil while extra-terrestrial radiation comes from cosmic rays. Thus, everyone on earth is exposed to background radiation. About 82% of humans are exposed to the natural radiation internally [2]. Naturally occurring radionuclides are found in soil, water and vegetation [3 4]. For a human being, external exposure occurs from soil and building materials while internal exposure is through inhalation and ingestion. In this context, assessment of gamma dose from natural source is very important. There are many mineral resources in Papua New Guinea. The major radioactive sources are ^{238}U, ^{234}Th and ^{40}K but traces of other elements like ^{45}Ca, ^{131}I, ^{203}Hg, ^{51}Cr, ^{60}Co, ^{109}Cd, ^{47}Sc, ^{198}Au, ^{140}Ba and ^{59}Fe are also present [5].

In this paper, we calculated the external and internal dose equivalent in different locations of Unitech campus by analyzing soil samples collected from five locations and also measured the dose rates in the same locations with Dosimeter. We also calculated the Radium Equivalent, Indoor and Outdoor Hazard Indices and Excess Lifetime Cancer Risk.

2. Materials and Methods

2.1 Study Area

Fig. 1a shows the location of UNITECH in Papua New Guinea and Fig. 1b shows the map of Unitech campus where study has been conducted. The five locations from where the soil samples were collected are shown in the map. The locations are 1. Swamp Area, 2. Cook's Town, 3. Sepik Drive, 4. Agriculture Farm and 5. School Dump. The study areas are selected randomly.

Fig. 1: a) Location of UNITECH campus in Papua New Guinea and b) Locations in UNITECH campus from where soil samples are taken.

2.2 Instrument and Measurement Techniques

The instrument used in our analysis is LB 2045 NaI(Tl) Gamma Spectrometer which can detect very low energies of the order of ~10 keV. The system consists of a computer unit, graphical display with touch panel and a power supply unit.

Radiation dose in air at a distance of 1.0 m above the surface of the soil where the samples were collected were measured using SOEKS Quantum Professional GM pocket survey meter. The locations of sample collection were measured using Garmin eTrex® 30x GPS with Digital Compass.

2.3 Sample Preparation

The soil samples, three samples each, were collected from the five locations using the ASTM C998 – 17 (American Society for Testing and Materials) Standard Practice for Sampling Surface Soil for Radionuclides). The samples were collected in plastic bags, brought to the Lab and exposed to florescent lamp to dry out. It was then powder and filtered with a strainer of micrometer diameter. The filtered samples are then kept in 20 ml containers and kept for one month for the radionuclide progenies to reach in equilibrium. The sample was put in the chamber of the Gamma ray detector for counting gamma rays of radionuclides. Two windows were used for different radionuclides whose energy ranges do not overlap. The counts were integrated over the energy range and compared with the energy ranges of the elements stored in the instrument. Observations were done for all the samples and tabulated in Table 1.

Table 1: The Specific activity of ^{232}Th, ^{226}Ra and ^{40}K, their absorbed Dose rate, Outdoor and Indoor Annual Effective Dose Equivalent, Radium Equivalent, Outdoor and Indoor Hazard indices and Excess Lifetime Cancer Risk in five different locations in UNITECH campus

Sample	Specific Activity (Bq/kg)			Outdoor Absorbed Dose ($nGyh^{-1}$)	Indoor Absorbed Dose ($nGyh^{-1}$)	Outdoor AEDE (μSvy^{-1})	Indoor AEDE (μSvy^{-1})	$Ra_{eq.}$ (Bq/kg)	H_{ex}	H_{in}	ELCR $x10^{-3}$
	^{232}Th	^{226}Ra	^{40}K								
1.1		36.29	277.5	57.04	98.11	69.95	481.28	124.78	0.34	0.44	0.179
1.2	38.1	30.06	205.1	45.10	77.16	55.32	378.52	98.90	0.27	0.35	0.141
1.3	43.8	45.36	432	64.69	111.30	79.34	545.97	138.23	0.38	0.50	0.203
2.1	17.7	17.36	308.9	31.07	55.25	38.10	271.05	64.29	0.18	0.23	0.100
2.2	35	10.96	267.1	36.89	66.93	45.24	328.33	79.71	0.22	0.25	0.121
2.3	33	22.35	372.3	45.15	80.31	55.37	393.98	95.60	0.27	0.33	0.146
3.1	36.9	18.02	249.2	40.58	71.95	49.77	352.95	88.23	0.24	0.29	0.131
3.2	46.1	24.49	150.1	45.16	78.05	55.39	382.89	100.92	0.28	0.34	0.142
3.3	46.9	32.94	336.6	57.01	99.28	69.92	487.02	123.57	0.34	0.43	0.181
4.1	41.2	46.24	232	55.53	92.78	68.10	455.15	121.40	0.33	0.46	0.170
4.2	36.6	62.03	261.1	61.21	99.87	75.07	489.91	132.65	0.36	0.53	0.184
4.3	32.2	40.84	189.2	45.88	76.07	56.27	373.15	100.13	0.27	0.38	0.140
5.1	21.6	22.67	233.3	32.85	56.71	40.29	278.21	69.89	0.19	0.25	0.104
5.2	33.1	26.25	292.7	43.83	76.39	53.75	374.76	94.07	0.26	0.33	0.139
5.3	29.5	32.64	202.9	41.01	69.12	50.30	339.08	89.03	0.24	0.33	0.127
Av.	**36.00**	**31.23**	**267.33**	**46.87**	**80.62**	**57.48**	**395.48**	**101.43**	**0.28**	**0.36**	**0.15**
STD	**8.23**	**12.49**	**68.94**	**9.50**	**15.37**	**11.65**	**75.40**	**20.97**	**0.06**	**0.09**	**0.03**

2.4 Dose Calculations

The naturally occurring radioactive materials (NORM) are ^{238}U, ^{232}Th and ^{40}K. The absorbed dose rate was calculated using the formula

$$D(nGyh^{-1}) = 0.462\, A_{Ra} + 0.604\, A_{Th} + 0.04 A_K \quad (1)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of Radium, Thorium and Potassium [6].

Annual Effective Dose Equivalent (AEDE) calculated in Sieverts (Sv) helps in setting up safety standards to protect people from harmful effects of radiation. The amount of time people spend indoor and outdoor varies significantly. The outdoor and indoor AEDE are given by

$$E_X = DR.\ T.\ K1.\ G1 \quad (2)$$

$$E_Y = DR.\ T.\ K2.\ G2 \quad (3)$$

where DR = Dose rate in micro-Sievert per hour in air at 1.0m from surface
T = time in hours in one year (8,760)
K1 = dose conversion factor (0.70)
G1 = indoor occupancy factor (0.80)
G2 = outdoor occupancy factor (0.20).

Radium Equivalent

Radium Equivalent is a measure used to simplify the assessment of radiation exposure from materials that contain multiple radioactive substances. It quantifies the total radiation hazard in terms of an equivalent amount of radium, which is a single, well understood radioactive element. It is a way to express the combined radiation risk of a material in terms of how much radium would produce the same radiation dose, making it easier to understand and regulate.

The equation used is:

$$Ra_{eq}(Bq.kg^{-1}) = A_{Ra} + 1.43 A_{Th} + 0.077 A_K \quad (4)$$

Radiation Hazard Indices

Radiation Hazard Indices are like safety measures to help us understand and control radiation exposure. Think of them as warning signs to keep us safe from harmful radiation.

They were calculated using the equations:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (5)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (6)$$

A value less than 1 indicates that the radiation is within safe levels signifying lower risk.

Excess Lifetime Cancer Risk (ELCR)

Excess lifetime cancer risk is the extra chance or probability of getting cancer due to exposure.

Calculations were made using the following equation:

$$\mathrm{ELCR} = \mathrm{AEDE_{tot}} \times \mathrm{DL} \times \mathrm{RF} \quad (7)$$

where DL = Duration of life which is taken to be 65 years average for Papua New Guineans and RF = risk factor which is 0.05

3. Results and Discussion

The dose rate, Annual Effective Dose Equivalent, Radium equivalent, Hazard indices and Excess Lifetime Cancer Risk were calculated using equations (1) – (6) and tabulated in Table 1. The outdoor and indoor AEDE values were found to be less than the threshold safe value of 1000 μSvy^{-1}. For all the samples analyzed, the radium equivalent was observed to be less than the threshold value of 370 $Bqkg^{-1}$. The external and internal hazard indices were found to be less than the maximum safe value of 1. The ELCR calculated was $1.5 \pm 0.03 X10^{-4}$ whereas the world average value is $1.45X10^{-4}$.

The dose is measured using a Dosimeter in the five locations and the Annual Effective Dose are calculated and tabulated in Table 2

Table 2: The Outdoor and Indoor Annual Effective Dose measured using Dosimeter in the five locations.

Sample	Latitude	Longitude	cpm	µSv/hr	Outdoor AED (µGy/yr)	Indoor AED (µGy/yr)
1	6.40422	146.59265	15.7	0.09	110.38	441.50
2	6.674361	146.99845	13.9	0.11	134.90	539.62
3	6.668179	146.9979	22.7	0.1	122.64	490.56
4	6.662663	147.00119	19.2	0.1	122.64	490.56
5	6.667038	146.99273	19.2	0.13	159.43	637.73
Mean					**130.00**	**520**
STD					**16.64**	**66.5**

The dose measured using dosimeter and the dose calculated by analyzing the samples were plotted in Fig. 2. The measured value of dose in all the regions were found to be higher than the calculated value. This is because the theoretical value is formulated under the assumption that the radiation is calculated 1m above the ground from a point source on the ground. Moreover, influence of other radiation sources such as cosmic rays and other radioactive elements were not considered in calculation. The weather conditions also influence the dose rate. The building materials in the region will also influence the dose measurements in that region [7]. Radon in air and ground water in the campus will also contribute to a small extend to the radiation level in the campus. These will be studied in our future work.

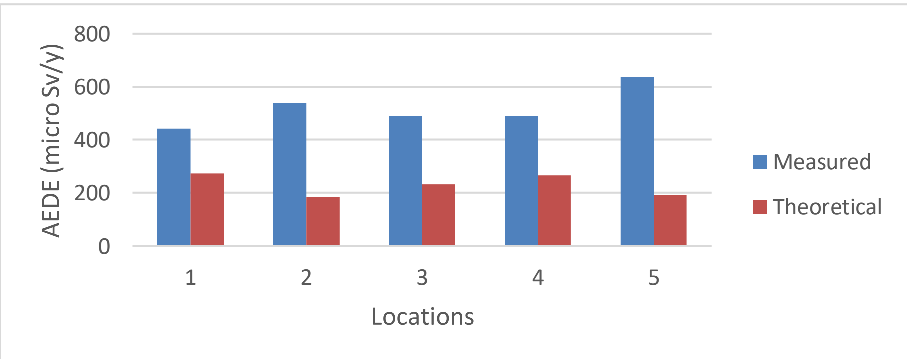

Fig. 2: The Annual Effective Dose Equivalent a) measured (Blue) and b) calculated (Red) in the five locations of Unitech campus

4. Conclusion

The Unitech campus situated in Lae falls in the 'Ring of Fire' region which is tectonically active. The tectonic activity results in frequent earthquakes and volcanic eruptions. The soil in Lae region is influenced by volcanic activity, sediment deposition and organic matter decomposition. The study of primordial radionuclides in soil gives insight into the radiation effects on inhabitants in the region. The soil samples collected from different regions were analyzed with LB 2045 NaI(Tl) Gamma ray spectrometer and the annual effective dose rates were calculated. The dose rates vary from 31.07 to 69.92 with an average value of 46.87$\pm$9.5 nGyh^{-1}. The indoor and outdoor Annual Effective Dose Equivalent varies from 152.4 to 317.35 with an average value of 229.91$\pm$48.12 µSvy^{-1} and 38.1 to 79.34 with an average value of 57.48+12.03 µSvy^{-1}. The dose rates were also measured using SOEKS Quantum Professional GM pocket survey meter. The measured dose rates were observed to vary from 0.09 to 0.13 with an average value of 0.106 mSvh^{-1}. The Indoor and Outdoor Annual Effective Dose varies from 441.5 to 637.7 with an average value of 520$\pm$66.5 µGyy^{-1} and 110.38 to 159.43 with an average value of 130$\pm$16.6 µGyy^{-1}. The measured value is greater than the calculated value because the measured value is influenced by weather conditions, cosmic rays and presence of radionuclides other than ^{238}U, ^{232}Th and ^{40}K and their progenies. The Radium Equivalent was found to be 101.43$\pm$20.97 Bqkg^{-1} which is much less than the maximum permissible limit of 370 Bqkg^{-1}. The indoor and outdoor Hazard Indices were found to be 0.028$\pm$0.06 and 0.36$\pm$0.9 which are within the safe limit of 1. The Excess Lifetime Cancer Risk is 1.5$\pm$0.3X10^{-4} comparable with the world average value of 1.45X10^{-4}.

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