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TERRESTRIAL GAMMA RADIATION ABSORPTION AND THE EFFECT OF ITS INHALATION TO THE INTERNAL ORGANS OF A HUMAN BODY: A CASE STUDY OF PAHANG STATE MALAYSIA

***Gabdo, H.T.[1] and Garba, N.N.[2]**
[1]Federal College of Education Yola, Nigeria
[2]Department of Physics, Ahmadu Bello University Zaria, Nigeria
*Correspondence author: tghamman2@gmail.com; GSM: +2348062291996, +2348034298444

ABSTRACT
Measurements for Terrestrial Gamma dose rate (TGDR) were made in Pahang state Malaysia with the average value found to be 176 nGy h^{-1}. The outdoor and the indoor annual effective dose is found to be 0.216 mSv and 0.863mSv respectively. This gives the Total annual effective dose (AED_{tot}) to be 1.079 mSv. The computed lifetime effective dose, cancer risk and the lifetime cancer risk for each person living in the state were 81 mSv, 6.28×10^{-5} and 4.7×10^{-3} respectively. These values are more than two times the world average values of 34 mSv, 2.82×10^{-5}, and 2×10^{-3} Considering the tissue weighing factors, the effective doses due to inhalation of gamma radiation on internal organs like the Gonads (testes or ovaries), Lung, liver and the bone surface of the body were found to be 35.2 nSv, 21.12 nSv, 8.8 nSv and 1.76 nSv respectively.
Key words: Terrestrial Gamma Dose Rate (TGDR), effective dose, cancer risk.

INTRODUCTION

Knowledge on terrestrial gamma radiation and radioactivity is important in health physics. The presence of naturally occurring radionuclides in the environment may result in an external and internal dose received by a population exposed to them directly and via the ingestion/inhalation pathways (Ramli *et al.,* 2003). The assessment of the radiological impact on a population, as result of the radiation emitted by these radionuclides, is important since they contributes to the collective dose of the population [UNSCEAR, 1998]. The biological effects of an absorbed dose of a given magnitude dependents on the type of radiation conveying the energy (X rays, Gamma rays, Beta Particle, Alpha Particles, Neutrons, or other form of Radiation) and the quantity of radiation absorbed. This variation is due to the differences in the way in which the different types of radiation interact with tissue. The cancer risk acquired from an equivalent dose depends on the organ receiving the dose. When different organ receive radiation then there is the need to make comparison of the risk involved and this is where effective dose is applied. The effective dose is calculated by determining the equivalent dose to each organ irradiated and then multiplying this equivalent dose by a tissue-specific weighting factor (w_t) for each organ or tissue type (ICRP 1990). This paper tried to show the effect of inhalation of Terrestrial Gamma Radiation (TGR) Dose Rate to the Internal Organs of a Human Body with a case study of Pahang state, Malaysia.

MATERIALS AND METHODS

- **The Study Area**

Pahang is the largest State in Peninsular Malaysia and the third largest state after Sabah and Sarawak in the whole of Malaysia (Fig.1). The state covers an area of 35,960 sq. km with a population of 1,500,817 inhabitants [Department of Statistics Malaysia (2010)]. The State is bounded on the north by Kelantan and Terengganu, the east by the South China Sea, the south by Johor and Negeri Sembilan and the west by Selangor and Perak (Fig. 2). Spanning north to the south of the state is the Titiwangsa mountain range that also forms a natural divider between the Peninsula's Eastern and Western regions. Pahang's highest point is Gunung Tahan (2,187 m). It is also Peninsular Malaysia's highest peak.

Pahang state is divided into eleven districts (Fig.2) with Cameron highlands district the smallest and Jerantut district the largest. Kuantan is the administrative capital. Pahang largest river is Pahang River which passes through most part of the state and it is the longest river in peninsular Malaysia.

Figure 1: Map of Malaysia with Pahang state highlighted. (wikipedia.org)

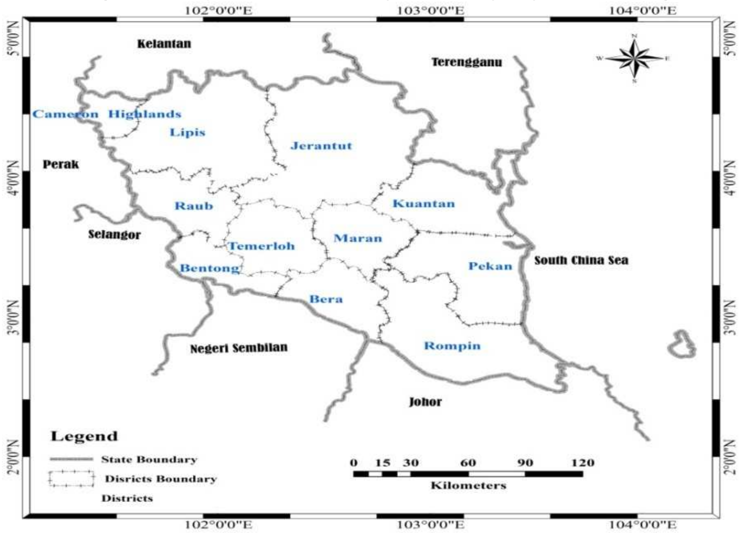

Figure 2: map of Pahang State Malaysia

- **Measurements of Gamma Dose Rate**

The TGDR were measured 1 meter above the ground by using Ludlum detector model 19, micro roentgen (μR) meter, manufactured by Ludlum, USA. It uses ($2.54 \times 2.54\ cm^2$) sodium iodide (NaI) crystal doped with thallium (Tl). The instrument was calibrated by Malaysia Nuclear Agency; it is a Secondary Standard Dissymmetry Laboratory (SSDL). A global positioning system receiver Garmin model GPSmap 76 was used for locating the latitude and longitude of each survey point.

The dose rates were measured from locations randomly covering the entire state (Fig. 3).

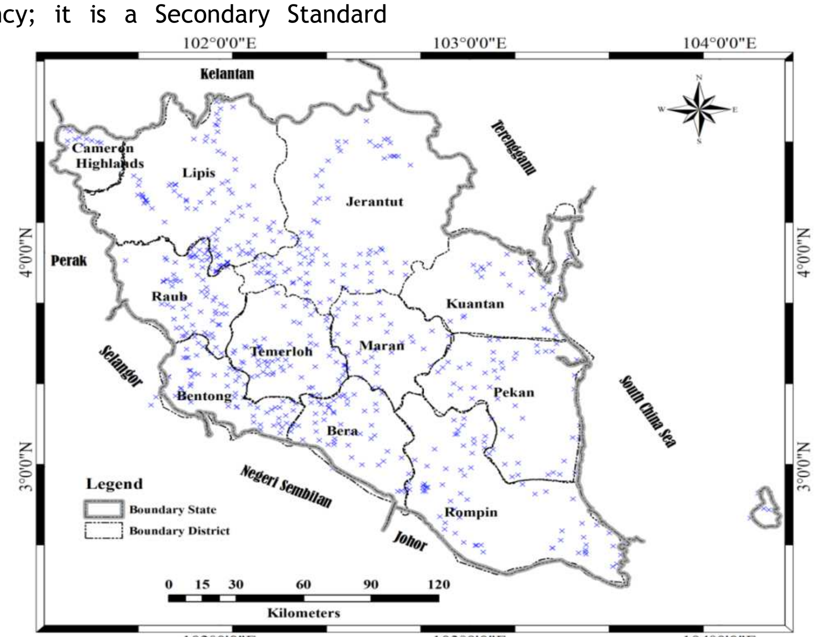

Figure 3: Map of the study area showing location of measurements.

RESULTS AND DISCUSSION

The value of TGDR measured from the outdoor locations, ranged from 26 nGy h^{-1} to 750 nGy h^{-1}, with a mean value of 176 ± 5 nGy h^{-1}. This value is three times the world and two times the Malaysian average of 59 and 92 nGy h^{-1} respectively, (UNSCEAR 2000). The mean values of terrestrial gamma radiation dose rates for the eleven districts are presented in Table 1. The Cameroun highland district has the highest mean dose rate of 285 nGy h^{-1} while Maran district the least with a value of 102 nGy h^{-1}.

Table 1: Descriptive Statistics of gamma dose rates in Pahang state, Malaysia.

Districts	Dose rate (nGy h^{-1})						95% Confidence Interval for Mean	
	N	Mean	Std. Error	Std. Deviation	Min	Max	Lower Bound	Upper Bound
Cameron Highland	11	285	13	42	222	350	257	313
Raub	85	235	17	158	26	750	201	269
Lipis	65	135	8	68	46	302	118	152
Temerloh	62	192	14	111	44	511	164	220
Jerantut	90	158	9	81	35	435	141	175
Bentong	62	248	19	146	78	631	211	286
Bera	84	139	10	89	39	522	119	158
Rompin	93	169	11	110	35	620	146	192
Pekan	32	154	14	78	39	348	126	182
Maran	29	102	9	51	39	216	82	121
Kuantan	27	149	13	68	59	349	122	176
Mean		**176**	**5**	**115**	**26**	**750**	**167**	**185**

The annual effective dose *(AED)* outdoors and indoors was obtained using the conversion coefficient, (0.7 Sv Gy^{-1}) from the absorbed dose in air. The outdoor and indoor occupancy factor (OF) are 0.2 and 0.8 (UNSCEAR 2000) respectively. Using Equation (1), the annual effective dose outdoor *(AED_{out})* and indoors are found to be $0.216\ mSv$ and $0.863\ mSv$ respectively.

AEDE (mSv y^{-1}) = Dose rate (nGy h^{-1}) × 24 hours x 365 days x OF × 0.7 x 10^{-6} ----------------- (1)

The values for AED_{out} and AED_{in} in the area are three times and two times the world average value of 0.07mSv and 0.41 mSv (UNSCEAR 2000) respectively. The Total annual effective dose AED_{tot} is given as $1.079\ mSv$. This is more than two times the world average value of total annual effective dose of 0.48 mSv.

Considering the tissue weighting factor, the biological effect on the internal organ of a human body due to inhalation of the radiation is calculated using equation (2).

Effective Dose (Sv) = Absorbed Dose (Gy) × tissue weighting factor (W_T) ------------- (2)

Table 2 shows the tissue weighing factor for individual organs of the body. This tissue or organ-specific weighting factor accounts for the variations in the risk of cancer induction or other adverse effects for the specific organ. These products of equivalent dose and tissue weighting factor are then summed over all the irradiated organs to calculate the "effective dose." The effective dose is, by definition, an estimate of the uniform, whole-body equivalent dose that would produce the same level of risk for adverse effects that results from the non-uniform partial body irradiation.

Table 2: Tissue Weighting Factors for Individual Tissues and Organs (ICRP 2012)

Tissue or Organ	**Tissue Weighting Factor (W_T)**	**ΣW_T**
Gonads (testes or ovaries)	0.20	0.20
Red bone marrow, Colon, Lung, Stomach	0.12	0.48
Bladder, Breast, Liver, Esophagus, Thyroid gland, Remainder**	0.05	0.30
Skin, Bone surfaces	0.01	0.02
TOTAL		**1.00**

** The remainder is composed of the following additional tissues and organs: adrenal, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus and uterus.

The effective dose received by each organ of the body from the mean absorbed dose rate of 176 nGy h^{-1} compared to the world average values with mean dose rate of 59 nGy h^{-1} is given in Table 3.

Table 3: Effective dose received by each organ of the body in the study area compared to the one obtain by using the world mean absorbed dose rate.

Tissue or Organ	**W_T**	**Effective dose (μSv) (This Study)**	**Effective dose (μSv) (world Average)**
Gonads (testes or ovaries)	0.20	0.035	0.012
Red bone marrow	0.12	0.021	0.007
Colon	0.12	0.021	0.007
Lung	0.12	0.021	0.007
Stomach	0.12	0.021	0.007
Bladder	0.05	0.009	0.003
Breast	0.05	0.009	0.003
Liver	0.05	0.009	0.003
Esophagus,	0.05	0.009	0.003
Thyroid gland	0.05	0.009	0.003
Remainder**	0.05	0.009	0.003
Skin,	0.01	0.002	0.0006
Bone surfaces	0.01	0.002	0.0006
TOTAL	**1.00**	**0.176**	**0.059**

This shows that the individual organ effective dose in this study is three times more than the world average values. The average lifetime effective dose *(AL_t ED)*, cancer risk *(R)* and life time cancer risk *(R_L)* to a person was estimated using Equation (3, 4 and 5) (ICRP, 1990).

$$AL_tED\ (mSv) = AED(mSv)\ L_tE\ (y) \quad (3)$$

$$R = AED \times RF \quad (4)$$

$$R_L = L_tE \times R \quad (5)$$

where; L_t *E* is a life expectancy in years and *RF* is the risk factor (5.82 × 10^{-2} Sv^{-1}) (BEIR VII 2006). The computed lifetime effective dose, cancer risk and the lifetime cancer risk for each persons living in Pahang were 81 mSv, 6.28×10^{-5} and 4.7 x 10^{-3} respectively. These values are more than two times the world average values of 34 mSv, 2.82 × 10^{-5}, and 2 × 10^{-3} (UNSCEAR 2000) respectively. This considers the life expectancy of 75 years for Malaysia (Department of Statistics Malaysia, 2014) and 70 years for the world (WHO, 2012).

CONCLUSION

The lifetime effective dose, cancer risk and the lifetime cancer risk for persons living in the state is more than twice the global average. The effective dose to each organ of the body due to inhalation of the gamma dose in the state is also found to be three times the global average. This computed effective dose and cancer risk values does not pose an immediate risk to individual living in the state but the continuous absorption of the radiation over time may results in cancer related ailments. It is also highly recommended that the people living in the state should be spending more time outdoor and also be living in a well ventilated area.

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