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ABSORBED DOSE RATE CONVERSION FACTORS FOR OUTDOOR AND INDOOR EXPOSURE IN TYPICAL NIGERIAN MUD HOUSES

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Abstract

This study present the findings of the absorbed dose rate conversion factors computed for external and internal exposure from sources of ionizing radiations in soil/floors and walls of a typical Nigeria mud houses. Two types of mud houses were considered in the study. Calculations were based on the point-kernel build-up factor method. The indoor dose rate in air per unit activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil of infinite depth are 0.442, 0.573 and 0.0423Gyh^{-1} per Bqkg^{-1} for mud walls with conical thatched roof building respectively, and 0.647, 0.799 and 0.0676nGyh^{-1} per Bqkg^{-1} for mud walls with dome mud roof house respectively. The outdoor dose rate in air per unit activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil of infinite depth are 0.401, 0.563 and 0.0397 respectively. The calculated outdoor dose rates results agreed satisfactorily with results of previous calculations that were based on similar assumptions while the indoor exposure values are higher and differ from one building design and material to another. The study recommends that external dose assessment should be based on conversion factors that take into consideration local (mud) building designs in their calculations.

Keywords: *Dose Rate Conversion Factor, Mud Houses, Nigeria.*

1.0 Introduction

Natural radioactivity and the associated external and internal exposures due to gamma radiation depend largely on the geological (soil and rock) and geographical conditions and appear at different levels and dimension in the environment of each region in the World **[1]**.

The natural terrestrial gamma dose rate is an important contributor to the average dose received by the world's population **[2,3]**. Estimation of the radiation dose distribution is vital in assessing the health risk to a population and serves as reference document to environment radioactivity changes **[4]**.

Estimation of doses is often based on conversion factors that relate dose to activity concentrations in the environment. Though some works have been carried out on the computation of conversion factors for various distributions of gamma ray isotopes and exposure geometrics **[5,6,7]**, much still have to be done in the area of domesticating the conversion factor to the model of buildings found in our rural communities. There are internationally adopted conversion factors for the commonly encountered geometries and distributions e.g. UNSCEAR gave a commonly conversion factor for outdoor exposures due to natural radionuclides in the ground**[1,8]**. However building exposure geometry varies according to building design and material used, hence there are no adopted standard indoor external dose conversion factors. Thus different values have been reported for various urban settlement and dwellings **[5]**. In rural dwellings in many parts of Nigeria, mud houses or buildings of simple designs and local material are common. It is often assumed that such houses have little effect of radiation exposure on the rural dwellers **[8]**.

This study is a deliberate effort to verify this assumption using two of the most common Nigeria rural building (mud houses) designs of one room building with cylindrical earth wall (mud) see figure 1, and conical thatched roof and cylindrical earth wall (mud) and a dome mud roof as shown in figure 2, by comparing conversion factors for indoor external dose in the houses with the corresponding outdoor values. These reported values will be a common conversion factor for indoor external dose rate for our local mud housed if verified by other authors.

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Fig1: A picture showing a typical Nigeria mud house with thatched roof.

Figure2: A picture showing a typical Nigeria mud house with dome roof

2.0 Computation Method

For a homogeneous distribution of γ-rays emitters in a medium of constant density ρ_m(gcm^{-3}), the dose rate conversion factor CF_D (r,ϵ) at a point in air (Gyy^{-1} per Bqg^{-1}) is given approximately by**[6,7]**

$$(CFD\ (r,\epsilon) = \frac{k.\rho m.P(\epsilon)}{4TT}.\frac{\mu}{\rho}(\epsilon)a.\left[\int_v^\infty \frac{1}{r2}.\beta(\mu m\epsilon.r_m).exp(-\mu a\epsilon.r_a).exp(-\mu m\epsilon.r_m).dv\right] \quad (1)$$

Where $P(\epsilon)$ is the emission probability ($s^{-1}Bq^{-1}$) of γ-rays with energy E per disintegration of the gamma emitter, $\mu a\epsilon$ is the linear attenuation coefficient in air (cm^{-1}), $\mu m\epsilon$ is the linear attenuation coefficient in the medium (cm^{-1}), $\frac{\mu}{\rho}(\epsilon)a$ is the mass energy absorption coefficient in air (cm^2g^{-1}), r is the total distance from the source to the receptor (cm), r_m is the distance travelled in the medium (cm), r_a is the distance travelled in air (cm), $\beta(\mu m\epsilon.rm)$ is the dose build-up factor for the medium, v is the volume of the medium (cm^3) and the proportionality constant k =5.04 x 10^{-3} $GygMeV^{-1}sy^{-1}cm^3Bq^{-1}$**[7]**. Dorschel et al,**[9]** build-up factor was used in this calculation i.e.

$$\beta(\mu m\epsilon, r_m) = Aiexp(\propto_1 \mu m\epsilon.r_m) + (1 - A_i)exp(-\propto_2 \mu m\epsilon.r_m) \quad (2)$$

The parameters $A_{i,}$ $\propto_1$ and $-\propto_2$ are not available for soil, but published data for concrete are considered to be a reasonable approximation **[9]**. The mass energy absorption and attenuation coefficients are obtained from the computations of Hubell, and ICRU**[10,11]**. CF_D is computed for two different exposure geometries. The outdoor exposure geometry is modeled with a point receptor in air at a height h above a semi-infinite volume of soil (earth floor) containing uniformly distributed gamma emitters. The CF_D is obtained by integrating contributions from volume elements dv_2 with co-ordinations from volume element dv_2 with co-ordinates ($r_2,\theta_{2,}\varphi_2$) over the entire soil volume. Substituting $dv_2 = r_2^2 \sin\theta_2 dr_2 d\theta_2 d\varphi_{2,} r_m = r_2 - {h}/{\cos\theta_2}, r_\alpha = {h}/{\cos\theta_2},$

The build- up factor and integration limits: ${h}/{\cos\theta_2}$ to $\propto$ for r_2, 0 to $for\varphi_{2,}$and 0 to ${\tau\tau}/{2}$ for θ_2 unto equation (1) and integratig over $r_2$and φ_2 given as.

$$CF_D(\epsilon) = \frac{k.\rho m.P(\epsilon).\epsilon.\mu}{2}\frac{}{\rho}C\epsilon D_\alpha.\frac{1}{\mu\alpha\epsilon}.\left[\frac{A_1}{1+\propto_1} + \frac{1-A}{1+\propto_2}\right].$$

$$\int_0^{\tau\tau/2} \exp\left(-\mu\alpha\epsilon\frac{h}{\cos\theta_2}\right).\sin\theta_2 . d\theta_2 \quad (3)$$

Equation (3) can be integrated analytically or numerically to obtained CF_D for the outdoor exposure.

The first building considered for the indoor external exposure in this study is a one room building with cylindrical earth wall (mud) and conical thatched roof. The house is modeled with a vertical annular cylinder of radius R, thickness L and height 2h closed at the lower end (floor) by a solid of infinite depth. The volume element in the wall dv_3 is described in terms of spherical coordinates (r_3, θ_3, φ_3) and Cartesian coordinates ($x_{1,}z_1$). It was assumed that both wall and the earth soil (floor) beneath the building are of the same homogeneous materials, the CF_D at height h above the ground along the axis of the cylinder is the sum of contributions from the two media given by.

$$CF_D(\epsilon) = \frac{k.\rho m.p(\epsilon).\epsilon.\mu}{4\tau\tau}\frac{}{\rho}(\epsilon)a\{2I_1 + I_2\} \quad (4)$$

Where I_1 and I_2 are integrals over the volume elements in the wall and the floor respectively given by:

$$I_1 = \int_{\varphi_{1=0}}^{2\tau\tau} \int_{Z_1=0}^{h} \int_{x_{1=R}}^{R+L} \frac{1}{(x_1^2+z_1^2)} . exp\left(-\mu_{\alpha\epsilon}\frac{R}{x_1}r_1\right) . exp - \mu m\epsilon$$

$$\left(1-\frac{R}{x_1}\right) r_{1.}\ \beta\left[\mu m\epsilon, \left(1-\frac{R}{x_1}\right) r_1\right] . x_1 . dx_1 . dz_1 . d\varphi_1 \quad (5)$$

and $I_2 = \int_{\varphi_{2=0}}^{2\tau\tau} \int_{r_{2=\frac{h}{\cos\theta_2}}}^{\propto} \int_{\theta_{2=0}}^{ta\,\mathrm{n}^{-1}\left(\frac{\mathrm{R}}{\mathrm{h}}\right)} exp\left(\mu\alpha\epsilon, \frac{h}{\cos\theta_2}\right) . exp\left[\mu m\epsilon\left(r_2 - \frac{h}{\cos\theta_2}\right)\right].$

$$\beta\left(\mu m\epsilon, r_2\frac{h}{\cos\theta_2}\right) . \sin\theta_2 . d\theta_2 . dr_2 . d\varphi_2 \quad (6)$$

The second building considered in the study is also a single room building with cylindrical earth wall (mud) and a dome mud roof. It is modeled with a vertical annular cylinder of radius R thickness L and height h, closed at the lower end (earth floor) by a solid of infinite thickness and at the top by a hemispherical shell of thickness T. Assuming the walls of the roof and the earth soil beneath the building are all of the same homogeneous materials, the CF_D along the axis at height h above the ground is the sum of contributions from the three media given by;

$$CF_D(\epsilon) = \frac{k.\rho m.P(\epsilon).\epsilon.}{4\tau\tau}\frac{\mu}{\rho}(\epsilon)a\{I_1 + I_2 + I_3\} \quad (7)$$

Where I_3 is the integral of volume element dv_3 with coordinates $(r_{3,}\theta_{3,}\varphi_3)$ over the volume of the hemispherical roof, while I_1 and I_2 are given by equations (5) and (6) respectively.

$$I_3 = \int_{r_{3=R}}^{R+T} \int_{\varphi_{3=0}}^{2\tau\tau} \int_{\theta_{3=0}}^{\tau\tau} exp(-\mu_{m\epsilon}R) . exp[-\mu_{m\epsilon}(r_3 - R)] . \beta(\mu_{m,\epsilon,} - R) \sin\theta_3 d\theta_3 d\varphi_3 d\mathrm{r}_3 \quad (8)$$

3.0 Results and Discussion

Table1: Dose rate conversion factors for outdoor and indoor external exposure (CF_D) of natural radionuclide

Natural Radionuclide	**Conversation factor CF_D (nGyh^{-1} per Bgkg^{-1})**			
	UNSCEAR standard	**Present work**	**Present work indoor**	
	Outdoor	**Outdoor**	**Indoor^1**	**Indoor^2**
^{226}Ra	0.461	0.401	0.442	0.647
^{232}Th	0.623	0.563	0.573	0.799
^{40}K	0.0414	0.0397	0.0423	0.0679

^{1}Houses with thatched roof. ^{2}Houses with mud dome roof

The integrals were performed numerically. The input data used are:

$h = 1m, R = 2m, L = 15cm, T = 10cm, \rho = 1.21\ x10^{-3} gcm^{-3}$ density for air and $\rho_m = 1.4gcm^{-3}$ for soil (medium) density.

The dose conversion factors calculated for monoenergetic gamma-rays from 0.011MeV to 10MeV strongly agreed with the reported values in those in**[6,7]**, particularly at energies above 0.049MeV. The slight variation at energies below 0.049Mev may be attributed to inadequacies in handling the soil/air interface problem as explained by Jacob and Paretzke**[12]**.

The dose conversion factors due to the natural radionuclide (^{266}Ra, ^{232}Th and ^{40}K) in the ground (floor) and walls were obtained by summing the products of emission probability and conversion factor for each of the γ-rays energies emitted by the radionuclides concerned. The results show that the indoor geometry leads to higher gamma dose than the outdoor geometry. The indoor effect is higher for building with a mud roof than buildings with thatched roof. The results for outdoor values compare reasonably well with earlier published values **[8]**. It is observe that real experimental exposure situations are slightly in variance with models that are based on assumption on the distributions of the γ-ray emitters and the symmetry of the media assumption made to simplify calculation. However, the results are considered to be reasonable estimates of the experimental values

Conclusion

The absorbed dose rate conversion factors for an outdoor and indoor exposure in two types of `Nigeria mud houses have been estimated. The conversion factor that relate absorbed dose rate in air to activity concentrations of γ-rays emitters in soil and walls of building were calculated. The calculation generated results that agree satisfactorily with results of previous calculations that were based on similar assumptions. It has also been observed that simple rural building designs could influence the external exposure of dwellers. Thus external dose assessment should be based on conversion factors that take into consideration local (mud) building designs and materials used in their calculations.

References

[1] UNSCEAR, 2000. Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation (Report to the General Assembly of United Nations) New York.

[2] Tso, M.Y and J.K Leung, 2000. Population dose distribution due to natural radiations in Hong Kong. Health Phys. 8:555-578.

[3] Senthilkumar., B., Dhavamani,V, Ramkuma,S and P. Philiminathan, 2010. Measurement of gamma radiation level in soil samples from Thanjavur, using γ-ray spectrometry and estimation of population exposure. J. Med. Phys.35: 48-53

[4] Obed R. I. Farai, I.P and N.N Jibiril, 2005. Population dose distribution due to soil radioactivity concentration level in 18 cities across Nigeria. J. Radiol. Prot.25:305-312.
[5] Stranden E. 1983; Assessment of the radiological impact of using fly-ash in cement. Health Phys.44(2):145-153
[6] Kocher, D.C. and Sjoreen A. L 1985. Dose-rate conversion factors for external exposure to photon emitters in soil. Health Phys.48(2):193-205
[7] Chen, S.Y., 1991; Calculation of effective dose equivalent responses for external exposure from residual photon emitters in soil. Health Phys.60(3):411-426.
[8] UNCEAR,1993. Sources of ionizing radiation, United Nations Scientific Committee on Effects of Atomic Radiation, 1993 Report to United Nations. New York.
[9] Dorschel, B., Schuricht, V., and J. Steuer, 1996. The Physics of radiation protection; Nuclear Technology Publishing, England (1996).
[10] Hubell, J. H., 1982. Photon mass attenuation and energy absorption coefficient from 1keV to 20MeV. Int.J. Appl Radiat. Isot. 33:1269-1290.
[11] International Commission on Radiation Unit and Measurements (ICRU 1994). Gamma-ray spectrometry in the environment ICRU Report 53 (International Commission on Radiation Unit and Measurements, Bethesda, Maryland).1994.
[12] Jacob, P. and Paretzke, H. G. 1986. Gamma-ray exposure from contaminated soil. Nucl. Sci. Eng.93:248-261