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Radioactivity Measurements for Some Building Materials in Yemen and Simulation of the Annual Effective Dose Rate

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Abstract. Fifty three samples were collected from two governorates in Yemen (Taiz and Hodeida) which covered the most citizens' use of these materials. Samples have been measured for gamma radiation using HpGe detector. The experimentally results for the activity concentrations have been used in the developed model of a Yemeni room to calculate the indoor exposure dose rate. The annual effective dose rate were ranged between [294.250 - 329.452],[1029.829] and[929.497] $\mu Svy^{-1}$for a habitant in a room built of concrete, granite and cement brick respectively.

Keywords: Radioactive contamination, MCNPcode, Annual effective dose and Yemen

1. Introduction

The environment in Yemen is varied between plains, deserts and volcanic islands. This variety has imposed the citizen using the available building materials. In the mountainous areas, nature has imposed the Yemenis to use rocks as the basic building material. Because of the big varieties of building materials used in different cities around Republic of Yemen and the shortage of information about the radioactivity of these materials, we did our research in order to make a regulation of the building materials in Yemen. Some very spread building materials like granite stone and cement brick were found with high value of the activity concentrations, a theoretical model was built for a Yemeni room with all the specification of the room in Yemen to calculate the indoor exposure dose rate. This modeled room was establish using MCNP code (Monte Carlo N-particle transport computer code) [1] and some mathematical treatments.

2. Experimental work

Fifty three samples were collected randomly from two governorates in Yemen Taiz and Hodeida. Taiz represents the mountainous areas and it is located between latitudes 14 ° and 12° to the north of the equator, and between longitudes 45° and 43° to the east of Greenwich, and Hodeida represents the plains, it lies the west on the red sea cost in the area between latitudes 14° and 16° to the north of the equator, and between longitudes 42° and 43° to the east of Greenwich. The raw building materials were collected partly from the places they were sold and partly from their original resources (mining places) or from actual building sites. The artificial building materials were collected from the places they were sold in either from shops or from factories so that the collected samples covered the most citizens' use of these materials.

3. Sample preparation

we followed the regular technique in the preparation of the natural samples measured by gamma spectrometry technique (HpGe detector).

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4. Experimental results

The most used building materials has been measured for gamma radiation using HpGe detector in order to assess the individual exposure dose rate and estimate the risks from spending most of our lifetimes inside buildings. The activity concentrations for raw materials were ranged between [(1.858±0.333-154.216±6.974),(0.288±0.165-229.141±3. 398),(3.389±0.266-1701.338±59.572)] $BqKg^{-1}$for^{226}Ra ,^{232}Th and^{40}K respectively, while the activity concentrations for the industrial materials were ranged between[(0.209±0.155-180.950±6.922),(0.491±0.088 252.854±3.939) and (2.480±0.958-1017.220±12.080)] $BqKg^{-1}$for ^{226}Ra,^{232}Th and ^{40}K respectively The heights value of the activity concentrations was in the cement brick (180.950±6.922 and 252.854±3.94) $BqKg^{-1}$ for ^{226}Ra and ^{232}Th respectively, and granite stone (154.216±6.974 and 229.141±3.398) $BqKg^{-1}$ for ^{226}Ra and ^{232}Th Radionuclides, which increases the risks from these radionuclides inside buildings, as we use these cement bricks as the main building materials in most of the buildings around the country and especially in the two areas under study in this research.

5. Activity analysis

5.1. The radium equivalent

The radium equivalent (Ra_{eq}) was calculated for all samples. Because the distribution of ^{238}U,^{232}Th and ^{40}K in nature is not uniform , the radium equivalent Ra_{eq} is proposed to comparing the specific activity of material containing different amount of ^{238}U, ^{232}Th and ^{40}K ,and it is defined as a weighted sum of the activity concentrations of the^{238}U, ^{232}Th and ^{40}K [2].The measured specific activity *(Bq/kg)* of ^{238}U, ^{232}Th and ^{40}K for each sample are used to calculate Radium equivalent Ra_{eq} *(B_q/k_g)* using the following equation [3] :

$$Ra_{eq} = C(R_a) + 1.43C(Th) + 0.077C(K) \quad (1)$$

Where *C(Ra), C(Th)* and *C(K)* are the activity concentrations in $BqKg^{-1}$. For the limitation of the annual effective dose to be *1mSv* for the population, the maximum value of this index must be less than 370 $BqKg^{-1}$.

5.2. The external hazard

Also for this limitation the external hazard which is given by [4]:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \le 1 \quad (2)$$

5.3. The internal hazard

The internal hazard index H_{in} can be examined according the following criterion [3].

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \le 1 \quad (3)$$

For the safe use of the materials in the Yemeni buildings H_{in} should be less than unity.

Table 1: The calculated Ra_eq ,Hin and Hex in industrial and raw materials.

Index	Industrial materials ($BqKg^{-1}$)	Raw materials ($BqKg^{-1}$)
Radium equivalent	**1.340±0.349– 603.698±13.463**	**5.718±1.747 - 593.177±12.856**
Internal hazard	**0.004±0.001- 2.120±0.055**	**0.023±0.007 – 2.019±0.054**
External hazard	**0.004±0.001-1.630±0.036**	**0.006±0.001-1.602±0.035**

6. Modeling

Our model is a developed for a Mustonen model [5] and according to Mustonen the indoor exposure dose rate at a point in dwelling may be written:

$$x = \frac{kC\rho}{4\pi}\sum_i EiN(Ei)\mu a(Ei)\int \frac{B_D(Ei,s)}{l^2}e^{-di}dv \quad (4)$$

, While *x* The exposure dose rate ρ is the density of the material, *C* is the activity per unit weight. *k* is the coefficient to change the exposure in to Roentgen unit ;(k = 1.462 $X10^{-2}$ $R.Mev^{-1}.cm^{-3}$) *E* is the photon energy, *N (E)* is the number of photons with energy *Ei* emitted per unit of primary disintegration, $\mu a(Ei)$ is the linear absorption coefficient in air, μ_m (Ei) is the attenuation coefficient in the material $B_D(E_i, s)$: The build-up factor, S the distance the photon travels in the material, l The distance from the source point and V the volume of the room, *di* The optical distance between the source and the detection point.

$$di = s\mu_m(Ei) + (L - S)\mu_a \quad (5)$$

The attenuation coefficients (μ_m) for (ordinary concrete, granite and cement brick) have been calculated, which are the mostly used building materials in the selected cities using MCNP code.

7. The specific exposure rate

The specific exposure rate per unit activity concentration (Q) is given by the following relation:

$$Q = \frac{k\rho}{4\pi}\sum_i EiN(Ei)\mu a(Ei)\int \frac{B_D(Ei,s)}{L^2}e^{-di}dv \quad (6)$$

We use in our calculation the Berger's formula of the build-up factor has the simplicity of the linear form but fits the buildup Factor data over a long range, and it is given by [6]

$$B\,(Ei,s)=1+a(Ei)\ \mu_m(Ei)s\exp(b\mu_m s) \quad (7)$$

Our assumption for the room that it is a spherical layer with radius of 150 cm and thickness of 30 cm. These specifications are compatible with the design of the Yemeni room. For the calculation of the flux at a point in the centre of the room, or any other point from a volume source like concrete or granite room we supposed that the gamma radiation source as a point source inside the material wall "q", then the contribution from all point sources to the total flux is added in the integral over the thickness of the room, while the integration was done using the spherical coordinates.

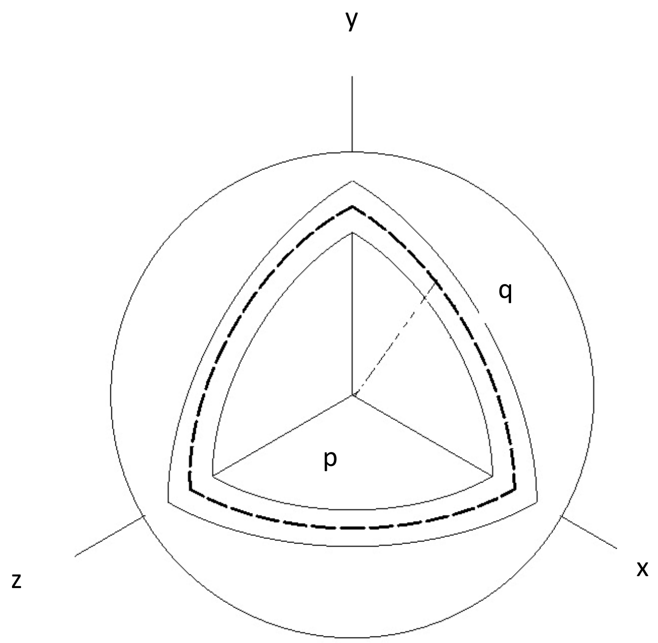

Fig. 1:

Table 2: The calculated specific exposure dose rate in μR Bq-1Kg-1

The material	The specific exposure rate in µR $Bq^{-1}Kg^{-1}$		
	^{226}Ra	^{232}Th	^{40}K
concrete	0.046	0.096	0.008075
Granite	0.0043	0.0867	0.00773
Cement brick	0.0436	0.0994	0.00523

8. The annual effective dose rate in the middle of a room built with different types of building material

The annual effective dose rate is calculated according to this relation [7]:

$$E_{wall} = Y\ T\ (C_{Ra}\ Q_{Ra} + C_{Th}\ Q_{Th} + C_K\ Q_K)\ m \quad (9)$$

Where *Y* is the factor that converts absorbed dose in air to effective dose in humans (Sv Gy^{-1}), T is the indoor occupancy factor and C_{Ra}, C_{Th} and C_K are radioactivity concentrations for ^{226}Ra, ^{232}Th and ^{40}K, respectively. The quantities Q_{Ra}, Q_{Th} and Q_K are the respective specific absorbed dose rates which have been calculated for a typical Yemeni room built with concrete, granite stone and cement brick, and m is the fraction of the wall that made up of the material type (concrete, granite or cement brick). It suppose here to equal (32%, 58% and 51) for concrete, granite and cement brick respectively.). It suppose here to equal (32%, 58% and 51) for concrete, granite and cement brick respectively

Table 3: Annual effective dose rate for different types of building material.

City	Type of material	The total annual effective dose rate of whole room (µSvy^{-1})
Hodeidah	Concrete	329.452
Taiz	Concrete	294.250
-	Granite stone	1029.829
-	Cement brick	929.497

The annual effective dose for concrete (329.452 ,294.250) Sv $y^{-1}$is less than that in Jordan (470µ Sv y^{-1})[8] ,Nigeria (400 Sv y^{-1}) [7], Cuba (429.2 µ*Svy*$^{-1}$)[9] and less than the dose in typical building in Hong Kong (1459) µ*Svy*$^{-1}$ [10] but lied within this range of the total (outdoors plus indoors) annual effective dose equivalent from terrestrial gamma radiation, averaged over the world's population (30µSv-400 µSv) [11].In granite stone the annual effective dose*(*1029.829*)* µ Sv y^{-1} is higher than that obtained in Jordan *(*520 µSv y^{-1}*)* [8] ,but within the range of the effective dose rate calculated for granite stone in Iran (480-1050 *µ*Svy^{-1}) [12],but it is twice the world average range .The effective dose rate calculated for cement brick in this work is higher than that dose calculated in Jordan (442 *µ*Svy^{-1}) [8] , Cuba (258.59 *µ*Svy^{-1}) [9], and also is twice the world average range.

9. Acknowledgements

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10.References

[1] X-5 Monte Carlo Team, MCNP — *A General Monte Carlo N-Particle Transport Code*, Version 5, April 24, 2003

(Revised 10/3/05).

[2] *United Nations Scientific Committee on the Effect of Atomic Radiation*. Ionizing radiation sources and biological effects. Report A/37/45 (NY: UN),(1982).

[3] J.Bereteka and P.J. Mathew, Natural Radioactivity of Australian building materials, industrial wastes and by-products, *Health Physics* 48 (1): 87-95 (1985).

[4] S.Roy, M.S.Alam, F.K.Miah and B.Alam, concentrations of naturally occurring radionuclides and fission products In brick samples fabricated and uses in and around greater Dhaka*, Radiation Protection Dosimetry* 88(3) 255-260 (2000).

[5] Mustonen, R. Methods of evaluation of radiation form building materials. *Radiation. Protection. Dosimetry* . 7, 235–238 (1984).

[6] Chilton, A. B., Shultis, J. K. and Faw, R. E. *Principle of Radiation Shielding* (Englewood Cliffs, NJ: Prentice-Hall Inc.) (1984).

[7] Ademola, J. A. and Farai, I. P. Annual Effective Dose Due to Natural Radionuclides in Building Blocks in Eight Cities of South Western Nigeria .*Radiation. Protection. Dosimetry*. 114, No. 4, 524–526 (2005).

[8] Ahmad, N., Hussein, A. J. A. and Aslam. Radiation dose in Jordanian dwellings due to natural radioactivity in construction materials and soil. J. *Environ. Radioact*. 41, 127–136 (1998)

[9] Brígido Flores, A. Montalván Estrada, R. Rosa Suárez, J. Tomás Zerquera, A. Hernández Pérez. Natural radionuclide content in building materials and gamma dose rate in dwellings in Cuba.*Journal of Environmental Radioactivity*.99,1834-1837 (2008).

[10] K.N. Yu, Z.J. Guan,M.J. Stokes, E.C.M. Young, The assessment of the natural radiation dose committed to the Hong Kong people, *Journal of Environmental Radioactivity*, 17 (1) , 31-48,(1992).

[11] *Nations Scientific Committee on the Effects of Atomic Radiation*, Ionizing radiation, sources and biological effects, report to the general assembly with scientific Annexes, (AnnexB) exposure to natural radiation sources,(UNSCEAR ,1982).

[12] Jahangiri, A., Ashrafi, S. Natural Radioactivity in Iranian Granites Used as Building Materials, *Journal of Environmental Studies*. 36, No. 56 (2011).