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Review studies of the radioactivity of building materials

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Abstract: Different types of houses where we stayed are radioactive due to background radiation emitted from the earth's crust and houses making materials like cement, bricks, and sand. The human body gets maximum exposure to natural radiation (about 80%) indoors compare with outdoors. This background radiation dose depends on the types of houses and materials used. The level of natural radiation differs from place to place around the world as the concentration of materials in the earth's crust varies. The main radionuclides in building materials are mainly from ^{238}U and ^{232}Th decay series and ^{40}K. The types of construction materials used in building houses can be affecting the dose rate of natural background radiations. The study of radioactivity in building materials is important to monitor the levels of radiation indoors to which human is exposed directly or indirectly. Several studies have been done very recently and different observations were reported. In this article, a review of studies of radioactivity in building materials was carried out.

Keywords: Natural radiation, building materials, radioactivity, dose rate

INTRODUCTION

Natural radioactive isotopes are found present in our environment and the knowledge of this radioisotope concentration level and their distribution in the environment has become a focus of much attention in assessing the human risk and other biotic organisms in the environment from the natural radiation exposure [1]. According to the UNSCEAR, 2000 [2], there exist about 340 naturally occurring nuclides, of which about 70 are radionuclides and are found mainly among the heavy elements, with the mass number (A) >200. Most of the general population spends their time (about 80%) indoors as compared with the outdoors (about 20% [3,4], and there is a high chance of getting both external as well as internal radiation exposure from natural radionuclides present in the building materials [5-7]. All construction materials used for building our houses such as concrete, brick, sand, marble, granite, limestone, and gypsum mainly contain natural radionuclides such as Uranium (^{238}U) and Thorium (^{232}Th) and their decay products and radioactive Potassium (^{40}K) [8,9]. 98.5% of the radiological effects in the ^{238}U series are produced by radium and its daughter products, so radium and its decay radionuclides are radiologically very important [8]. Radon, thoron, and their progenies contribute the maximum natural radiation absorbed dose to occupational workers and the general public [9]. These radionuclide gases (Radon & Thoron) are present in the ambient air as well as in the indoor atmosphere [10]. It is also expected to be more concentrated indoors than outdoors. Radon and Thoron exhalation is associated with the presence of ^{226}Ra and ^{232}Th. This naturally occurring Radon gas is considered the second commonest cause of lung cancer [11,12]. The natural radioactivity in building material or even in a soil sample is usually determined from ^{226}Ra, ^{232}Th, and ^{40}K contents. The average indoor-effective dose of the worldwide population due to gamma rays from building materials is estimated to be about 0.4 mSv/y [2]. Studies on building materials have reported that granite and phosphogypsum enhance indoor absorbed dose rate up to five times than the dose criterion [13], whereas building materials collected from Yan'an, China may be used safely as the construction materials of houses [14]. Hence, monitoring natural radioactivity in building materials becomes important to evaluate any possible risk to human health and develop any precautionary measures in using building materials. This research work aims to survey and implement a radiometric analysis for several international studies on the radioactivity of building materials to provide data and a baseline map of natural radioactivity levels in building materials.

Sample preparation

Samples such as building materials and soil from the study area are collected and crushed into small sizes [15]. The samples are then subjected to drying in a hot air oven at 110°C for 24 hr or a suitable temperature and duration. After that, the sample is ground into a fine powder, homogenized, and sieved through appropriate mesh sizes. The samples are then packed in suitable air tide plastic containers to restrict the escape of radon gas from the packed. The processed samples are weighed and stored carefully for about one month to achieve the equilibrium condition of ^{226}Ra and ^{232}Th along with their respective daughter nuclides [16,17].

Radiological analysis of building materials

The prepared Samples of building materials from the study areas are then sieved through a mesh size of about 0.45 mm [16], approximately 250 g of this homogeneous fine mesh of each sample material is then packed inside a plastic container with predefined geometry, weighed, and properly sealed to restrict the escape of radon gas from the packed. The processed samples are then stored carefully for about 4 weeks to achieve the equilibrium condition of ^{226}Ra and ^{232}Th along with their respective daughter nuclides [16]. A suitable scintillation detector (e.g. 3" x 3" NaI(Tl)) or Germanium-based gamma spectrometer is employed with adequate shielding [18-21]. Measurements of the radiation emitted from the building materials are normally performed using calibrated standard source samples, which contain a known activity of gamma-ray emitters radionuclides, namely ^{133}Ba (356.1 keV), ^{137}Cs (661.6 keV), ^{60}Co (1173 KeV and 1332 KeV), and ^{226}Ra (1764.5 keV) [11 - 15]. All samples are then subjected to gamma spectral analysis with a suitable counting time of e.g. 36,000 s [23]. The activity concentration of ^{226}Ra is determined from the average activity concentration obtained from the prominent gamma lines of ^{214}Bi (1.76 MeV) and ^{214}Pb (0.35 MeV) and that of ^{232}Th is estimated from the average concentration obtained from the gamma lines of ^{212}Bi (0.73 MeV), ^{228}Ac (0.91

MeV), and ^{208}Tl (2.61 MeV) respectively. However, ^{40}K is evaluated from its gamma photo-peak (1.46 MeV) [15,18-19]. The activity concentrations of ^{226}Ra, ^{232}Th series, and ^{40}K are calculated using the following equation [20].

$$A\left(\frac{Bq}{Kg}\right)=\frac{N}{\epsilon\beta M} \qquad (1)$$

where, N = the net gamma counting rate (counts per second), ε = the detector efficiency of the specific gamma-ray, β = the absolute transition probability of gamma decay, and M = the mass of the sample (kg).

The relative concentration and distribution of ^{226}Ra, ^{232}Th, and ^{40}K are usually not uniform in the environment as well as in building materials. Hence, Radium equivalent (Raeq) is the most commonly used single quantity to represent natural radioactivity associated with those materials containing ^{226}Ra, ^{232}Th, and ^{40}K. Estimation of the activity concentration is made on the assumption that 370.0 Bq/kg of ^{226}Ra, 259.0 Bq/kg of ^{232}Th, and 4810.0 Bq/kg of ^{40}K produce similar gamma dose rates as mentioned by the following equation [24].

$$Ra_{eq}=A_{Ra}+1.43A_{Th}+0.077A_{K} \qquad (2)$$

where, A_{Ra}, A_{Th}, and A_K are the specific activities of ^{226}Ra, ^{232}Th, and ^{40}K in Bq/kg, respectively.

Activity concentration index or gamma index "I," is defined to examine the applicability of using building materials in construction. It is defined by the following expression [25] as

$$\mathrm{I}=\frac{A_{Ra}}{300}+\frac{A_{Th}}{200}+\frac{A_{K}}{3000}\leq 1 \qquad (3)$$

This is a very simple criterion of the applicability of building materials.

Adsorbed dose rate (D): The absorbed dose rate due to gamma radiation in the air for a standard room dimension and common building materials with naturally occurring radionuclides ^{226}Ra, ^{232}Th, and ^{40}K was determined using the guidelines given in EC report 112[25] as

$$\mathrm{D(nGy/h)}=(0.092\times A_{Ra})+(1.1\times A_{Th})+(0.08\times A_{k}) \qquad (4)$$

The annual effective dose (D_{eff}) is calculated by using the dose conversion factor of 0.7 Sv/Gy from the absorbed dose in air received by an adult and a value of 0.8 as an indoor occupancy factor [2]. The D_{eff} due to gamma radiation from building materials was evaluated as

$$D_{eff}(mGy/y)=D(nGy/h)\times 8760h\times 0.8\times 0.7(Sv/Gy)\times 10^{-6} \qquad (5)$$

Result and Discussions

The radioactive materials present in the construction materials are the main sources of gamma radiation apart from the natural background radiation of the location. The general population uses building materials that may contain naturally or technologically enhanced levels of radioactivity in high-background radiation areas, which may result from the building materials containing high levels of primordial radionuclides and other radionuclides. Maximum people spend more than 80% of their time in houses and office buildings and are exposed to radiation emitted by the radionuclides present in the building materials [26]. As an example, the average person in the UK spends only 8% of his/her time out of doors. Maximum irradiation of natural gamma radiation is from building materials, where the concentration of Radon (^{222}Rn) is high compared with outdoor. Geology is a very important factor in controlling and impacting the natural source and distribution of natural gamma radiation and radon gas, so areas with a high level of radon potential and natural radioactivity can be mapped using geological and geophysical information. However, the natural radiation absorbed dose rate to the population depends on additional factors such as soil type, house design of construction, and lifestyle [27]. Some developed countries such as Germany, China, Canada, Finland, Sweden, the USA, and the UK, have already analyzed the relationship between concentrations of radon in houses and the incidence of lung cancer. All these studies indicate that higher lung cancer rates occur in people exposed to higher levels of radon gas. Table 1 presents typical values of radionuclides in constructing common building materials used in different countries of the world [28-33]. Whereas, Table 2 represents the natural radionuclide concentration of building materials and their radiological parameters in India [17, 34].

Conclusion:

Humans are always exposed to natural radionuclides present in building materials. The concentration of radionuclides in soils is an indicator of natural radioactive accumulation in the environment, which affects humans, animals, and plants. These natural radionuclides have a long life, with half-lives often about hundreds of millions of years. Exposures to natural radiation sources in the building are due to indoor inhalation exposures due to ^{222}Rn and their daughters. Natural radiation exposures depend on the location, elevated levels of NORMs in specific localized regions, and human activities and practices. Especially, building materials of various types of houses and the design and ventilation systems strongly influence the indoor levels of radon and its decay products, which contribute to the doses through inhalation. The global value of the total contribution from natural radiation sources to the general population is about 2.4 mSv/y. Most of the exposures are produced by the natural radiation of the natural radionuclides present in the environment and building materials.

Table 1: Radioactivity content of building materials in some countries

Building materials	Radioactivity concentration (Bq/Kg)			Country reference
	226Ra	232Th	40K	
Cement	39.6±1.4	28.9±0.9	290.8±1.2	Iran
	26.1	28.6	272.9	Pakistan
	41	27	422	Brazil
	20	13	241	Greece
Gypsum	8.1±0.9	22±0.2	116.2±12	Iran
	9.4	3.9	40.7	Turkey
	14	2	31	Syria
	6.2	13.3	173.7	Pakistan
	13.3	5.3	39.5	Bulgaria
Gravel	20.4±1.2	6.3±0.3	450.7±14	Iran
	13.9	14.8	171	Australia
	10.3	BDL	933	Brazil
	33.3	33.3	14.8	USA
Bricks	37±1.5	12.2±0.7	851.4±15	Iran
	65	51	675	Algeria
	12	7	332	Kuwait
	35	45	710	Greece
	23	35	431	Pakistan
	35	72	585	Sri Lanka
	59	50	714	China

Table 2: Natural activity concentration of building materials in India

Building materials	Activity concentration (Bq/Kg)			Ra_{eq} (Bq/Kg)	I	D nGy/h
	226Ra	232Th	40K			
Bricks	9.0-32.9	69.9-140.2	366.6-1596.4	137.2-356.3	0.5-1.3	114.5-312.2
Sand	8.7-46.6	83.5-129.4	302.7-2159.6	151.4-397.9	0.6-1.5	124.1-358.0
Cement	35.0-38.0	33.0-35.0	187.7-1766.5	102.3-218.8	0.4-0.9	88.3-211.0
Soil	BDL-94.1	56.2-146.5	346.4-1222.9	107.1-397.7	0.4-1.5	89.6-345.6
Clay	8.7	72.2	428.8	145.0	0.6	121.7

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