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Assessment of natural radioactivity levels and radiation hazards for building materials used in Kuthua area ofJ&K UT

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Abstract
Building materials are one of the potential sources of indoor radioactivity because of the naturally occuring radionuclides in them. External as well as internal exposures are the two pathways of radiation dose imparted to the human beings from the building materials. Natural radioactivity levels of 35samples of natural and manufactured building materials used in Kuthua area, J&K have been investigated by using gamma spectrometer with NaI(Tl) detector. The samples were collected from local market and construction sites. From the measured γ-ray spectra, activity concentrations were determined. The activity ranged from 12.7 ±3.4 to 38.4 ±4.4 Bqkg^{-1} for ^{226}Ra, from 13.2±0.7 to 49.2±2.3 Bqkg^{-1} for ^{232}Th and from 64±3 to 340±6.7 Bqkg^{-1}^{40}K. The activities are compared with available reported data from other countries and with the world average value for soils. The radium equivalent activity Raeq, the external hazard index Hex and the absorbed dose rate in air D in each sample was evaluated to assess the radiation hazard for people living in dwelling made of materials studied. All building materials have shown ranged from 39.64 to 122.71 Bqkg^{-1}. These values are lower than the limit of 370 Bq kg^{-1} adopted by OECD the Organization for Economic Cooperation and Development. The absorbed dose rate in indoor air are lower than the international recommended values of 55 n Gy h^{-1} for all test samples. All the materials examined are acceptable for use as building materials as defined by the OECD criterion.

***Key words:** natural radioactivity, building materials, radiation hazard parameters.*

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I. Introduction

All building raw materials and products derived from rock and soil contain various amounts of mainly natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series, and the radioactive isotope of potassium (^{40}K). In the ^{238}U series, the decay chain segment starting from radium (^{226}Ra) is radiologically the most important and, therefore, reference is often made to ^{226}Ra instead of ^{238}U. These radionuclides are sources of the external and the internal radiation exposures in dwellings. The external exposure is caused by direct gamma radiation while theinhalation of radioactive inert gases radon (^{222}Rn, a daughter product of ^{226}Ra) and thoron (^{220}Rn, a daughter product of ^{224}Ra), and their short-lived secondary products lead to the internal exposure of the respiratory tract to alpha particles. The specific activities of ^{226}Ra, ^{232}Th and ^{40}K in the building raw materials and products mainly depend on geological and geographical conditions as well as geochemical characteristics of those materials.

The radiological impact from the natural radioactivity is due to radiation exposure of the body by gamma-rays and irradiation of lung tissues from inhalation of radon and its progeny. From the natural risk point of view, it is necessary to know the dose limits of public exposure and to measure the natural environmental radiation level provided by ground, air, water, foods, building interiors, etc., to estimate human exposure to natural radiation sources. Low level gamma-ray spectrometry is suitable for both qualitative and quantitative determinations of gamma-ray-emitting nuclides in the environment. The concentration of radio-elements in building materials and its components are important in assessing population exposures, as most individuals spend 80% of their time indoors. The average indoor absorbed dose rate in air from terrestrial sources of radioactivity is estimated to be 70 nGyh^{-1}.

Great attention has been paid to determining radionuclide concentrations in building materials in many countries.

In J&K UT the information about the radioactivity of building materials is limited therefore, it is important to study: 1) Assess natural radioactivity (^{226}Ra, ^{232}Th and ^{40}K) in building materials used in J&Kby using γ-ray spectrometry, 2) Calculate the radiological parameters (radium equivalent activity Raeq, external hazard index Hex and absorbed dose rate) which is related to the external γ-dose rate to assess the radiological hazards to human health and for checking its quality in general and knowing its effect on the environment, 3) The measured activity concentrations for these natural radio-nuclides were compared with the reported data for other countries. The data obtained are essential for development of standards and guidelines concerning the use and management of building materials.

Sampling and sample preparation

A total of 35 samples of natural and manufactured building materials used in Kuthua area, J&K UT have been collected from local market and construction sites. The sample each about 1 kg in weight were dried in an oven at about 105°C to ensure that moisture is completely removed. The samples were crushed, homogenized, and sieved through a 200 mesh, which is the optimum size enriched in heavy minerals. Weighted samples were placed in polyethylene beaker, of 350 cm^3 volume each. The beakers were completely sealed for 4 weeks to reach secular equilibrium where the rate of decay of the daughters becomes equal to that of the parent. This step is necessary to ensure that radon gas confined within the volume and the decay products will also remain in the sample.

Instrumentation

Radioactivity measurements were performed by gamma ray spectrometer, employing a scintillation detector 3"x 3". Its hermitically seald assembly which includes a high-resolution NaI (Tl) crystal, photomultiplier tube, an internal magnetic light shield, an aluminum housing and a 14 pin connector coupled to PC - MCA Canberra Accuspes. It has the following specifications:

1 - Resolution 7.5% specified at the 662 keV peak of ^{137}Cs.
2 - Window Alumminum 0.5mm thick, density 147 mg/cm^2.
3 - Reflector oxide; 1.6mm thick; density 88 mg/cm^2.
4 - Magnetic / light shield-conetic lined steel.
5 - Operating voltage positive 902V.dc

The efficiency calibration curve was made using different energy peaks covering the range up to ≈2000 keV. Measurements were performed with calibrated source samples, which contain a known activity of one or more gamma-ray emitters of the radionuclides ^{60}Co (1173.2 and 1332.5 keV), ^{133}Ba (356.1keV), ^{137} Cs (661.9 keV) and ^{226}Ra (1764.49 keV). With certified accuracies of $\leq$ 2 % supplied by PTB Braunschweig, Germany. We used for calculating the absolute efficiency the eq.(1)

$$Eff = \frac{100.N(p)}{I.TOC.A(BOC)} \text{---------------} (1)$$

With: N_p= net peak area (count/ S) at E_γ, I_γ= intensity of emitted γ-ray(%), *TOC* = time of counting (S),and A_{BOC}= activity (Bq) of the standard source at beginning of counting (*BOC). A_{BOC}* was calculated by eq. (2)

$$A_{BOC} = A_{DOC} \;.\; \exp(-\lambda\cdot(BOC\text{-}DOC) \text{----------} (2)$$

Where A_{DOC} is the activity (Bq) of the standard source at date of calibration *DOC,* and $\lambda(s^{-1})$ is the decay constant. Daily efficiency and energy calibrations for each sample measurement were carried out to maintain the quality of the measurements. (BOC - DOC) defined as elapsed time between initial calibration and moment of measurement.

Calculation of activity

Calculations of count rates for each detected photopeak and radiological concentrations (activity per mass unit or specific activity) of detected radionuclides depend on the establishment of secular equilibrium in the samples. The ^{232}Th concentration was determined from the average concentrations of ^{212}Pb (238.6 keV) and ^{228}Ac (911.1 keV) in the samples, and that of ^{226}Ra was determined from the average concentrations of the ^{214}Pb (351.9 keV) and ^{214}Bi (609.3 and 1764.5 keV) decay products .

The activity concentration in $Bqkg^{-1}$ (A) in the environmental samples wasobtained as follows:

$$A=\frac{Np}{e \times \eta \times m} \text{---------------} (3)$$

Where Np = net count rate (cps), measured count rate minus background count rate,e is the abundance of the γ-line in a radionuclide, η is the measured efficiency for each gamma-line observed for the same number of channels either for the sample or the calibration source, and m the mass of the sample in kilograms.

II. Results And Discussion

Cement is an important construction material for houses and buildings in urban areas of J&K UT. It is used for blocks and concrete manufacturing as well as for plastering the buildings walls, which made of bricks. However, detailed information of the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in cement and other building materials used in J&K UT is not available in literature.

Table-1

The average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq.kg^{-1}for building materials used in Kuthua area of J&K UT

Type of Material	Ra-226	Th-232	K-40
cement	38.4 ±3.8	45.3±1.2	86±4
Sand	12.3 ±1.4	19.7±1.5	260±5
Soil	28.6±4.2	49.2±2.5	66±3.6
Gypsum	33.28±4.7	47.2±2.8	88±4.4
Granite	23±1.4	30.0±0.4	340±6.7

Table-2

The average values of radiation hazard parameters for Building materials used in Kuthuaarea,ofJ&K UT

Type of material	Raeq (Bq kg^{-1})	Dose rate (nGy h^{-1})	Hex
Cement	108.23	48.94	0.19
Sand	59.88	29.49	0.17
Soil	83.84	37.01	0.17
Gypsum	122.71	54.27	0.24
Granite	61.89	25.08	0.17

This study is a continuation of our ongoing project related to the measurement of specific activity of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K in environmental samples from J&K UT using gamma-ray spectrometric technique and estimation of the gamma dose rate from these radionuclides. The average of measured activity values together with their respective standard deviation (SD) of the above natural radionuclides are presented in Table 1. As can be seen from Table 1, the activity concentrations of ^{226}Ra, of sand, gravels, marble, Soil, gypsum and granite were lower than that of the world average for soil 35 Bq kg^{-1}. The activity levels of cement samples were slightly higher than the world average value of soil. For all building materials under investigation the measured thorium activities were higher than the radium activities. The observed thorium-232 activities were in the range 13.2-49.2 Bqkg^{-1} while the observed potassium-40 activities were in the range 64-340 Bqkg^{-1}.

Estimation of exposure risk

In this study, the radiological parameters such as indices of radium equivalent activity, external hazard index, and indoor absorbed gamma dose rate were calculated to estimate the exposure risk for building materials used in Kuthua area in J&K UT. Table 2 presents the average values of absorbed dose rate, radium equivalent activity and external hazard index.

Absorbed dose rate

Conversion factors to transform specific activities A_K, A_{Ra} and A_{Th} of K, Ra and Th, respectively, in absorbed dose rate at 1m above the ground (in nGy h^{-1} by Bq kg^{-1}) are calculated by Monte Carlo method as

$$D\ (\text{nGy h}^{-1}) = 0.0417\ A_K + 0.462\ A_{Ra} + 0.604\ A_{Th} \text{---------------(4)}$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}. From Table 3, the average values of calculated absorbed dose rates in samples under investigation are ranged between 18.17 to 54.27 nGyh^{-1} and found to be comparable to the world average of 55 nGyh^{-1}.

Radium equivalent activity

The natural radioactivity of building materials is usually determined from ^{226}Ra, ^{232}Th and ^{40}K contents. As Radium and its daughter products produce 98.5 % of the radiological effects of the Uranium series, the contribution from the ^{238}U has been replaced with the decay product ^{226}Ra. Radium equivalent activity is an index that has been introduced to represent the specific activities of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them. This first index can be calculated according to as

$$Raeq = A_{Ra} + 1.43A_{Th} + 0.077A_{K}, \text{---------------}(5)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively. The Ra_{eq} is related to the external γ-dose and internal dose due to radon and its daughters. The radium equivalent activity (Raeq) values for all building materials under investigation ranged from 39.64 to 122.71 Bqkg^{-1}. These values are less than 370 Bqkg^{-1}, which are acceptable for safe use .

III. Conclusion

Materials derived from rock and soilcontain mainly natural radioisotopes of the uranium-238 and thorium-232 series and radioactive isotope of potassium-40. Gamma ray spectrometry is powerful experimental tool in studying natural radioactivity and determining elemental concentration in various building materials. The radium-equivalent activities obtained for the building materials in this study were below the criterion limit of γ-radiation dose (370 Bq kg^{-1}) adopted by the OECD, 1979 criterion. Therefore, the use of these materials in construction of dwellings is considered to be safe for inhabitants. The obtained results show that the most majority of the building materials used in Kuthua area have the exemption level, thus they can be exempted from all controls concerning their radioactivity. Thus from the radiation safety, these materials are below the recommended limits for their gamma dose rates, therefore, they can be used for all kinds of public buildings.

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