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RESEARCH ARTICLE

MEASUREMENT OF RADON (^{222}Rn) EMANATION COEFFICIENT IN SOME BUILDING MATERIALS AND INTERNAL HAZARDS ASSOCIATED WITH EXPOSURE OF ALPHA PARTICLES

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ABSTRACT

Solid state nuclear track detectors (LR-115, type II) were used to measure the radon (^{222}Rn) emanation coefficient in some building materials and internal hazards associated with exposure of alpha particles in Shahjahanpur District of Uttar Pradesh. For the same measurement, cylindrical can technique was used containing LR-115, type II plastic detector. The ^{222}Rn-emanation coefficient, alpha index, ^{222}Rn-exhalation and activity of ^{226}Ra concentration was found varied from 0.0683 to 0.1802, 0.11 Bqkg^{-1} to 0.35 Bqkg^{-1}, 15.37 mBqKg^{-1}h^{-1} to 20.97 mBqKg^{-1}h^{-1} and 11.37 BqKg^{-1} to 35.15 BqKg^{-1} respectively. There is a significant variation between the observed values of the different building material samples. There variations in the radon emanation coefficient might suggest that building material sample has almost similar grain size. The estimated values of ^{222}Rn emanation coefficient $(Rn)_{EC}$, alpha index (I_{α}), ^{222}Rn exhalation (E_m) and activity of radium concentration (C_{Ra}) were found below the standard value as recommended by environmental protection agency (EPA).Thus the use of building materials for construction work in the study area is safe from health hazards as well as radiation protection point of view.

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INTRODUCTION

It has been found that the building materials such as granite, bricks, marble, cement, gypsum, concrete, fly ash, coal slag and other items contain natural radioactivity. The amount of radioactivity in building materials depends on the type of material used. When the natural radioactivity in building materials decays, it releases the radioactive gas radon. This release of radon may contribute to elevated radon levels in homes and buildings. Indoor radon is a more common and a far larger public health risk than radiation from building materials. Radon exists in small quantities in all building materials. When it decays, it can get into the air of your home. This is a constant but usually very small source of the overall radon that is likely to enter your home. The only exception is when one or more of your home's building materials comes from a contaminated source. Building materials made from sand, gravel, brick maker's clay, fly ash and slag or waste materials from ore processing usually contain some amount of uranium. These materials therefore contain some radium called mother of radionuclide of radon. A higher amount of radium results in a higher concentration of radon, and also a higher level of gamma radiation in the building.

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The radon is more concentrated in the lower levels of the home i.e. the basement, ground floors and the first floors (K. Stephen et al,1995) The natural radioactivity in building materials gives rise to internal and external radiation exposure. However, the internal radiation exposure mainly affecting the respiratory tract is caused by the short-lived daughter-products viz 218 Po and 214 Po of radon which are emitted from the construction materials into the room air. It gets lodged to the inner walls and membranes of human respiratory system and continues causing constant damage due to their alpha activity and there is a possibility of lung cancer (L. Xinwei, 2005., A. M. Ahad et al, 2004).During respiration, radon progeny 218 Po and 214 Po deposit in the lungs and irradiate the tissue, thereby damaging the cells, and may cause lung cancer (R. Mehra et al, 2006). Therefore in the interest of public health from the radon radiation hazards and radon free home, the amount of natural radioactivity in the building materials. The radon emanation coefficient is defined as the fraction of the total amount of radon produced by radium decay that escapes from the solid phase and gets into the pores of the material. It is also called the emanating power, emanating fraction, release ratio, and escape-to-production ratio. The radon emanation coefficient is a dimensionless parameter and is represented as either a fraction or a percentage. The emanation coefficient ranges from 0 to 1. The radon emanation coefficient is determined from the measured radon exhalation rate of some sample with a certain mass and geometry.

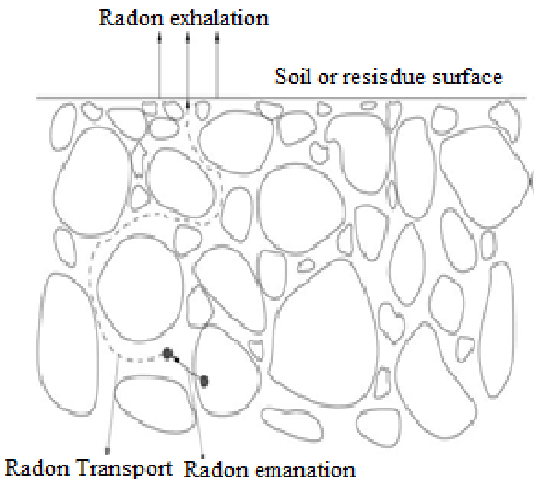

Fig.1 Processes leading to radon release to the atmosphere

The radon emanation coefficient $(Rn)_{EC}$ can be determined either from the ^{226}Ra activity concentration of the material and the measured mass radon exhalation rate. The process of radon exhalation, radon emanation, radon transport from the soil or residue surface is illustrated in figure 1.

Experimental Detail

The Measurement of radon emanation coefficient in the building materials were carried out by using cylindrical closed can technique. The experimental setup is shown in figure 2. It is expected that the radon emanation coefficient can be determined with high reasonable accuracy with this technique.LR-115, type II solid state nuclear track detector (SSNTD) was used to record the alpha tracks because this detector is more attractive, cheap and non-hazardous than other plastic track detectors. It provides adequate tool for large scale measurement and also suitable for the measurements of radon (^{222}Rn) emanation coefficient radon exhalation rate. Now a day's these detectors are widely used in various field of science and technology viz environmental science, nuclear physics, health physics, material science, space physics, nuclear geophysics, cosmic ray etc. Sample of different building materials are collected and then crushed into grain size fine powder by using mortar and pestle (size of the grain $\approx 150\mu m$). The powder form of the sample was dried in an oven at a temperature of 110^0C for 24 hours. Now the sample is ready to put into the closed cylindrical can containing LR-115 type II plastic track detector. The detector film is fitted on the lead of the cylindrical can from inner side in such a way that the sensitive part of the LR-115detector film was always facing the to the emergent radon from the sample in the can so that it could record alpha particles resulting from the decay of radon (^{222}Rn) in the remaining volume of the can. The sample of building materials that included in the study are sand, bricks, cement, marble, granite and gypsum. About 400 grm. of the building materials sample were kept in a separate cylindrical can containing the LR-115, type II detector film. After the radioactive equilibrium have been reached between the radon (^{222}Rn) and its daughter product, the detector film was exposed for a period of ninety days (90 days) to record the tracks of alpha particles from radon gas emitted by building materials

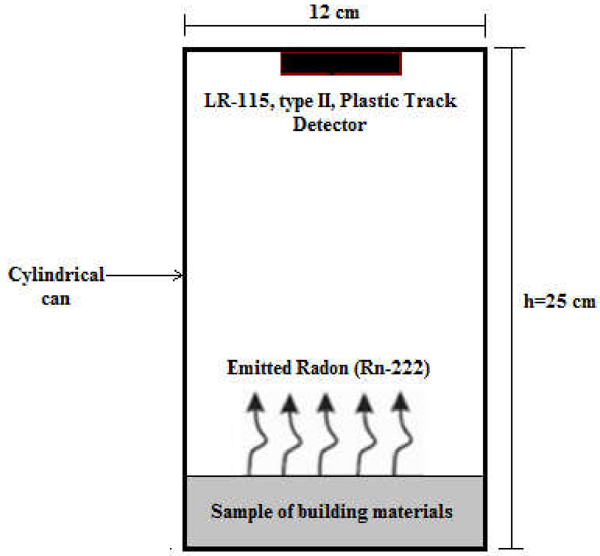

Fig. 2 Experimental setup

and fi1led in the intervening space between the sample and the detector (M. Sowmya et al, 2010., M. O. Isinkaye et al, 2 010., A. K. Mohanty et al, 2004 & P. A. Karam et al, 1999). After the completion of exposure period, the detectors were removed and etched in a solution of 2.5 NaOH for a period of 70 minutes in a constant temperature bath at 60^0C for the detection of alpha tracks. The resulting alpha tracks on the exposed surface of the LR-115 film were counted by using spark counter. The tracks density is converted into activity concentration by using calibration factor 0.0245 tracks $cm^{-2}.day^{-1}.Bqm^{-3}$. Actually the radon ($^{222}Rn$) emanation coefficient is determined from the measured radon exhalation rate of some sample with a certain mass and geometry. A fraction of ^{222}Rn which diffused through the building materials is known as the emanation coefficient of the material. It is a dimensionless parameter and is represented as either a fraction or a percentage (S. Turhan, 2008).The radon emanation coefficient $(Rn)_{EC}$ of the materials may be calculated by using the relation (Y. Ishimori et al, 2013).

$$(Rn)_{EC} = E_m/(C_{Radium} \times \lambda)$$

Where E_m is the mass exhalation rate in $Bq.kg^{-1}h^{-1}$, λ is the radon decay constant in $s^{-1}$and C_{Radium} is the activity of radium concentration in $BqKg^{-1}$.The exhalation rate in term of mass is given by

$$E_m(Bqkg^{-1}h^{-1}) = C_{Radon}\ V\ \lambda\ /M\ T_{eff}$$

Where C_{Radon} is the activity of radon concentration in Bq/m^3, V is the effective volume of the can in m^3 ($2826 \times 10^{-6} m^3$), λ is the radon decay constant in s^{-1} ($0.18d^{-1}$or $.0075h^{-1}$), M is the mass of the sample in Kg (0.200kg), T is the time of exposure in hours and T_{eff} is the effective exposure time. The effective exposure time (T_{eff}) is related to the exposure time (T) in the following way (A. Rawat et al, 1991 & G. Somogyi, 1986).

$$T_{eff} = T + 1 / \lambda\ [\{\exp(-\lambda T) - 1\}]$$

Where the symbols carry the same meaning as explained above. The internal hazard associated with exposure of alpha particles evaluated from an index is called alpha index or internal index.

It can be used to estimate excess alpha radiation caused by the inhalation of radon emitted from building materials and it is denoted by I_α. The value of alpha index or internal index for building materials sample was determined by using the formula (M. Rafique et al, 2011& S. Righi et al, 2006).

$$I_\alpha = C_{Ra}\,(\mathrm{Bq\ kg^{-1}}) / 200$$

Where C_{Ra} is the activity concentration of ^{226}Ra in $\mathrm{Bqkg^{-1}}$.Radon exhalation from building materials that are used in construction may lead to indoor radon concentrations that exceed the recommended action level of 200 $\mathrm{Bqm^{-3}}$ if the activity concentration of radium ^{226}Ra in the material exceeds a value of 200 $\mathrm{Bqkg^{-1}}$.The safe limit defined for alpha index (or internal index) is less than or equal to one as recommended by Environmental Protection Agency (UNSCEAR, 2000 & EPA, 2005). i.e. $C_{Ra}\,(\mathrm{Bq\ kg^{-1}}) / 200 \le 1$

RESULTS AND DISCUSSION

The observed values of radon emanation coefficient, radon exhalation, activity of radium concentration and internal hazards associated with alpha particles i.e. alpha index for the selected building materials are reported in the Table 1.

These building materials are commonly used in the construction work all over the country. The radon emanation coefficient varied from 0.1161 to 0.1075 with an average value of 0.1118 for the cement sample, 0.0856 to 0.0881 with an average value of 0.0940 for sand sample, 0.0683 to 0.0733 with an average value of 0.0708 for bricks sample, 0.1198 to 0.1165 with an average value of 0.1176 for marble sample, 0.0733 to 0.0893 with an average value of 0.0833 for granite sample and 0.1802 for gypsum sample. There is a significant variation between the values of radon (^{222}Rn) emanation coefficient. These significant variations in the radon (^{222}Rn) emanation coefficient might suggest that building material sample has almost similar grain size. Similarly the radon exhalation rate in the building materials sample varied from 19.59 $\mathrm{mBqKg^{-1}h^{-1}}$ to 20.15 $\mathrm{mBqKg^{-1}h^{-1}}$ with an average value of 19.86 $\mathrm{mBqKg^{-1}h^{-1}}$ for cement 20.67 $\mathrm{mBq\ Kg^{-1}\ h^{-1}}$ to 20.97 $\mathrm{mBqKg^{-1}h^{-1}}$ with an average value of 20.82 $\mathrm{mBqKg^{-1}h^{-1}}$ for sand, 18.00 $\mathrm{mBqKg^{-1}h^{-1}}$ to 18.56 $\mathrm{mBqKg^{-1}h^{-1}}$ with an average value of 18.28 $\mathrm{mBqKg^{-1}h^{-1}}$for bricks,17.48 $\mathrm{mBqKg^{-1}h^{-1}}$ to 17.78 $\mathrm{mBqKg^{-1}h^{-1}}$with an average value of 17.63 $\mathrm{mBqKg^{-1}h^{-1}}$ for marble, 17.49 $\mathrm{mBqKg^{-1}h^{-1}}$ to 18.85 $\mathrm{mBqKg^{-1}h^{-1}}$ with an average value of18.17 $\mathrm{mBqKg^{-1}h^{-1}}$ for granite and 15.37 $\mathrm{mBqKg^{-1}h^{-1}}$ for gypsum.

Table 1. Observed values of radon emanation coefficient and internal hazards associated with the exposure of alpha particles i.e. alpha index along with radon exhalation and activity of radium concentration.

Building materials	Sample code	Radon exhalation ($\mathrm{mBqKg^{-1}h^{-1}}$)	Radium concentration ($\mathrm{BqKg^{-1}}$)	Radon emanation coefficient (RnEC) (Rn)EC=Em/CRa× λ	Alpha Index (I_α) ($\mathrm{Bqkg^{-1}}$)
Cement	C1	20.13	23.12	0.1161	0.23
Cement	C2	19.59	24.30	0.1075	0.24
Sand	S1	20.67	32.20	0.0856	0.32
Sand	S2	20.66	25.39	0.1085	0.25
Sand	S3	20.97	31.75	0.0881	0.31
Bricks	B1	18.00	35.15	0.0683	0.35
Bricks	B2	18.56	33.75	0.0733	0.34
Marble	M1	17.78	19.80	0.1198	0.19
Marble	M2	17.48	20.00	0.1165	0.20
Granite	G1	17.49	30.15	0.0773	0.30
Granite	G2	18.85	28.15	0.0893	0.28
Gypsum	Gy	15.37	11.37	0.1802	0.11

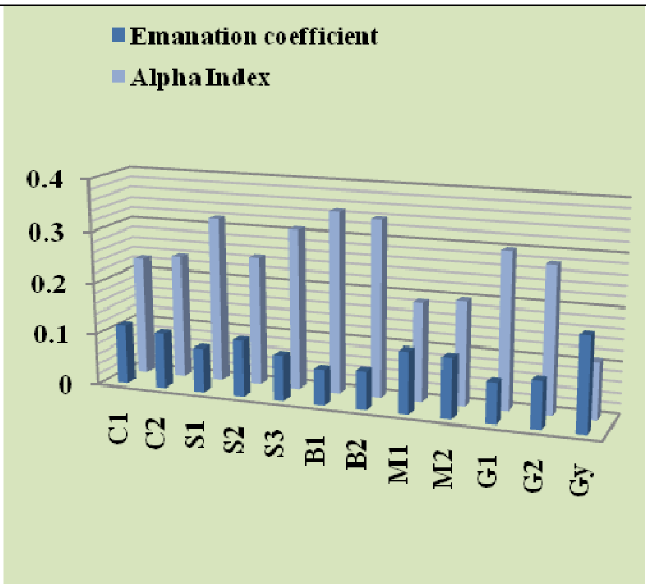

Fig. 3 Variation of ^{222}Rn-emanation coefficient& alpha Index with building materials

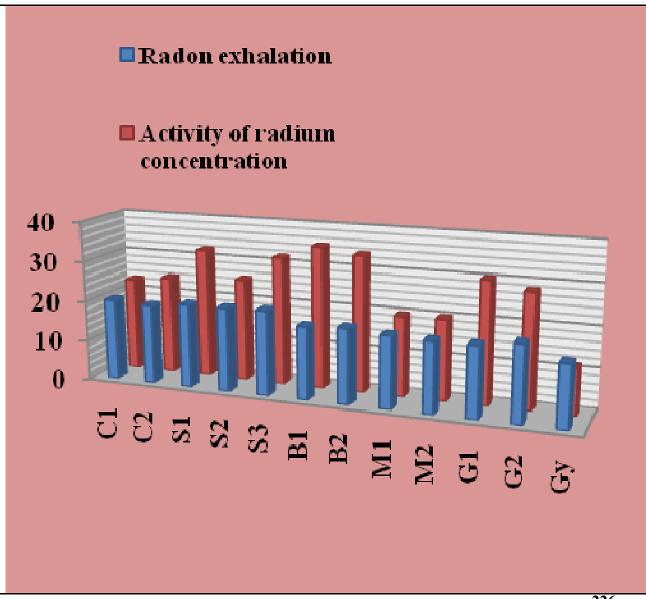

Fig. 4 Variation of radon exhalation & activity of ^{226}Ra-concentration with building materials

There is a significant variation between the values of radon exhalation rate. These variations may be arisen due to the difference in the nature of the samples of the different building materials. The activity of radium concentration in the building material samples also varied from 23.12 $BqKg^{-1}$ to 24.30 $BqKg^{-1}$ with an average value of 23.71$BqKg^{-1}$ for cement, 25.39 $BqKg^{-1}$ to 32.20 $BqKg^{-1}$ with an average value of 28.79$BqKg^{-1}$ for sand, 33.75 $BqKg^{-1}$ to 35.15 $BqKg^{-1}$ with an average value of 34.45$BqKg^{-1}$ for bricks, 19.80 $BqKg^{-1}$ to 20.00 $BqKg^{-1}$ with an average value of 19.90$BqKg^{-1}$ for marble, 28.15 $BqKg^{-1}$ to 30.15 $BqKg^{-1}$ with an average value of 29.15$BqKg^{-1}$ for granite and 11.37 $BqKg^{-1}$ for gypsum sample. The observed values of radium content in building materials sample are less than the permissible value of 370 $Bqkg^{-1}$ as recommended by Organization for Economic Cooperation and Development (OECD, 2009). Thus the use of building materials in the study is safe from radiation hazards. The internal hazards associated with the exposure of alpha particles i.e. alpha index (I_α) values determined for building material samples have also reported in the table 1.The observed values of alpha index in the samples varied from 0.11 $Bqkg^{-1}$ to 0.35 $Bqkg^{-1}$. The estimated values of alpha index were found below standard value as recommended by environmental protection agency (EPA). Thus the use of building materials for the construction work in the study area is safe from radiological hazards of radiations (N. Damla et al, , 2012).The variations of radon exhalation rate (E_m), activity of radium concentration (C_{Ra}) radon emanation coefficient $(Rn)_{EC}$ and internal hazards associated with exposure of alpha particles i.e. alpha index (I_α) are shown graphically in figures 3 and 4 respectively

Conclusion

The observed values of radon (^{222}Rn) emanation coefficient, internal hazards associated with exposure of alpha particle i.e. alpha index (or internal index), radon exhalation and activity of radium concentration are reported in the table1.It was found that the values of the ^{222}Rn-emanation coefficient, alpha index, radon(^{222}Rn) exhalation and activity of ^{226}Ra concentration varies from 0.0683 to 0.1802, 0.11 $Bqkg^{-1}$ to 0.35 $Bqkg^{-1}$, 15.37 $mBqKg^{-1}h^{-1}$ to 20.97 $mBqKg^{-1}h^{-1}$ and 11.37$BqKg^{-1}$ to 35.15 $BqKg^{-1}$ respectively. The values of the radon (^{222}Rn) emanation coefficient, alpha index, radon (^{222}Rn) exhalation and activity of radium (^{226}Ra) concentration are found under the safe limit recommended by Organization for Economic Cooperation and Development (OECD). Thus the use of building materials for the construction work in the study area is safe from health hazards and they do not pose any significant radiological hazards to inhabitants living in the study area.

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