



Measurements of Radon Exhalation Rates from Some Building Materials by Using Solid State Nuclear Track Detector (SSNTD)

M. S. A. Khan

Department of Physics

Gandhi Faiz-a-Aam College, Shahjahanpur-(U.P.), India

Abstract: Radon exhalation rates in terms of mass and area and radon concentration from the sample of some building materials in shajahanpur district of U.P. (India) were carried out by using cylindrical can technique (CCT) based on LR-115 type II plastic track detector. From the result it was found that the radon concentration, radon exhalation rates (in terms of mass and area) and annual effective dose in the sample of different building material varies from 145Bq/m^3 to 180Bq/m^3 with an average values of 158.25Bq/m^3 , $23.04 \times 10^{-3} \text{ Bqm}^{-2}\text{d}^{-1}$ to $28.06 \times 10^{-3} \text{ Bqm}^{-2}\text{d}^{-1}$ with an average of $25.02 \times 10^{-3} \text{ Bqm}^{-2}\text{d}^{-1}$, $0.69 \times 10^{-3} \text{ Bqkg}^{-1}\text{d}^{-1}$ to $0.86 \times 10^{-3} \text{ BqKg}^{-1}\text{d}^{-1}$ with an average value of $0.76 \times 10^{-3} \text{ BqKg}^{-1}\text{d}^{-1}$. and 4.57 mSv/y to 5.67 mSv/y with a an average value of 4.98 mSv/y respectively. Measured values of radon concentration, radon exhalation rate in terms of mass and area and annual effective dose in the sample of different building materials in the study area were found to be less than the permissible value of 200 Bqm^{-3} , $0.016 \text{ Bqm}^{-2}\text{s}^{-1}$ ($57.6 \text{ Bqm}^{-2}\text{h}^{-1}$) and 10.00 mSv/y respectively as recommended by ICRP (ICRP, 1993). The present result shows that the building materials do not pose a significant radiation hazards. Thus the use these materials for the construction of building in the study area is considered to be safe from radiation protection point of view.

Keywords: Radon, cylindrical can technique, building material, LR-115 type II plastic detector

I. Introduction

Radon is a naturally occurring radioactive gas that is part of the uranium decay series. Its presence in the environment is associated mainly with trace amounts of uranium and its immediate parent, radium-226, in rocks and soil. Materials obtained from the earth crust's such as building materials bricks, white cement, black cement, gypsum, sand, marble, ceramic, different types of stones, etc. may contain traces of U-238 and Th-232. These radionuclides decay to radon (Rn-222) which is a radioactive gas with half life 3.82 days. Prolong exposure to radon may increase the risk of lung cancer ([1], [2]) because it delivers 55% of the total dose to the cells of the respiratory system [3]. Due to long half- life of radon gas it can reach from the earth's crust or from the walls and floors of the buildings into both outdoor and indoor air. In case of indoor air, the risk of exposure to radon is higher, especially for building with poor ventilation systems which may lead to a higher indoor radon concentration. The radon exhalation is also important factor, since it gives the exhalation rate of the radon from the study material. Building materials are the main source of radon inside houses. The most popular building materials are bricks, white cement, black cement, gypsum, sand, marble, ceramic, different types of stones, etc. These building materials contains some amount of radon. Radon is released into ambient air from soil and stones due to ubiquitous uranium and radium in them, thus increasing the airborne radon concentration. The radioactivity in soils is related to radioactivity in the rocks from which the soil is formed. Soil gas measurements have shown radon concentrations ranging from a few hundred to several thousand pCi/l [4]. The United States Environmental Protection Agency has estimated that the average soil in the country contains about one part per million of uranium; phosphate rock contains 50 to 125 ppm and granite contains about 10 to 50 ppm in the north east but as much as 500 ppm in the west [5]. When a radon atom is produced inside a grain of a porous material, it can escape from this grain by at least two mechanisms: (1) Due to recoil the radon atom receives momentum, which enables it to travel a certain distance through a material. This recoil range is about 65 pm in air, 0.1 pm in water and 35 nm in clay [6]. (2) Radon atoms not escaping the grain by recoil may still be able to leave the material by diffusion. This involves diffusion through a solid structure diffusion coefficients will be small and only atoms close to the surface will stand a chance to escape. The radon released from the grain by recoil may be imbedded in adjacent grains and may no longer be available for transport. The fraction of radon atoms, generated in the soil grains and reaching the pore volume of the soil, is known as the emanation coefficient. This coefficient depends basically on the soil grain size-distribution, on the porosity and on the water content. The geometry and the size of soil grains and the pores determine the 'static' emanation coefficient in the sense that they do not change with

time. So the type of soil determines the general radon level in the soil [7]. The water content has a large impact on the emanation coefficient and L on the soil transport parameters for radon gas and therefore affects the radon concentration in the soil ([8],[9],[10]). Another effect of moisture is that a sudden increase in humidity may result in a transient, increase of radon emanation due to adsorption of water molecules on the grain surfaces, these molecules will compete with radon atoms for adsorption sites and thus lead to an increase in emanation [11]. Besides moisture temperature also has been reported to influence radon emanation. The amount of radon at the solid surface is determined by the interplay of adsorption and desorption. If the temperature of the material is increased the probability of desorption will increase and thus the total amount of radon adsorbed will decrease. A sudden change in temperature may thus result in a short extra release of radon. The aim of present study is to estimate the radon exhalation rates from some building materials such as black cement, white cement, gypsum, sand, bricks, soil, marble, stone granite etc. in order to detect any harmful radiation effect on human being.

II. Experimental Technique

For the measurements of radon exhalation in different building material, cylindrical can technique was used. In such measurements it is expected that the exhalation rate depend upon the material, its amount as well as geometry and dimension of the can. It has been observed [12] that the sealed can technique, mass and area exhalation rates for radon in the solid sample can be determined with high reasonable accuracy. Can technique with LR-115 detector film was used to estimate the radon exhalation rate and concentration of the most commonly used building materials in the study area. All collected sample are crushed into fine powder (grain size) by using Mortar and Pestle. Fine quality of sample is obtained by using sieve of 200 micron-mesh size. All samples were dried in oven at about 110°C for twenty four hours. $200\mu\text{m}$ grain size samples of 120gram. The lower sensitive part of the detector was exposed freely to the emergent radon from the sample in the can so that it could record alpha particles resulting from the decay of radon in the remaining volume of the can and from ^{218}Po and ^{214}Po deposited on the inner walls of the can. Radon and its daughters reach equilibrium in about 4 hours and hence the equilibrium activity of emergent radon could be obtained from the geometry of the can and time of the exposure. The sealed can technique arrangement is shown in the figure1. After the exposure, the detectors were etched in 2.5N NaOH solution at 65°C for a period of 75 minutes in a constant temperature water bath for detection of tracks. The resulting alpha tracks on the exposed face of the track detector were counted using the spark counter. The radon activity or integrated radon exposure inside the can was obtained by using the calibration factor $0.0245 \text{ tracks.cm}^{-2}\text{.d per Bq.m}^{-3}$ [13]. The exhalation rate is obtained from the following expressions ([14], [15]). Radon concentration in the samples was calculated using the following formula [16],

$$C_{\text{Rn}} = \rho / kT$$

Where C_{Rn} is the radon concentration in Bq/m^3 , ρ is the track density in tracks/ cm^2 , T is the exposure time in days and k is the calibration constant ($k = 0.0245 \text{ tracks cm}^{-2}\text{.day}^{-1}\text{.Bqm}^{-3}$) [13]. The radon exhalation rate in building material samples in terms of area and mass can be calculated by using formula

$$E_A (\text{Bq.m}^{-2}\text{h}^{-1}) = C V \lambda / A T_{\text{eff}} \quad \text{for area exhalation rate}$$

$$\&$$

$$E_M (\text{Bq.kg}^{-1}\text{h}^{-1}) = C V \lambda / M T_{\text{eff}} \quad \text{for mass exhalation rate}$$

Where C is the integrated radon exposure as measured by the LR-115 type-II plastic track detector (Bq/m^3), V is the effective volume of the can in m^3 ($0.30 \times 10^{-3} \text{ m}^3$), λ is the decay constant for radon (0.0075 h^{-1}), T is exposure time (h), A is the area of can or surface area of the sample in m^2 ($38.46 \times 10^{-4} \text{ m}^2$), M is the mass of sample in Kg ($120 \times 10^{-3} \text{ Kg}$) and T_{eff} is the effective exposure time. The effective exposure time (T_{eff}) is related to the exposure time in the following way

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

The annual effective dose can be calculated by using the following formula

$$H = C_{\text{Rn}} \cdot D \cdot F \cdot T$$

Where C_{Rn} is the measured radon concentration in air (Bq/m^3), F is the indoor equilibrium factor equal to 0.4, T is the time (8760h/y) and D is the dose conversion factor ($9 \text{ nSv/h per Bq m}^{-3}$) ([17],[18]),

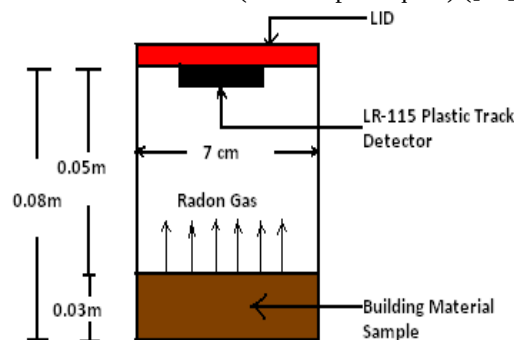


Fig.1: Sealed Can Technique Arrangement (Experimental Setup)

III. Result and Discussion

The observed values of radon concentration and radon exhalation rates in terms of mass and area for different building materials are given in table 1. The average values of radon concentration, area exhalation rate, mass exhalation rate and annual effective dose for white cement was found 146 Bq/m^3 , $23.04 \times 10^{-3} \text{ Bqm}^{-2} \cdot \text{d}^{-1}$, $0.70 \times 10^{-3} \text{ BqKg}^{-1} \cdot \text{d}^{-1}$ and 4.60 mSv/y respectively. For black cement the average values of radon concentration, area exhalation rate, mass exhalation rate and annual effective dose was found 158 Bq/m^3 , $24.96 \times 10^{-3} \text{ Bqm}^{-2} \cdot \text{d}^{-1}$, $0.76 \times 10^{-3} \text{ BqKg}^{-1} \cdot \text{d}^{-1}$ and 4.98 mSv/y respectively. For gypsum the average value of radon concentration, area exhalation rate, mass exhalation rate and annual effective dose was found 147 Bq/m^3 , $23.28 \times 10^{-3} \text{ Bqm}^{-2} \cdot \text{d}^{-1}$, $0.71 \times 10^{-3} \text{ BqKg}^{-1} \cdot \text{d}^{-1}$ and 4.63 mSv/y respectively. For sand the average value of radon concentration, area exhalation rate, mass exhalation rate and annual effective dose was found 167 Bq/m^3 , $26.40 \times 10^{-3} \text{ Bqm}^{-2} \cdot \text{d}^{-1}$, $0.80 \times 10^{-3} \text{ BqKg}^{-1} \cdot \text{d}^{-1}$ and 5.26 mSv/y respectively. For marble the average value of radon concentration, area exhalation rate, mass exhalation rate and annual effective dose was found 153 Bq/m^3 , $24.00 \times 10^{-3} \text{ Bqm}^{-2} \cdot \text{d}^{-1}$, $0.73 \times 10^{-3} \text{ BqKg}^{-1} \cdot \text{d}^{-1}$ and 4.82 mSv/y respectively. For bricks the average value of radon concentration, area exhalation rate, mass exhalation rate and annual effective dose was found 170 Bq/m^3 , $26.88 \times 10^{-3} \text{ Bqm}^{-2} \cdot \text{d}^{-1}$, $0.82 \times 10^{-3} \text{ BqKg}^{-1} \cdot \text{d}^{-1}$ and 5.36 mSv/y respectively.

Table 1: Measured values of radon concentration, exhalation rate and annual effective dose in different building materials

Building Materials	No. of Samples	Radon Con. (Bq/m^3)	Area Exhalation $E_A(\text{Bqm}^{-2} \cdot \text{d}^{-1})$	Mass Exhalation $E_M(\text{BqKg}^{-1} \cdot \text{d}^{-1})$	Annual Effective Dose $H(\text{mSv/y})$
White Cement	5	146	23.04×10^{-3}	0.70×10^{-3}	4.60
Black Cement	4	158	24.96×10^{-3}	0.76×10^{-3}	4.98
Gypsum	3	147	23.28×10^{-3}	0.71×10^{-3}	4.63
Sand	4	167	26.40×10^{-3}	0.80×10^{-3}	5.26
Marble	5	153	24.00×10^{-3}	0.73×10^{-3}	4.82
Bricks	4	170	26.88×10^{-3}	0.82×10^{-3}	5.36
Stone	2	180	28.56×10^{-3}	0.86×10^{-3}	5.67
Ceramic	4	145	23.04×10^{-3}	0.69×10^{-3}	4.57
Average		158.25	25.02×10^{-3}	0.76×10^{-3}	4.98

For stone the average value of radon concentration, area exhalation rate, mass exhalation rate and annual effective dose was found 180 Bq/m^3 , $28.56 \times 10^{-3} \text{ Bqm}^{-2} \cdot \text{d}^{-1}$, $0.86 \times 10^{-3} \text{ BqKg}^{-1} \cdot \text{d}^{-1}$ and 5.67 mSv/y respectively. Similarly for ceramic building material the average value of radon concentration, area exhalation rate, mass exhalation rate and annual effective dose was found 145 Bq/m^3 , $23.04 \times 10^{-3} \text{ Bqm}^{-2} \cdot \text{d}^{-1}$, $0.69 \times 10^{-3} \text{ BqKg}^{-1} \cdot \text{d}^{-1}$ and 4.57 mSv/y respectively. From the obtained results the values of radon concentration, exhalation rate and annual effective dose for stone sample higher than the values of other building materials. The radon concentration and exhalation rates are found to vary appreciably in various samples. The variation of radon concentration and radon exhalation for different building material in terms of mass and area are shown in the figures 2, 3 & 4. The observed values of radon concentration and radon exhalation rates from different building materials are less than world recommended value [19]. Thus as far as health hazards are concerned, the use of these building materials in the study area are safe.

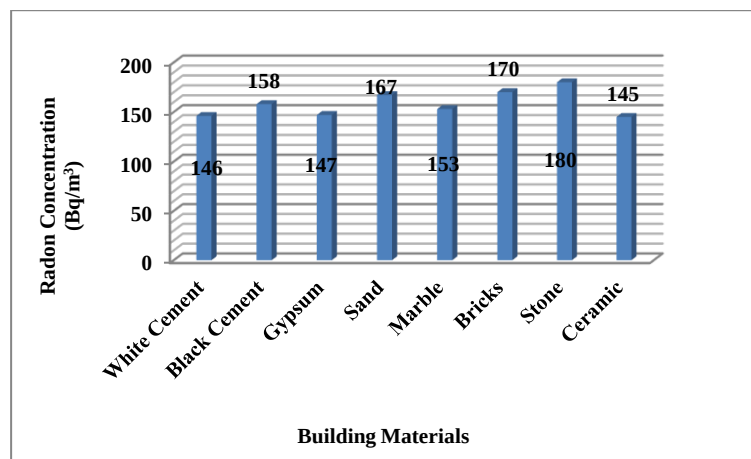


Fig.2: Variation of radon concentration with building materials

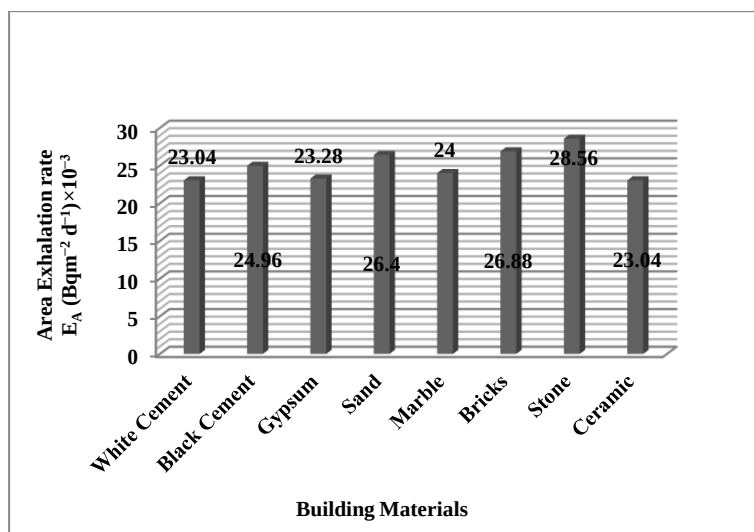


Fig. 3: Area exhalation rate with building materials

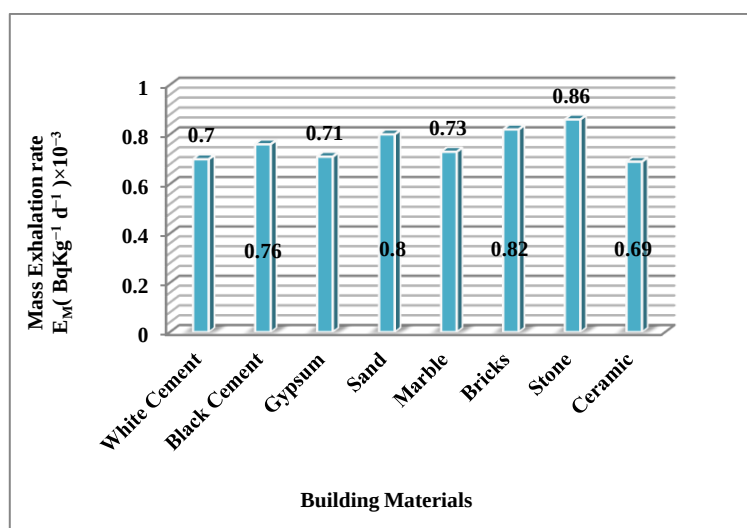


Fig.4: Mass exhalation rate with building materials

IV. Conclusion

Measured values of radon concentration, area exhalation rate, mass exhalation rate and annula effective dose from different building materials are reported in the table1. The radon concentration, exhalation rate rates and annula effective dose were determined to assess the radiological hazards from the building materials. The result shows that the stone samples have a higher radon concentration and radon exhalation rates (180 Bq/m^3 , $28.56 \times 10^{-3} \text{ Bqm}^{-2} \cdot \text{d}^{-1}$ and $0.86 \times 10^{-3} \text{ BqKg}^{-1} \text{d}^{-1}$) than other building materials where as the ceramic buliding material samples have a lower valeue. The lower radon activity in the ceramic floors is due to good insulation material between the ceramic flooring and the soil bellow the buildings, or it might be due to low radioativity of the ceramic raw materials itself. The values of rafon concentration and exhalation rate were varied from sample to another due to variation in the chemical composition of the sample. The observed result shows that the values of radon concentration, radon exhalation rates (both area and mass) and annual effective dose for all the samples are less than the world action level 200 Bq/m^3 , $0.016 \text{ Bqm}^{-2} \text{s}^{-1}$ ($57.6 \text{ Bqm}^{-2} \text{h}^{-1}$) ([15], [20]) and 10 mSv/y respectively as recommended by ICRP,1993[19] and ICRP,1987[21]. The present result shows that the building materials do not pose a significant radiation hazards. Thus the use these materials for the construction of building in the study area is considered to be safe from radiation protection point of view.

V. Acknowledgement

The author is grateful to Dr. Mohammad Tariq, Department of Physics M.B.P. Govt. (P.G.) College Ashiana, Lucknow, Dr. R.B.S. Rawat and Dr. Anil Kumar Singh Department of Physics S.S. (P.G.) College Shahjahanpur for providing necessary help to carry out this work.

IV. References

- [1]. ICRP, International Commission on Radiological Protection. "Lung cancer risk from indoor exposure to radon daughters" Report 50, Vol.17, No.1, 1978.
- [2]. S.A. Durrani, Radon as a Health at home: What are the Facts?", Nucl. Tracks Radiat. Meas., 22,303-317, 1993.
- [3]. P.C. Deka, S. Sarkar, B. Bhattacharjee, T.D. Goswami, B.K.Sharma and T.V. Ramchandaran "Measurements of Radon and thoron concentration by using LR-115 type-II Plastic Track Detectors in the environment of Brahmaputra Valley, Assam, India", Radiation Measurements, 36 431-434, 2003.
- [4]. UNSCEAR, Sources and effects of ionizing radiation. United Nations Scientific Committee on Effects of Atomic Radiation. Report to General Assembly with annexes. United Nations sales Publications E.94.IX.2. United Nations New York, 1993.
- [5]. M. Lafavore, "The radon report", New Shelter, 7, 1986.
- [6]. D. A. W. Bossus, "Emanating power and specific surface area". Rad. Prot. Dos.7, 73-76, 1983.
- [7]. G. Jonsson, Radiat. Meas. 31, 265-268, 1999.
- [8]. E. Straden, A. K. Kolstad, and B. Lind, Health Phys. 47, 480-484, 1984.
- [9]. L. Morawska and C. R. Phillips, Geochem. Cosmo-chim. Acta, 57, 1783-1785, 1993.
- [10]. C. Baixeras, Erlandsso n and L. I. Font, Rad. Meas.34, 441-445, 2001.
- [11]. T. H. Gan, G. C. Mason, K.N. Wise, S. Whittle stone and H. A. wayllie, Health Physics. 50, 407-410, 1986.
- [12]. G. Somogy., Abdel-Fateh., I. Hunyadi and S. M. Toth., Nucl.Tracks. Vol.12, pp.701-704, 1986
- [13]. K.P. Eappen and Y. S. Mayya, Radiat. Meas. 38, 5-17, 2004.
- [14]. R. L. Fleischer and A. Morgo-campero, "Mapping and integrated radon earth; techniques and principles" Geophys. Res. Lett. 83, 3539-3549, 1978.
- [15]. A. J. Khan, R. Prasad and R. K. Tyagi "Measurement of radon exhalation rate from some building materials". Nuclear Tracks Radiat. Meas. 20,609-610, 1992.
- [16]. V. Z. Hamza and M. N. Mohan Kumar, "Cytogenetic Damage in Human Blood Lymphocytes Exposed in vitro to Radon". Mutation Research, 6,1-9.<http://dx.doi.org/10.1016/j.mrfmmm.2008.10.010>. 2009
- [17]. K. Ali, B. Alsaeidi Almayahi and A. H. Alasadi, "²²²Rn and ²²⁶Ra concentration measurements in selected samples from different companies". Asian Journal of natural and Applied Sciences, 2,195-200, 2013.
- [18]. El-Zain, "A study of indoor radon levels and radon effective dose in dwellings of some cities of Gezira state in Sudan". Journal of nuclear Technology and radiation protection, 29,307-312, 2014.
- [19]. ICRP, International Commission on Radiological Protection. "Protection against radon-222 at home and at work", ICRP Publication 65, Annals of the ICRP 23(2), Pergamon Press, Oxford. , 1993.
- [20]. UNSCEAR "Sources and Effects of Ionization Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation Report to the General Assembly with scientific annexes Volume1 United Nations New York, 2000.
- [21]. ICRP (1987) Lung Cancer Risk for Indoor Exposure to Radon Daughters. ICRP Publications 50.pergamon press, Oxford