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Studies on Radon Exhalation Rate from Construction Materials of Mandya District, Karnataka State, India

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ABSTRACT: Human beings are continuously exposed to ionizing radiation from naturally occurring radioactive elements present in the earth crust and in the atmosphere. On the surface of the earth, the concentration of radionuclides varies from place to place depending on local geology and geography. Radon is a radioactive inert gas, which contribute a major portion of the radiation dose received by the world population. The ^{222}Rn exhalation rate was studied in the samples of construction materials used in Mandya district, Karnataka state, India. The ^{222}Rn exhalation rate in the samples of construction materials used in large amounts varied from 5.75 to 15.62 mBq kg^{-1} h^{-1}. Higher ^{222}Rn exhalation rates were observed in M-sand and crusher dust. The ^{222}Rn exhalation rate in the samples of construction materials used in small amounts varied from below detection level to 32.73 mBq kg^{-1} h^{-1}. Maximum rate of ^{222}Rn exhalation was observed in the samples of red granite.

Keywords: Radon Exhalation, Smart Radon Monitor (SRM), Radiation dose, Mandya.

I. INTRODUCTION

Radiation is omni present in the environment both beneath the surface of the earth and in the atmosphere. Human beings are continuously exposed to ionizing radiation from naturally occurring radioactive elements which are emitted from both terrestrial sources and cosmic radiations. About 87% of the radiation dose received by the mankind is due to natural sources and the remaining is from anthropogenic activities [1]. Radon originates from the earth's crust and transported into atmosphere by advection, convection and diffusion through pore spaces in the soil [2]. The presence of radionuclides in the environment varies from place to place on the earth depending on local geology and geography. Higher background radiation was observed at some places like coastal belt of Kerala, Tamilnadu and Singhbum district of Bihar in India, and in some places of Brazil, Iran, Germany [1]. The local population in such localities receives a relatively higher radiation dose.

Soil is widely used as a construction material in the form of bricks and as a filling material. It is the main source of radiation exposure to the public. Under certain conditions the concentration of radioactive elements may increase in the environment and can reach hazardous radiological levels. The measurement of natural radioactivity in soil and fluid materials is very essential to recognize the health risks and to establish the base line data for the radiation protection [3,4]. As the natural radiation is the largest contributor to the external radiation dose of the world's population, majority of the studies related to radioactivity in soil and construction material have been carried out. Construction materials contain trace amounts of radioactive elements such as uranium, thorium, potassium and their decay products. They may contribute to the total radiation dose to the population through the gamma radiation and through radon inhalation.

The rate at which radon escapes or emanates from soil into the surrounding air is known as radon emanation rate and the amount of radon coming out of the soil surface is referred to as radon exhalation rate. The rate of ^{222}Rn exhalation from building materials depends on the concentration of ^{226}Ra in it and on the properties of the material like porosity and moisture content [2,4]. Ragavayya *et al* (1982) have found that soil moisture had a strong influence on the ^{222}Rn exhalation rate [5]. However, Arabzedegan *et. al.,* (1982) observed that, the meteorological parameters had no significant influence on the value of ^{222}Rn exhalation rate [6].

^{222}Rn exhaled from the surface soil enters the atmosphere and further decays to a series of short-lived radionuclides *viz,* ^{218}Po, ^{210}Pb and ^{214}Bi which are the most important radionuclides as far as the inhalation dose is concerned. The exhalation rate of radon could be used as an index for selecting the building material with respect to radon levels in dwellings. Exposure to higher levels of radon concentration is one of the causative factors of human lung and stomach cancer [7].

The understanding of distribution of radionuclides and radiation levels in the environment is important for assessing the levels of radiation exposure to the local population. The details of the survey of the experimental work done in different parts of India and globe give the importance of data acquired with regard to the levels of concentration of radioactive elements present in the soils, underground water, surface water, environment including the indoor radioactivity in human habitation [7]. Radon and its decay products are the main sources of ionizing radiation, contributing about 55% of global mean effective dose to the public [2]. A systematic and long period study of radon exhalation rate from soil and building materials is necessary for understanding the phenomena and to minimize the radiation risk to the population.

Several researchers have carried out studies on radon exhalation rate from building materials of different types [8-14].

II. STUDY AREA

Mandya District lies between 76° 19' and 77° 20' E and 12° 13' and 13° 04' N. It is surrounded by Hassan, Tumkur, Bangaluru rural, Ramanagar and Mysuru district. It has a total area of 4962 km^2. The rock formations in the district belong to the most ancient types and can be identified as the Dharwad Schists, Peninsular Gneisses and Granites. The soils of Mandya district can be classified as Red Sandy Loams, Red Clayey Loams, Clayey Loams [15]. The study area is shown in Fig. 1 [15]. Fired brick made from local soil, and concrete bricks, cement, river sand, crusher dust, and m-sand are used in large quantity for the dwellings. For flooring and decoration of walls, white marble, granite slabs, lime stone, sand stone, ceramic tile, terracotta tile, mosaic tile were used in small quantities. Because of scarcity of river sand Manufactured sand (M-sand) and crushed dust are being used in large quantity. M-sand and crushed dust were manufactured in the nearby quarries by crushing locally available rocks.

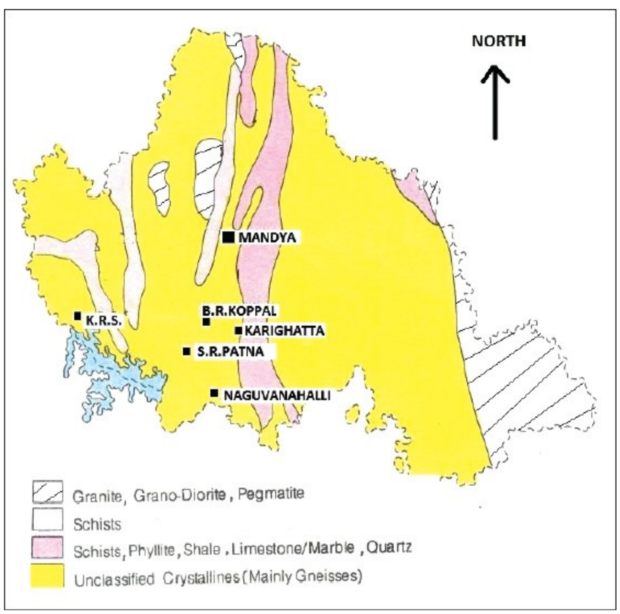

Fig. 1. Mandya District.

II. MATERIALS AND METHODS

Radon mass exhalation rate from the samples of soil and building materials was determined using scintillation based Smart Radon Monitor (SRM) [16-18]. The experimental set-up for the measurement of radon mass exhalation rate from the samples of construction materials using SRM is shown in the Fig. 2.

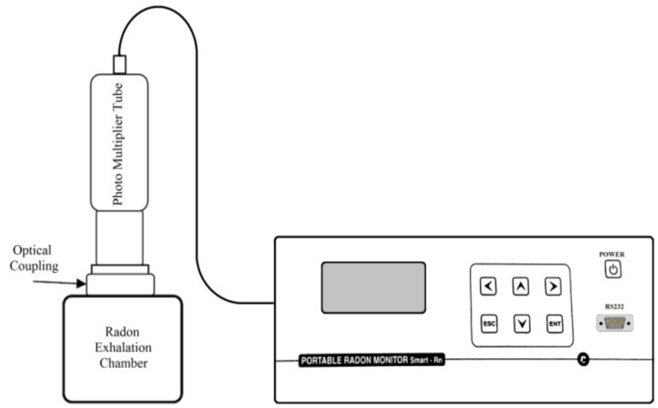

Fig. 2. Experimental set-up for the measurement of radon mass exhalation.

SRM is a technologically advanced, real time, portable Radon monitor designed by Bhabha Atomic Research Centre (BARC) Mumbai, for multiple applications in radon studies. Radon measurements are based on the detection of alpha particles emitted from radon and its decay products in the scintillation cell [16-18]. The building materials were crushed, powdered, oven dried at a temperature of 110°C and sieved through 150 µm sieve. About 400 grams of the sample was used for the study of radon exhalation rate.

Radon exhalation rate J_m (mBq kg^{-1} h^{-1}) is given by the equation,

$$J_m = \frac{(C_t - C_o)V}{Mt}$$

Where, $\boldsymbol{C_t}$ is the ^{222}Rn concentration at time t (Bq m^{-3}); $\boldsymbol{C_o}$ is the ^{222}Rn concentration at time t=0 (Bq m^{-3}); M is the total mass of the dry sample (kg); t is the measurement time (h) and V is the effective volume (m^3).

III. RESULTS AND DISCUSSIONS

The exhalation rate of^{222}Rn was studied in the samples of building materials collected from different parts of Mandya district, Karnataka state, India. The construction materials were collected from different parts of Mandya district and classified in to two groups based on the amount of the material used for the construction purpose. The variation of radon mass exhalation rate and total dose estimated due to radon exhalation rate from the samples of construction materials, which were used in large amounts are shown in the Table 1 and Fig. 3. Among the construction materials used in large amounts, the ^{222}Rn exhalation rate varied from 5.75 to 15.62 mBq kg^{-1} h^{-1} with an average of 9.34 mBq kg^{-1} h^{-1}. Higher ^{222}Rn exhalation rate were observed in M-sand and crusher dust, and this could be attributed to the higher concentrations of ^{226}Ra in granite stones from which M-sand and crusher dust were produced. Fired bricks has a radon exhalation rate of 5.75 mBq kg^{-1} h^{-1}whereas unfired brick has 8.57 mBq kg^{-1} h^{-1}. Bricks were made from locally available mud and clay, even though it contains traces of uranium, thorium and radium, there is a possibility of evaporation of radium in the bricks during the process of baking at higher temperature for more than 14 days. M-sand and crusher dust were produced by crushing locally available granitic and other forms of rocks.

The variation of radon mass exhalation rate and total dose estimated due to radon exhalation rate from samples of construction materials used in small amounts are shown in the Table 2 and Fig. 4. The ^{222}Rn exhalation rate varied from below detection level BDL to 32.73 mBq kg^{-1} h^{-1} with an average of 10.22 mBq kg^{-1} h^{-1}. Maximum rate of ^{222}Rn exhalation was observed in the samples of red granite. Granite has been used extensively as flooring tiles in public and commercial buildings. The higher exhalation rate of radon from granite may be due to higher activity concentrations of ^{226}Ra in granite rocks.

If building materials with higher natural radionuclide concentration are used, the indoor radiation dose rate will also increase accordingly. The characterization of various building material with respect to radon exhalation is essential for dose estimation [2]. The estimated effective dose rate due to radon exhalation from the construction materials varied from BDL to 1.01 mSv y^{-1}. This value is found to be less than the recommended dose limit by ICRP [7].

Table 1: Mass exhalation rate of ^{222}Rn in samples of construction materials used in large amount.

Sl. No.	Construction material	Number of samples	Exhalation Rate (mBq kg^{-1} h^{-1})
1.	Soil	16	7.09
2.	Brick (fired)	14	5.75
3.	Brick (unfired)	6	8.57
4.	Concrete brick	4	9.23
5.	Cement	9	8.29
6.	Concrete	5	9.98
7.	Sand	14	8.25
8.	Crusher dust	11	11.28
9.	M-Sand	12	15.62
	Min		5.75
	Max		15.62
	Average		9.34

Table 2: Mass exhalation rate of ^{222}Rn in samples of construction materials used in small amount.

Sl. No	Construction material	Number of samples	Exhalation Rate (mBq kg^{-1} h^{-1})
1.	White granite	4	1.97
2.	Pink granite	3	15.12
3.	Green granite	3	18.24
4.	Red granite	4	32.73
5.	Lime stone	3	10.71
6.	Sand stone	4	4.19
7.	Ceramic tile	4	BDL
8.	Terracotta tile	4	2.58
9.	Mosaic tile	5	3.88
10.	White Marble	4	12.81
	Min		BDL
	Max		32.73
	Average		10.22

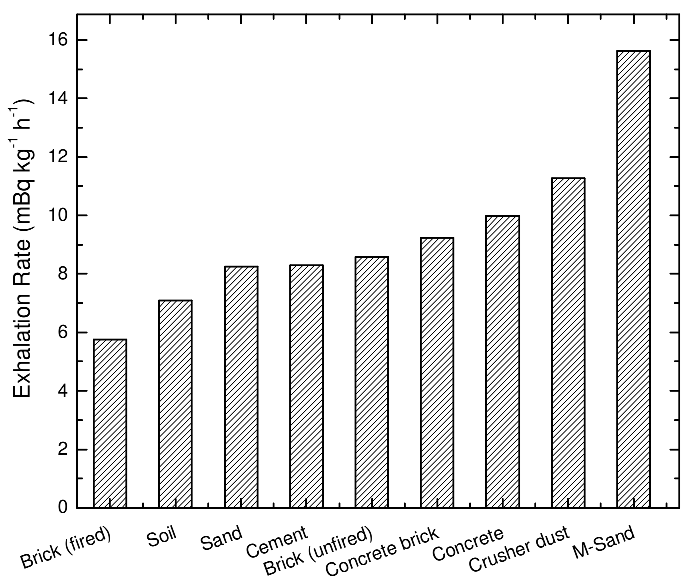

Fig. 3. Mass exhalation rate of ^{222}Rn in samples of construction materials used in large amount.

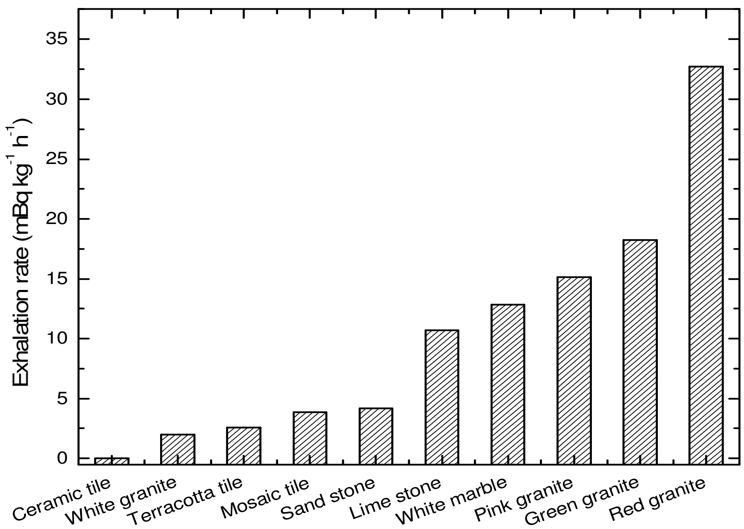

Fig. 4. Mass exhalation rate of ^{222}Rn in samples of construction materials used in small amount.

IV. CONCLUSION

The rate of ^{222}Rn exhalation was studied in the building material samples collected from different parts of Mandya district, Karnataka state, India. The ^{222}Rn exhalation rate in the samples of construction materials used in large amounts was varied from 5.75 to 15.62 mBq kg^{-1} h^{-1} with an average of 9.34 mBq kg^{-1} h^{-1}. Higher ^{222}Rn exhalation rate was observed in M-sand and crusher dust. The ^{222}Rn exhalation rate in the samples of construction materials used in small amounts varied from BDL to 32.73 mBq kg^{-1} h^{-1} with an average of 10.22 mBq kg^{-1} h^{-1}. Maximum rate of ^{222}Rn exhalation was observed in the samples of red granite. Fired bricks has a radon exhalation rate of 5.75 mBq kg^{-1} h^{-1} whereas unfired brick has 8.57 mBq kg^{-1} h^{-1}. The reduction of radon exhalation rate in fired bricks may be due to the possibility of evaporation of radionuclides from the bricks during the process of baking at higher temperature.

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