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Measurement and analysis of ^{222}RN in the commonly used building construction materials

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***Abstract*---**Humans are constantly exposed to ionizing radiation, which is naturally occurring in the earth's crust. On the surface of the earth, the composition of radionuclides varies from place to place depending on the geological condition. Radon is a radioactive inert gas that emits radiation, contributing a large portion of the amount of radiation received by humans on earth. For radon studies, commonly used building material and soil samples are collected such as rocks, soil, sand and various types of cement etc from the local market, construction site and hardware stores. The concentration of 222Rn and mass exhalation rate was studied in the samples of building materials used in the province of Pune District, Maharashtra, India. In the present study active device AQTEK Smart RnDuo was used to measure the radon concentration and mass exhalation rate for the building construction material. In the current study, for soil samples shows radon concentration varies from 279±22Bq/m3 to 457±23Bq /m3 for with a mean value 342±22 Bq/m3, radon mass extraction rate varied from 9.64±0.54 mBq/Kg/hr to 18.84±1.5mBq/Kg/hr with mean value 13.5±1.04 mBq/Kg/hr. Similarly for various building material, radon concentration varies from 232±19Bq/m3 to 384±19Bq/m3 for with a mean value 301±21 Bq/m3, radon mass extraction rate varied from 4.82±0.233 mBq/Kg/hr to 16.98±1.17mBq/Kg/hr with mean value 9.29±077 mBq/Kg/hr. Radon concentration information is useful in determining radon exhalation rate which can be helpful in assessing the risk of health problems associated with radon exposure. Research on the level of radon emissions in building materials is important to understand the indoor exposure of radon exposure to each component of the material.

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Introduction

It is common practice that the majority of natural resources used as building materials for homes and buildings, such as sand, soil, cement, and rock, come from various rocks and earth's crusts. These building materials are frequently high in radioactive elements that exist naturally. The concentrations of radionuclide's found in construction materials vary depending on the geological conditions in the area (Raste et al. 2018; Sharma el at. 2015; Semwal et al. 2018) Large amount of trash from other sectors are also mix in these building substances by the construction industry, however these building materials may cause radioactivity levels to rise dramatically above background levels (Rafat, 2015). Long-term exposure to low amounts of ionizing radiation can pose serious health risks to humans (UNSCEAR 2000). Because alpha radiation is 1000 times more carcinogenic than gamma radiation, studying alpha activity in construction materials could be very relevant (Ghosh et al. 2008). Because people spend 85% of their lives indoors, understanding natural radioactivity in building materials as a primary non- stop source of indoor radiation exposure is critical in assessing population exposures (Stoulos et al. 2003; Zikovskyet al., 1992).

Radon (^{222}Rn) is a noble gas with a half-life of 3.8 days that can be released from the ground, rocks, and building materials, and accumulate ((Rawat et al.1991). Lung cancer has been connected to the inhalation of ^{222}Rn and its short-lived daughters in humans (Darby et al. 2004). When radium decays in soil grains, the radon isotope's atoms escape the mineral grains and enter the atmosphere. The radon emanation rate, also known as the radon exhalation rate, is the rate at which radon escapes or emerges from the earth. Radium concentration in soil, soil shape, soil grain length, soil moisture, temperature, air pressure, and rainfall are only a few of the variables that influence radon exhalation (Khan et al., 2012). This type of research could be valuable for measuring public radiation exposure and epidemiological performance, as well as archiving statistics and tracking changes in environmental radioactivity produced by commercial, nuclear, and other human activities (Singh et al. 2009). With the aforementioned crucial parameters in mind, a study was conducted to assess the natural distribution of radon exhalation rates in building samples collected from Pune, Maharashtra, India.

Materials and Methods

Study area

Fieldwork was conducted in the Pune region of Maharashtra, on the western peninsula, at 18031'N and 73055'E. The Western Ghats and the Deccan Plateau are the two primary sections of the Pune zone province. Deep holes can be found in each band, as well as a succession of small or low hills that run into the plains. The Pune region is around 2,000 meters in diameter and formed 60 to 68 meters from the Eocene to Cretaceous epoch. It is made up of numerous layers of reinforced basalt fluid. A massive deposit of Amygdular vesicular zeolitic basalt and big basalt with a Red bole interface makes up the region.

Measurement of exhalation rate of ^{222}Rn

The active device AQTEK SMART RnDuo was used to assess radon content and exhalation rate in building materials in the current investigation. The SMART RnDuo is a commercially available portable instrument that detects ^{222}Rn, ^{220}Rn, and alpha rays in the air, ground, and water. The basic principle of the SMART RnDuo instrument is to detect alpha particles using ZnS:Ag scintillation. The acquisition policy and measurement processes are described in further detail elsewhere (Gaware et al. 2011). Commonly used building materials samples (~ 1000 g) such as rock, soil, sand, and various types of cement are obtained from local markets,construction sites, and hardware stores for the mass exhalation rate of ^{222}Rn and concentration. Amortar and pestle or a vibrating ball machine is used to grind the sample into a fine powder. To test radon, a fine powder of an object is placed in the breathing chamber. The Smart RnDuo is coupled to a ~500gm sample capacity closed accumulation chamber(Figure 1). The chamber is made up of stainless steel cylinders with dimensions 8cm height and 10 cm diameter that are connected at the top to a Lucas cell and photomultiplier tube. To avoid ^{222}Rn interruptions, the SMART Duo was used in diffusion mode at ^{222}Rn (if available in samples). After 1 hour, the concentration of 222Rn in the compartment was measured and continued until it was saturated. The 222Rn concentration data with time elapsed was plotted. Radon growth with time in Bq / m^{3}withinthe accumulator chamber is given (Aldenkamp et al. 1992).

$$C_{(t)} = \frac{J_m M}{V\lambda}(1 - e^{-\lambda t}) + C_0 e^{-\lambda t} \text{ -----}(1)$$

Where $C_{(t)}$ is ^{222}Rn concentration (Bqm^{-3}) at time t Bqm^{-3}

$J_m = {}^{222}Rn$ mass exhalation rate $(Bq/Kg/h)$

$\lambda = effective\ decay\ const.(h^{-1})$

C_0 = ^{222}Rn concentration (Bqm^{-3}) present in the chamber volume at t=0

M = mass the dry sample (Kg)

V= Volume of accumulator chamber and scintillation cell volume (volume of detector + porous volume of sample +residual air volume of the mass exhalation chamber) (m^{-3})

The porous volume (Vp) can be estimated using the following equation

$$V_p = V_s - \frac{M}{\rho_g} \text{------}(2)$$

V_s is the sample volume in the mass exhalation chamber

ρ_g is the specific gravity of sample which can be taken as 2.7 gm/cc for clay type soil sample.

Radon mass exhalation rate can be calculated by the formula

$$J_m = \frac{BV}{M} \quad \text{--------------------(3)}$$

Where J_m=Radon (^{222}Rn) mass exhalation rate
B=Slop of the linear fit graph of radon concentration (Bqm^{-3}) Vs Time (hr)
V=Effective volume, M=Total mass of the dry sample

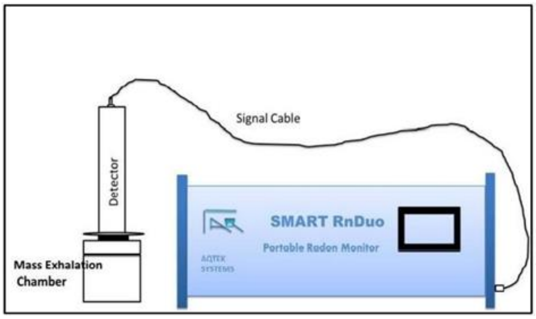

Figure 1. Photograph Set-up for in-situ measurement of the radon mass exhalation rate frommaterial using RnDuo in diffusion mode of sampling

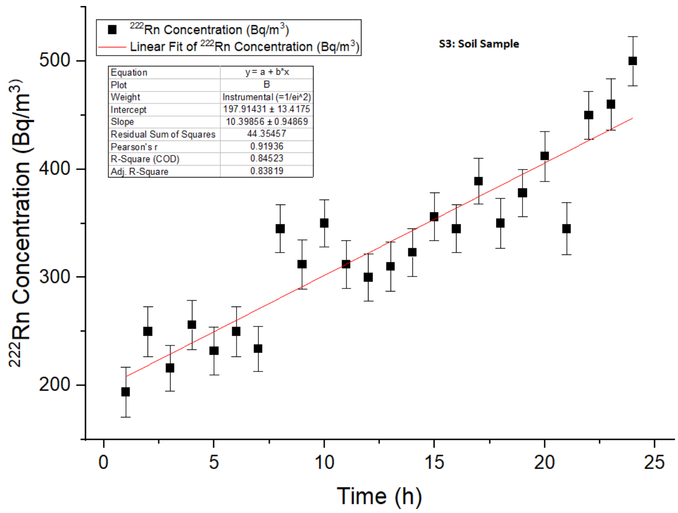

Figure 2. A: Linear regression to the radon builds up data in the mass exhalation chamber(for soil sample)

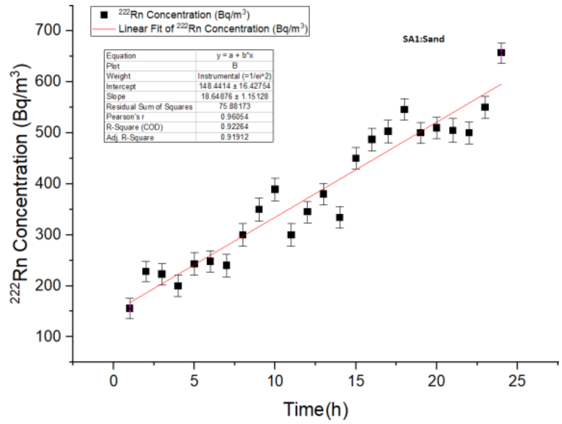

Figure 2. B: Linear regression to the radon builds up data in the mass exhalation chamber(for building material: sand sample)

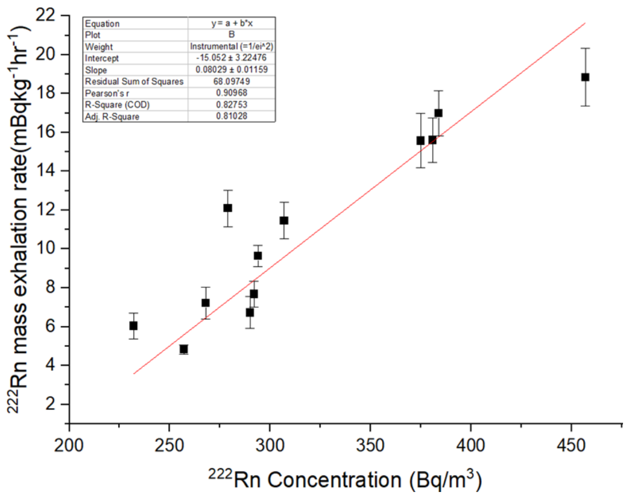

Figure 3. Variation of radon concentration with radon mass exhalation (all samples)

Results and Discussion

In the current work, ^{222}Rn concentrations and radon mass inhalation rates of 12 widely used construction materials were measured and analysis by using the activated AQTEK Smart RnDuo (Figure 1). Concentration levels of radon and exhalation rates of soil and construction building materials are given in Tables 1 and 2. The results of the current study for soil samples, radon concentration vary from 279 ± 22Bq / m^3 for sample S3 to 457 ± 23Bq / m^3 for sample S5, with an mean value of 342 ± 22 Bq / m^3. The radon mass exhalation rate varies from 9.64±0.54 mBq/kg/hr for sample S1 to 18.84 ± 1.5 mBq/ kg/hr for sample S5 with mean value 13.5 ± 1.04 mBq/kg/hr (Table 1).

Figure 2A, the strong linear correlation (average value of R-0.848) between the radon concentration and the time (total 05 soil samples) represents the linear structure of the radon data in a large exhalation chamber in a one case. The density of the samples was calculated using the mass to volume ratio (Kumar et al. 2014), which is 1853 kg/m^3 ~ 2507 kg/m^3 for soil samples (Table 1). Radon exhalation rate decreases as density increases but the current study did not follow the radon exhalation rate verse density pattern. There is a positive relationship between radon concentration and exhalation rate (Figure 3). This may be due to the radium content in the soil samples and the porosity of the samples with different geographical and topographical locations. Radon gas enters the atmosphere through two processes, first releasing radon from the soil grain into the soil pores called exhalation and then transporting the radon gas to the stomata space in the atmosphere, which is the exhalation process. Radon mass exhalation rate is the sum of the activity per unit mass per unit time. The concentration of radon depends on many parameters such as depth, porosity, diffusion coefficient and humidity of the samples (Durani et al. 1997).

Similar to the results obtained for different construction materials, the radon concentration varies from 232 ± 19 Bq/m^3 for sample C5 to 384 ± 19 Bq/m^3 for sample R1, with an average value of 301 ± 21 Bq/m^3, the radon mass exhalation rate ranges from 4.82 ± 0.233 mBq/kg/hr for sample C1 to 16.98 ± 1.17 mBq/kg/hr for sample R1, with an average value of 9.29 ± 077 mBq/kg/hr (Table 2). Figure 2B, the strong linear correlation (average value of R-0.862) between the radon concentration and the time (total 07 building material samples) represents the linear structure of the radon data in a large exhalation chamber in a one case. The density of the samples was calculated using the mass to volume ratio (Kumar et al. 2014), which is 1813 kg/m^3 ~ 2779 kg/m^3 for building material samples (Table 2). Concentrations from cement C5 were observed to be lower than the R1 (rock) content, whereas the radon mass exhalation rate to R1 was higher than that to C1. One reason for this may be the different and varied porosity of the immature materials used in the production of this cement. Figure 3 shows the variation of radon concentration with radon exhalation rate. It has been observed that there is a positive correlation (R-0.8) between radon concentration and radon mass exhalation rate. The concentration of radon in soil or building materials is ^{226}Ra and ^{232}Th depending on the parent rock or earth-based material from which it is formed. ^{226}Ra is transported and deposited from parent rock into the soil during meteorological processes, but ^{232}Th is highly insoluble in water, so meteorological processes are not transported ^{232}Th and remain in its source material. This bond, found in gravel deposits and coarse sandstone, caused it to be transported by frictional suspension. The exhalation rate of the radon mass of soil and construction material in the present study is comparable to or less than what is reported in the literature to the valley shown in Table 3 and is comparable to or less than that of other regions.

Conclusion

Radon concentration information is useful in determining the rate of radon inhalation which helps to assess the risk of health problems associated with radon exposure. Research on radon emissions levels in construction materials is important to understand the indoor exposure to radon exposure for each component of the material.

Table 1
Radon concentration and Radon mass exhalation rate of soil samples

Sr.No	Sample code	Slop ($Bq/m^3/h$)	Linear Regression Coeff.(R)	Density (kg/m3)	222Rn Conc. (Bq/m3)	Mass Exhalation J_M(mBq/kg/hr)
1	S1	9.96	0.938	2507	294±21	9.64±0.54
2	S2	10.08	0.837	2227	307±20	11.45±0.94
3	S3	10.39	0.845	2188	279±22	12.09±0.94
4	S4	13.7	0.811	2227	375±24	15.57±1.4
5	S5	13	0.811	1853	457±23	18.84±1.5
Mean		11.42	0.848	2200	342±22	13.5±1.04
Max.		13.7	0.938	2507	457±23	18.84±1.5
Min.		9.96	0.811	1853	279±22	9.64±0.54

Table 2
Radon concentration and Radon mass exhalation rate of building material

Sr.No	Sample code	Slop ($Bq/m^3/h$)	Linear Regression Coeff.(R)	Density (kg/m3)	222Rn Conc. (Bq/m3)	Mass Exhalation J_M(mBq/kg/hr)
1	C1	3.48	0.91	1912	257±22	4.82±0.233
2	C2	8.18	0.817	2685	268±19	7.21±0.82
3	C3	5.58	0.741	1813	290±22	6.72±0.82
4	C4	6.76	0.851	2227	292±22	7.68±0.66
5	C5	5.76	0.851	2365	232±19	6.04±0.66
6	SA1	18.64	0.922	2779	381±21	15.60±1.15
7	R1	15.9	0.948	2255	384±19	16.98±1.17
Mean		9.18	0.862	2290	301±21	9.29±0.77
Max		18.64	0.948	2779	384±19	16.98±1.17
Min		3.48	0.741	1813	232±19	4.82±0.233
C1:Corobandal cement, C2: Birla Super cement,C3:Shree Cement,C4:Rajeshree Cement, C5: J.K.cement,SA1:Sand,R1:Rock						

Table 3
Literature value of radon of building substances in various region of India

Sr. No.	Material	Rn-222 Concentration (Bqm^{-3})	Rn-222 Mass Exhalation Rate ($mBqkg^{-1}hr^{-1}$)	Reported by
01	Cement	-	5.9±0.9	Kumar et al.(2007)
		-	2.3±0.9	Sahoo et al.(2007)
		205.05	350	Najam et al.(2013)
		258±12.8	1.75±0.047	Sonkawade et al.(2008)
02	Sand	480.71	1.2	Hussain et al(2013)

		238±13	1	Sonkawade et al (2008)
03	Soil	941-10050	--	Mittal et al.(2016)
		--	28.2-91.2	Chauhan et al. (2014)
		1100-31800	0.001-0.057	Prasad et al (2009)
		271-837	2.06-30.77	Raste(2019)

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References

1. Aldenkamp, F.J., Meijer R.J., Stoop, P.,(1992). An assessment of in situ radon exhalation measurement and the relation between free and bound exhalation rates. Radiat.Prot.Dosim.45,449-453.
2. Chauhan, R.P.,Kumar,A., Chauhan,N., Joshi, M. Aggarwal,P., Sahoo, B.K., (2014) Ventilation effect on indoor radon-thoron levels in dwellings and correlation with soilexhalation rates. Indoor Built Environ., 25: 1-10.
3. Darby,S.,Hill,D.,Auvinen,A., Baysson,H.(2004), Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. BMJ 63:4-6.https://doi.org/10.1136/bmj.38308.477650.63.
4. Durrani,S.A. ans Ilic,R., (1997),Eds Radon measurement by Etched Track Detector (Singapore: Word Scientific) pp. 180-181 Chap.3.
5. Gaware,J.J,et al (2011). Development of online radon and thoron monitoring systems for occupational and general environmental. BARC News Lett. 318:45-51.
6. Ghosh,D.,Deb,A., Bera,S.,Sengupta,R.,& Patra,K.K.(2008), Assessment of Alpha Activityof Building Materials Commonly used in West Bengal,India. J.of Env.Rad.,99,316- 321.
7. Hussein, Z.A., Jaafar, M.S., Ismail, A.H., Battawy, A.A., (2013) Radon exhalation rate from building materials using Passive Technique Nuclear Track Detectors.International Journal of Scientific and Engineering Research, 4: 1276-1282.
8. Khan,M.S.,Srivastava,D.S., & Azam, A.(2012). Study of radium content and radon exhalation rates in soil samples of northern India,Env.Earth Sci.67(5),1363-1371.
9. Kumar,A.,Chauhan, R.P.Joshi,M., Prajith,R.,Sahoo,B.K., (2015) Estimation of radionuclides content and radon/thoron exhalation from commonly used building materials in India. Environ. Earth Sci.,74: 1539 -1546.
10. Kumar,A.,Chauhan,R.P.,Joshi,M.Sahoo,B.K.,(2014). Modeling of indoor radon concentration from radon exhalation rates of building material and validation throughmeasurements. J. Environ. Radioact. 127: 50-55.
11. Mittal,S., Rani, A., Mehra,R., (2016) Estimation of radon concentration in soil and groundwater samples of Northern Rajasthan, India. J. Radiat.Res. App. Sci., 9: 125- 130.
12. Najam,L.A.,Tawfiq,N.F., Mahmood,R.H., (2013) Radon Concentration in Some Building Materials in Iraq Using CR-39 Track Detector. Int. J. Phy., 1: 73-76.

13. Prasad, G., Prasad, Y., Gusain, G. S.,Ramola, R.C., (2008) Measurement of radon and thoron levels in soil, water and indoor atmosphere of Budhakedar in Garhwal Himalaya, India. Radiat. Meas., 43: 375 -379.
14. Rafat, M.Amin., (2015). A Study of radon emitted from building materials using solid nuclear track detector, J.of Rad. Res. & App. Sci. 8(2015)516-522.
15. Rahmadeni, A. S. ., Hayat, N. ., Alba, A. D. ., Badri, I. A. ., & Fadhila, F. . (2020). The relationship of family social support with depression levels of elderly in 2019 . International Journal of Health & Medical Sciences, 3(1), 111-116. https://doi.org/10.31295/ijhms.v3n1.188
16. Raste, P. Estimation and Analysis of Radon and Thoron in the Soil and Radiation Shielding Materials in and Around Kolhapur,Ph.D thesis, Shivaji University Kolhapur, http://hdl.handle.net/10603/275844.
17. Raste, P.M., (2018) et al., Assessment of radon in soil and water in different regions of Kolhapur district, Maharashtra, India, Rad.Pro.Dosi.1-6.
18. Rawat,A.,Jojo,P.J.,Khan, A.J.,Tyagi,R.K.,&Rajendra Prasad.(1991). Nuclear Track and Radiation Measurement, 19(14), 391.
19. Sahoo,B.K., Nathwani,D., Eappen, K.P., Ramachandran,T.V., Gaware, J.J., Mayya,Y.S., (2007) Estimation of radon emanation factor in Indian building materials. Radiat. Meas., 42: 1422-1425.
20. Sharma, Anil.,(2015) et al., Measurement of natural radioactivity, radon exhalation rate and radiation hazard assessment in Indian cement samples, Physics Procedia, 80 (2015)135-139.
21. Singh, J., Singh,H., Singh,S., & Bajwa,B.B., (2009). Uranium radium and radon exhalation studies in some soil samples using plastics track detector. Ind. J. of Phy.83(8),1147- 1153.
22. Snmwal, Poonam., et al. (2015), Measurement of ^{222}Rn and ^{220}Rn exhalation rate from soil samples of Kumaun Hill, India, Special issue Acta Geophysica (2018).
23. Sonkawade,R.G., Kant,K., Muralithar, S., Kumar,R., Ramola, R.C., (2008) Natural radioactivity in common building construction and radiation shielding materials,Atmos. Environ., 42: 2254-2259.
24. Stoulos,S.,Manolopoulou,M.,&Papastefanou,C.(2003).Assessment of natural radiation exposure and radon exhalation from building materials in Greece. J.of Env.Rad., 69,225-240.
25. Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2021). The COVID-19 pandemic. *International Journal of Health Sciences*, *5*(2), vi-ix. https://doi.org/10.53730/ijhs.v5n2.2937
26. UNSCEAR (2000). Source and effects of ionizing radiation. United Nations Scientific Committee on the Effect of Atomic Radiation, New York.
27. Zikovsky, L., & Kennedy, G. (1992).Radioactivity of building materials available in canada. Health Physics, 63(4), 449-452.