Effect of plastering and paints on radon exhalation rate and radon effective dose from fired bricks

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In the present study, we estimate the effect of paints on the radon exhalation rate from building materials. For the experimental study some bricks were collected from the local market of Aligarh district, Uttar Pradesh, India. They were coated with a soup of cement and sand, and then dried for at least 24 h. After drying, the coated bricks were plastered with whitewash and re-dried for a minimum of 2 h. They were then ready to be painted with different colours of paints from different brands. Radon exhalation rate and effective dose were measured for the painted brick samples by adopting sealed can technique, which utilizes LR-115 type-II track detectors. The radon activity varied from 768.8 to 1529.8 Bq m^{-3} and exhalation rate varied from 460.1 to 915.6 mBq m^{-2} h^{-1}, whereas the dose equivalent for radon daughters varied from 54.2 to 107 μSv yr^{-1}. Exhalation of radon in the case of Snowcem (limeproof yellow), Asian Paints (peach organza) and Berger Paints (yellow breeze) was found to increase slightly, while it decreased for the other paint brands.

Keywords: Building materials, fired bricks, paints, radon, thoron.

SINCE its inception, the biosphere has been subjected to nuclear radiation from radioactive species such as plutonium, thorium, potassium and the remains of naturally occurring, very long-lived nuclides. Human scientific advances have slightly altered the radiation exposure levels. The emission of radon is mainly related to radium and its ultimate counterpart uranium. Brick and stone are considered to be radioactive because they contain naturally radioactive materials like uranium and thorium. Scientific studies have confirmed that for brick-facade houses, the building materials subsidize about 0.008 μSv/h. This value is taken from a report of the National Council on Radiation Protection and Measurements, USA. The exhalation of radon due to bricks and other building materials has been studied by Chandrashekara[1] in Mandya district, Karnataka, India. The airing of populace to excessive concentrations of radon and its decay products for a protracted duration results in pathological effects like respiratory functional changes and the prevalence of lung cancer[2]. Radon is a radioactive element which is naturally occurring in the environment. It comprises the decay of radium isotopes, which might be the decay products of ^{238}U, ^{232}Th and ^{235}U. Subsequently, the concentration of uranium and thorium within the soil types determines the amount of radon produced in the soil[3]. ^{222}Rn from the soil has been recognized as one of the important mechanisms influencing indoor radon levels in several homes. A global average of 60% of indoor radon comes from the ground and the surrounding soil of homes. The radiation dose from radon and its daughters product indoor is the highest of all human exposures derived from natural as well as man-made sources[4]. There is possibility of high levels of radiation in rooms which are kept closed for a long time as well as in air-conditioned rooms due to accumulation of radon gas[5]. Radon in the indoor spaces originates from the walls, floors, ceiling and soil. Since building construction materials and their uranium contents differ geographically, different building materials contribute differently to indoor radon. Radon occurs predominantly by the process of diffusion from floors, walls and ceilings made from cement, sand and other building materials. Bricks are ground-based and shot in kilns. Burnt clay bricks are the oldest and most popular brick variety, which are manufactured by suitably pressing wet clay into moulds, then drying and firing them in kilns. These bricks are solid blocks of dense clay, usually red in colour. Generally, building materials such as concrete, brick, gypsum and aerated concrete may contain natural radionuclides. Every construction material from natural rock – depending on the geological origin – consists of a natural proportion of uranium and radium. Radon and its decay products are formed from uranium and radium decay, and released from the building materials into the buildings. Measurements show that building materials contribute little to the indoor radon concentration. The propagation of radon depends on the permeability of the soil. Up to a depth of about 1 m, the dispersion of radon also driven by weather situations. Locally, radon occurs in exceptional concentrations inside homes. It does not contain radiation exposure relevant to the health of

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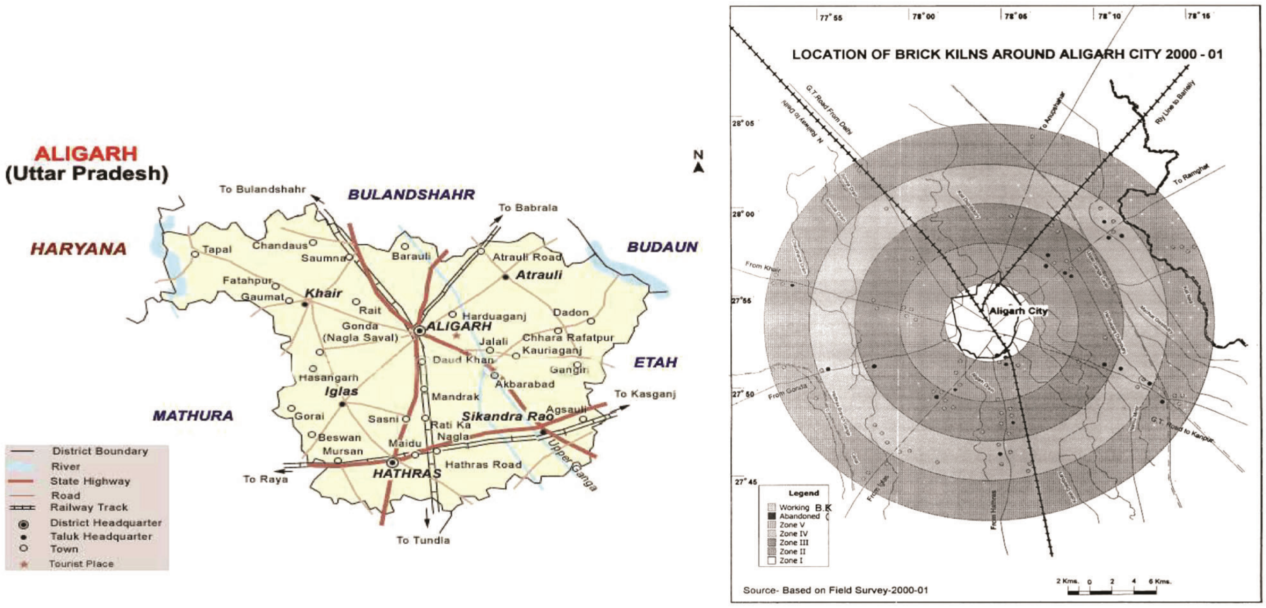

Figure 1. The study area.

residents. Such bricks are used to build walls, and these walls are then plastered with a combination of cement and sand. Materials used for construction are the major sources of indoor radon concentration in homes and contribute significantly to the level of radiation exposure among humans[6–8]. The presence of three fundamental radionuclides (^{40}K, ^{238}U and ^{232}Th) in the building materials is the main cause for people to be exposed internally and externally. ^{40}K-emitted gamma radiation and daughter products of ^{238}U and ^{232}Th cause external exposure[9]. It is widely known that due to inhalation of ^{222}Rn, which is a daughter product of the ^{238}U decay chain, the equivalent dose is higher in the lungs than in the other tissues[10]. The radon emanation or radon exhalation rate may be defined as the rate of diffusion of radon from solid material into the encompassing air. This is of two types – if it is measured per unit mass, then it is known as the mass exhalation rate, or if it is measured per unit surface area, it is the surface exhalation rate. Emanation power is defined as the ratio of radon figuratively created and radon escapes into the pores. It is also termed as coefficient of emanation or emanation ratio. Depending on their microstructure, some materials may be possible for expanded radon levels inside the homes, either because of their high radon exhalation rates or because of their uranium/radium advancement in comparison with other materials[11,12]. Radon is a noble gas produced from the soil underneath homes and from materials used to construct houses. In the earth's crust due to radioactive transformation in the ^{238}U decay chain, inert radon gas is emitted[13]. The integrated measurement of indoor and outdoor radon is directly related to the assessment of radiological hazards of inhaled radon and its progeny. The main source of radon in the indoor environment is its exhalation from the earth's crust and building materials[12]. The walls and rooftops are coated with various kinds of paints and this may influence the exhalation rate of radon from such materials. As several brands of paints are accessible commercially and broadly used as spread for put blocks for expanding their life and for an elaborate reason, it is necessary understand the impact of wall paints on the exhalation rate of radon from the building construction materials.

Geography of the sampling region

The study area of Aligarh (27.88°N, 78.08°E), Uttar Pradesh, India, has an elevation of about 178 m (587 ft). It is situated between the Ganga and Yamuna rivers in the middle of the doab (Figure 1).

Experimental technique

To study the radon exhalation rate, the sealed can technique[14] was adopted, in which a cylindrical plastic can having fix dimensions of 7.5 cm height and 7.0 cm diameter was used. Individual samples were sealed with plasticine (Figure 2). Radon decays in the total volume of the can which has a plastic nuclear track detector LR-115 type-II (2 cm * 2 cm) at the top, with its sensitive surface free to be exposed to the emitted radon. The detector films help detect the alpha particles released from the radon decay as well as those present on the inner walls of the can deposited by ^{218}Po and ^{214}Po. In this type of passive measurement, the radon exhalation depends upon the material, geometry and dimensions of the can[12]. Equilibrium in the concentration of radon and its daughters will be achieved after one week or more. Hence, using the geometry of the can and exposure time, the equilibrium activity of the emergent radon can be estimated. Radon was exposed to each detector for 100 days.

When exposed, all the detector films were removed and then etched in 2.5 N NaOH solution at 600°C in a constant-temperature water bath to reveal the nuclear tracks produced by alpha particle. Track density of the detector was determined using a calibration factor equal to 0.56 tracks cm^{-2} d^{-1} obtained from a prior calibration experiment using an optical microscope with magnification 400×. Radiation exposure within the can was calculated from the track density of the detector[13]. The exhalation rate was estimated using the following relation[15–19]:

$$E_x = \frac{CV\lambda}{A\left[T + \frac{1}{\lambda}(e^{\lambda t} - 1)\right]},$$

where E_x is the exhalation rate of radon (Bq m^{-2} h^{-1}), C the LR-115 type-II measurement of integrated radon exposure, V the volume of the can (m^3), λ the decay constant, T the time of exposure (h) and A is the total area of the plastic can used (m^2).

Risk estimation

We estimated the incidence of lung cancer among humans because of domestic exposure of ^{222}Rn and its daughters by calculating the indoor inhalation exposure (radon) effective dose using the relation: $C_{Rn} = (E_x \times S)/(V \times \Delta V)$, where C_{Rn} is the radon concentration (Bq m^{-3}), E_x the radon exhalation rate (Bq m^{-2} h^{-1}), S the radon exhalation area (m^2), V the room volume (m^3) and ΔV is the rate of exchange of air (h^{-1}). The foremost extreme radon concentration from the artefact was surveyed by expecting the room as a cavity with ratio $S/V = 2.0$ m^{-1} and rate of exchange of air is 0.5 h^{-1}. The annual exposure to potential alpha energy E_p also referred to as effective dose equivalent is said to the typical radon concentration C_{Rn} (Bq m^{-3}) by the expression[15]

$$E_p \text{ (WLM yr}^{-1}) = 8760 \times n \times f \times C_{Rn}/170 \times 3700,$$

where n is the fraction of time spent indoors, 8760 is the number of hours per year, 170 is the number of hours per working month and F is that the equilibrium factor for radon which measures the state of equilibrium between radon and its progeny and should have values $0 < F < 1$. The value of F was taken as 0.4 as recommended by UNSCEAR[5]. When dose calculations are made on the basis of radon concentration, the equilibrium factor for progeny of radon becomes the most important quantity. Thus, the values of $n = 0.8$ and $F = 0.4$ were used to calculate E_p. From radon exposure, effective dose equivalents were estimated by using a factor of 3.88 mSv $(WLM)^{-1}$ (ref. 20).

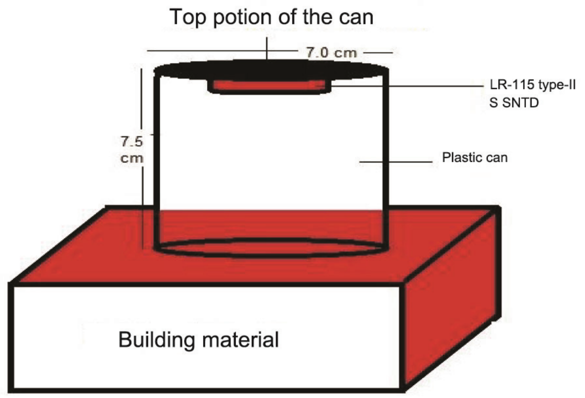

Figure 2. Measurement of radon exhalation rate using the 'can technique II'.

Results and discussion

Various types of paints available in the local market have been tested for radon exhalation and activity. Table 1 shows the measured values of radon activity and radon exhalation rates from unplastered bricks, plastered bricks and plastered bricks after painting them with different brands and colours of paints. Radon emission had significantly reduced when the bricks were plastered. There was not much significant effect of the paints although different colours of different paint brands showed slightly different effects. This change in values could be attributed to different amounts of uranium in plasters and paints, or to the differences in porosity. From the observed data, radon activity was found to vary from 768.8 to 1529.8 Bq m^{-3}. Among inhabitants, radon exhalation rate ranged from 460.1 to 915.6 mBq m^{-2} h^{-1}, whereas the effective dose equivalent of decay products varied from 54.2 and 107.9 μSv yr^{-1}. There was a tendency for radon exhalation to increase with Snowcem (limeproof yellow), Asian Paints (peach organza) and Berger Paints (yellow breeze), while it decreased for the other paint brands. According to UNSCEAR, the exhalation rate of walls and floors of 0.1 and 0.05 m thickness in the year 2000 was 5760 and 2860 mBq m^{-2} h^{-1} respectively. In the present study, the radon exhalation rate and radon activity were found to be less than the above-mentioned values.

Conclusion

The results of this study show maximum radon exhalation rate (777.29 ± 25.8 mBq m^{-2} h^{-1}) from unplastered bricks. Radon can escape from brick walls depending on their surface area. Plastered brick walls with different brands

Table 1. Activity concentration, radon exhalation rate and effective dose equivalent from plastered and painted fired bricks

Brands/colours of paints	Track density (track/cm^2 × day)	Radon activity (Bq m^{-3})	Exhalation rate (mBq m^{-2} h^{-1})	Effective dose equivalent (μSv yr^{-1})
Plastered bricks	59.4 ± 2.2	1062.3 ± 38.8	635.8 ± 23.3	74.9 ± 2.7
Unplastered bricks	72.7 ± 2.4	1298.7 ± 43.0	777.29 ± 25.8	91.6 ± 3.0
Snowcem				
Sky blue	72.5 ± 2.4	1296.1 ± 43.0	775.7 ± 25.8	91.4 ± 3.0
Bright red	63.7 ± 2.3	1137.6 ± 40.3	680.9 ± 24.1	80.2 ± 2.8
Limeproof black	62.6 ± 2.2	1119.4 ± 40.0	670.0 ± 24.0	79.0 ± 2.8
Limeproof yellow	85.6 ± 2.6	1529.8 ± 46.8	915.6 ± 28.0	107.9 ± 3.3
Bright green	57.1 ± 2.1	1020.7 ± 38.2	610.9 ± 22.8	72.0 ± 2.7
Nerolac Paints				
Black	56.5 ± 2.1	1010.3 ± 38.0	604.7 ± 22.8	71.3 ± 2.8
Crimson	62.9 ± 2.2	1124.9 ± 40.1	673.1 ± 24.0	79.3 ± 2.8
Forest green	64.1 ± 2.3	1145.4 ± 40.4	685.5 ± 24.2	80.8 ± 2.9
Jockey red	62.4 ± 2.2	1114.2 ± 39.8	666.9 ± 23.8	78.6 ± 2.8
Sunflower yellow	62.9 ± 2.2	1124.6 ± 40.0	673.1 ± 24.0	79.3 ± 2.8
Pacific blue	58.1 ± 2.1	1038.9 ± 38.6	621.8 ± 23.1	73.3 ± 2.7
Phirozi	47.2 ± 1.9	844.1 ± 34.8	505.2 ± 20.8	59.5 ± 2.4
Natural white	67.4 ± 2.3	1205.1 ± 41.5	721.3 ± 24.9	85.0 ± 2.9
Shalimar Paints				
Silver	56.5 ± 2.1	1010.3 ± 38.0	604.7 ± 22.8	71.3 ± 2.7
Asian Paints				
Sunny yellow	58.9 ± 2.2	1051.9 ± 38.8	629.6 ± 23.2	74.2 ± 2.7
Moon light	46.4 ± 1.9	828.5 ± 34.4	495.9 ± 20.6	58.4 ± 2.4
Peach organza	72.8 ± 2.4	1301.3 ± 43.1	778.8 ± 25.8	91.8 ± 3.0
Signal red	50.7 ± 2.0	906.4 ± 36.0	542.5 ± 21.5	63.9 ± 2.5
Blue harmony	54.1 ± 2.1	966.2 ± 37.1	578.3 ± 22.2	68.1 ± 2.6
Mineral green	66.4 ± 2.3	1187.0 ± 41.2	710.4 ± 24.7	83.7 ± 2.9
Apollo Paints				
Green	56.1 ± 2.1	1002.6 ± 38.9	600.0 ± 22.7	70.7 ± 2.7
White	59.0 ± 2.2	1054.5 ± 38.9	631.16 ± 23.2	74.4 ± 2.7
Phirozi	54.9 ± 2.1	981.8 ± 37.5	587.6 ± 22.4	69.2 ± 2.6
Yellow	48.4 ± 2.0	864.9 ± 35.2	517.6 ± 21.0	61.0 ± 2.4
Red	46.6 ± 2.0	833.7 ± 34.5	499.0 ± 20.1	58.8 ± 2.4
Berger Paints				
Black	43.05 ± 1.9	768.8 ± 33.1	460.1 ± 19.8	54.2 ± 2.2
Garden green	52.2 ± 2.0	932.4 ± 36.5	558.0 ± 21.8	65.8 ± 2.5
Blue waltz	55.7 ± 2.1	994.8 ± 37.7	595.4 ± 22.6	70.2 ± 2.6
Yellow breeze	77.9 ± 2.5	1392.2 ± 44.6	833.2 ± 26.7	98.25 ± 3.1
White	64.1 ± 2.3	1145.4 ± 40.5	685.5 ± 24.2	80.8 ± 2.9
Nippon Paint				
Rose white	48.8 ± 2.0	872.7 ± 35.3	522.3 ± 21.1	61.5 ± 2.5
Average	59.6 ± 2.2	1065.6 ± 38.9	637.8 ± 23.3	75.1 ± 2.7
Standard deviation	9.5 ± 0.2	169.8 ± 3.1	101.6 ± 1.9	11.9 ± 0.2
Relative standard deviation	9.6 ± 0.2	172.5 ± 3.1	103.2 ± 1.9	12.1 ± 0.2

of paints reduced the void spaces to a great extent, so that most of the radon could escape from the surface. As unfired bricks may have many voids, radon can escape from inside, i.e. from a few centimeters under the surface. Therefore, the content of required data can be used as references for assessing any changes in the radioactive hazardous level that may have occurred due to geological changes in the studied area. Statistical data from this study can be used for the mapping of natural radioactivity and also as a baseline for future studies. To understand how different paint brands affect the radon concentration, it is necessary to assess their effects on radon. Additionally, these may serve as a reference for tracking possible future pollution from radioactivity. Based on the results of this study, it can be concluded the painted walls are not at the risk of radon poisoning due to building materials, since the values the values of radon exhalation rates and effective dose equivalent obtained from observed data are lower than the recommended level.

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