December 2009 Volume 4 Issue 6

Trade Science Inc.

Environmental Science

An Indian Journal

Current Research Papers

ESAIJ, 4(6), 2009 [484-492]

Radiation dose due to indoor radon and thoron

L.A.Sathish[1,*], K.Nagaraja[2], H.C.Ramanna[1], V.Nagesh[1], S.Sundareshan[3]

[1]Department of Physics, Government Science College, Bangalore – 560 001, (INDIA)

[2]Department of Physics, Bangalore University, Bangalore – 560 056, (INDIA)

[3]Department of Physics, Vijaya College, Bangalore – 560 004, (INDIA)

E-mail: lasgayit@yahoo.com

Received: 2nd September, 2009 ; Accepted: 12th September, 2009

ABSTRACT

Radio nuclides ^{222}Rn and ^{220}Rn, from the uranium and thorium decay chains are noble gases produced by the decay of their immediate respective nuclides ^{226}Ra and ^{224}Ra present in the rocks, uranium ores and soils. These gases can leave the earth's crust by processes such as diffusion, advection, and enter in the atmosphere. ^{222}Rn and ^{220}Rn decay products are the radioactive isotopes of polonium, bismuth, lead and thallium. These daughter products, being the isotopes of heavy metals, get attached to the existing aerosol particles in the atmosphere. The significant contribution to the total dose received by the population is subjected to the natural radiation due to the inhalation of ^{222}Rn, ^{220}Rn and their decay products. This work is intended to obtain the ^{222}Rn, ^{220}Rn concentrations and the associated inhalation dose rates in the dwellings of different characteristics. Higher dose rates were observed in lower volume houses and the granite flooring houses.

KEYWORDS

Indoor radon;
Thoron;
Volume;
Dose rate;
Floorings.

INTRODUCTION

^{222}Rn and ^{220}Rn in indoor environment originate from emanation of the gases by the walls, floor and ceiling which are constructed of building material, rock, soil by release from materials brought into the room, such as radon-rich water or gas and by radon or thoron in the inlet air, which may in turn have a normal concentration of the gases or an increased concentrations derived from sources outside the room. Primary sources are in all cases ^{226}Ra or ^{224}Ra. The great differences in their half-life are important for the release from the ground and the distribution in their atmosphere above the ground and in the room air of building.

Elimination of these radio nuclides from the atmosphere occurs either by its radioactive decay or by the removal processes such as plate out or surface deposition and washout by rain. Vast difference in the half-lives of ^{222}Rn (3.8d) and ^{220}Rn (55s) is a crucial parameter, governing their release from the ground and subsequent distribution in the free atmosphere[1].

^{222}Rn and ^{220}Rn daughter aerosol in the atmosphere is generated in two steps. After the formation from the isotopes by decay, the freshly generated radio nuclides react very fast with trace gases and air vapor, and become small particles, called clusters or unattached radio nuclides with diameters varying from 0.5 to 5mm. In addition, these radio nuclides attach to the existing

aerosol particles in the atmosphere within 1-100s forming the radioactive aerosols. Most of the newly formed decay product clusters are positively charged and have a high mobility[2]. Mobility is characterized by the diffusion coefficient that mainly controls the formation of the radioactive aerosol by attachment and the deposition on surfaces and in the human lung.

In view of this it was felt that, to estimate the effective dose rates to the population of Bangalore city, India due to the exposure of indoor ^{222}Rn, ^{220}Rn and their progeny levels in different seasons, different walls of the houses, different floorings of the houses, different rooms of the houses and in different volume of the houses and this type of study strengthens the results for specific area and adds up as a data bank for radon measurements.

STUDY AREA

The area of the present study is Bangalore City in Karnataka, India. Bangalore is the capital city of Karnataka. It lies in the south – east quadrant at 12º 8' at latitude and 77º 37' in longitude. The geology of this part of southern India[3] forms predominantly a granitic terrain with numerous varieties of granite and granitic gneiss, charnockites, alkaline rocks etc. Within this vast granitic complex, deposits of quartzite, sandstone, and marble are found in significant quantities. The rocks are of peninsular gneiss and are widely distributed throughout this area. The emplacement of alkaline dykes has domed up the area. The rocks around Bangalore rural District are called closepet granites. These rocks are younger than peninsular granites. These rocks are concentration of pegmatite. The soil in this area is red sandy loam with traces of yellow and black. The soil being porous permits free internal and downward movement of water. Mixed red and black colored soil is formed the underlying parent rock, which is mostly granite. The houses are constructed with different types of materials, most of them are cement houses and a minor component comprising of huts with mud walls. The materials used for building the cement houses consist of cement, reinforced concrete, burnt clay bricks, hollow blocks, Terracotta bricks and tiles. The floor finishes are made up of stones, concrete tiles, mosaic tiles, granite and marble slabs. The materials used for constructing huts are sand lime bricks, mortar, clay and asbestos sheets[4]. April is usually the hottest month with the mean daily maximum temperature of 30-35 ºC and mean daily minimum at 20-24 ºC. Relative humidity is high during the Rainy season for the South-West Monsoon months and decreases thereafter. During the months from May to September, the winds are west to South-West to West, while during the period from November to March, they are east to North-East and East to South-East. The year is divided into four season's viz.: Summer season [March to May], rainy season [June to August], autumn season [September to November] and winter season [December to February]. An attempt has been made to see the variation of dose rates in season wise, wall wise, floor wise, room wise and volume wise of the houses in about 10 different locations of Bangalore city, India by deploying more than 150 dosimeters and more than 1400 measurements have been made during 2007-2009.

METHODS AND MEASUREMENTS

Solid state nuclear track detectors

The concentrations of ^{222}Rn, ^{220}Rn and their progeny are measured in dwellings of Bangalore city using Solid State Nuclear Track Detectors (SSNTD), which are thin sheets of dielectric materials such as cellulose nitrate (CN) and polycarbonates. They are sensitive to alpha but not to beta and gamma radiations. They are unaffected by moderate humidity, heat and light. For indoor measurements normally LR-115 type II plastic track detector is preferred. The detailed description of the methodology and the calibration experiments has been given by Sathish et al[5].

RESULTS AND DISCUSSION

About 150 dwellings in ten different locations of Bangalore city, India were selected on the basis of construction, age of the building, nature of walls, different rooms and floorings to see the effective dose rates due to indoor ^{222}Rn, ^{220}Rn and their progeny levels in dwellings in different seasons of the year, different wall houses, different flooring houses, different rooms of the houses and different volume of the houses. The results of 2007 to mid of 2009 are discussed.

Current Research Paper

Area wise seasonal variations and dose rates

Area wise seasonal variations of ^{222}Rn and ^{220}Rn concentrations in different locations of Bangalore city is shown in Figure 1-2. The ^{222}Rn concentration during winter season of the studied locations ranged between12.28 – 100 Bq m^{-3}, the higher value of arithmetic mean concentrations with standard error during winter was 61.95 ± 9.2 Bq m^{-3} and the winter minimum value was 24.95 ± 2.7 Bq m^{-3}, whereas during summer season the concentration ranged between 4.05 – 50.29 Bq m^{-3}, the higher value of arithmetic mean concentrations with standard error during summer was 26.26 ± 3.8 Bq m^{-3} and the summer minimum concentration was 10.91 ± 1.0 Bq m^{-3}. The ^{220}Rn concentration during winter season of the studied locations ranged between 6.18 – 72.92 Bq m^{-3}, the maximum value of arithmetic mean concentrations with standard error observed during winter was 35.24 ± 4.2 Bq m^{-3} and the winter minimum was 15.39 ± 1.7 Bq m^{-3}, whereas during summer season the concentration ranges between 2.78 - 40.97 Bq m^{-3}, the maximum value of arithmetic mean concentrations of ^{220}Rn with standard error during summer was 18.67 ± 3.6 Bq m^{-3} and the summer minimum was 12.27 ± 2.0 Bq m^{-3}.

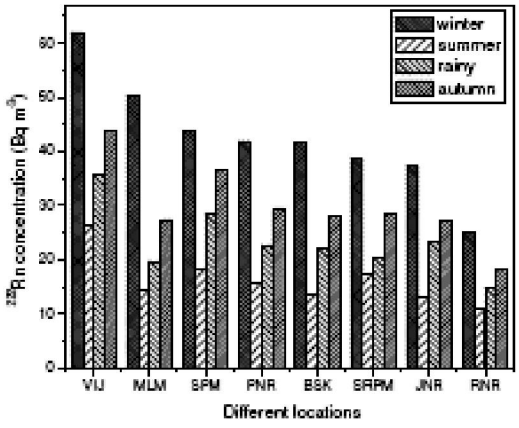

Figure 1 : Season wise ^{222}Rn concentrations

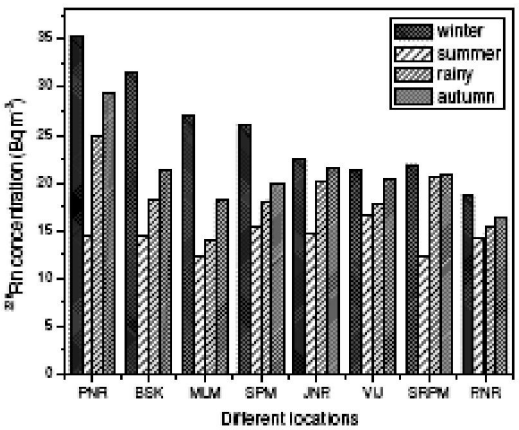

Figure 2 : Season wise ^{220}Rn concentrations

The winter maximum concentration of ^{222}Rn was observed in Vijayanagar area and the winter minimum was observed in Rajajinagar. The summer maximum concentrations of ^{222}Rn is observed in Vijayanagar and the summer minimum concentrations of ^{222}Rn is seen in Rajajinagar and it is true for rainy and autumn seasons for the same locations. The higher value of ^{220}Rn concentrations during winter was seen in Padhmanabhanagar area and the winter minimum was observed in Rajajinagar. The higher value during summer was seen in Rajajinagar and the lower was observed in Srirampuram. The arithmetic mean value of the ^{222}Rn concentrations of all the studied locations during winter, summer, rainy and autumn seasons are 42.66, 16.18, 23.41 and 24.95 Bq m^{-3} respectively, where as for ^{220}Rn they are 24.35, 15.01, 18.80 and 19.24 Bq m^{-3} respectively and are shown in Figure 3.

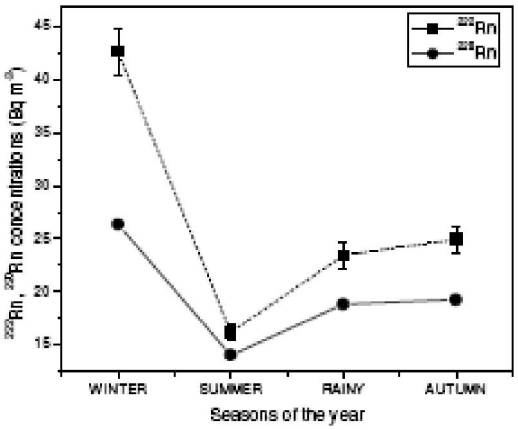

Figure 3 : Seasonal variations of ^{222}Rn, ^{220}Rn

Especially in the winters, most of the dwellings show ^{222}Rn concentrations on an average 43 Bq m^{-3} otherwise the highest concentration during winter season was observed as 100 Bq m^{-3}. Whereas the average ^{220}Rn concentration during winter season was 24 Bq m^{-3} and the highest was 34 Bq m^{-3}. These large variation of the indoor ^{222}Rn and ^{220}Rn concentration between different dwellings of the studied locations can be explained due to different ventilation rate, nature of the soil underneath and particularly due to the geological considerations. Even it has been established that the radon activity in soil–gas is highly variable and it differ dramatically from place to place, takes value of 30 KBqm^{-3} in one place to 900 KBqm^{-3}, 10 m away[6]. The aver-

age indoor ^{222}Rn concentration published for dwellings of different cities around the world vary between 8, 7 Bq m^{-3} (Australia) and 190 Bq m^{-3} (German states of Saxony and Turingia), with a weighed arithmetic mean, for all the cities considered, of 40 Bq m^{-3}[7].

Annual effective dose rates due to ^{222}Rn, ^{220}Rn and their progenies during different seasons of the year are shown in Figure 4.

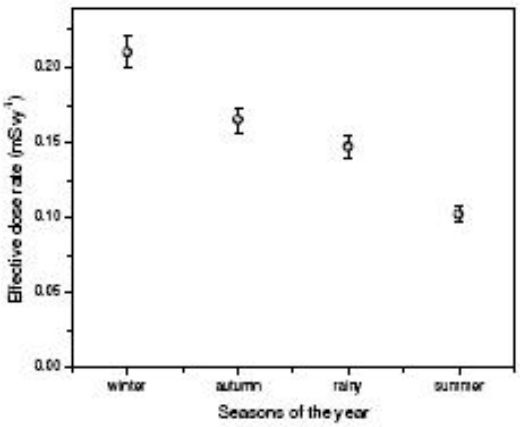

Figure 4 : Effective dose rate in different seasons

During winter season it was found to vary between 0.171 – 0.322 mSv y^{-1}, whereas during summer season it was 0.108 – 0.171 mSv y^{-1}. The arithmetic mean dose with standard error during winter and summer seasons were 0.267 ± 0.01 and 0.126 ± 0.007 mSv y^{-1} respectively. The geometric mean concentration of dose during the winter and summer seasons are 0.262 and 0.125 mSv y^{-1} respectively. The higher dose rates were observed during winter seasons of all the locations. The higher concentration of dose during the winter and summer seasons were observed in Vijayanagar and the lower concentrations were seen in Rajajinagar. This may be due to the fact that during winter season the radioactive gases are trapped near the surface because of temperature inversions. In summer, the higher rate of vertical mixing and dispersions lifts the aerosols to higher altitudes resulting in a decrease in the concentration near the ground level air[8]. Wilkening[9] reported similar trend of variations for the environment of USA. Magalhaes et al[10] have observed a two order of magnitude of variability, with a maximum of 50 Bq m^{-3} in winter and a minimum of 0.5 Bq m^{-3} in the summer months. In addition ^{222}Rn exhalation rate also decreases during monsoon as soil pores get filled by water and hence, resulting in lower concentration of ^{222}Rn and ^{220}Rn[11].

Wall wise variations and dose rates

The concentrations of ^{222}Rn and ^{220}Rn in different types of walls of the houses in all the studied locations and are shown in Figure 5 - 6. The arithmetic mean concentrations of ^{222}Rn and ^{220}Rn level in different walls of the study area are shown in Figure 7. The ^{222}Rn concentrations in concrete, cement, brick and mud wall houses in the studied locations were found to vary between 9.24 – 17.88, 13.74 - 27.13, 19.57 – 40.46 and 27.1 – 83.75 Bq m^{-3} respectively. The arithmetic mean concentrations were 12.55 ± 1.0, 13.74 ± 1.5, 19.57 ± 2.6 and 42.66 ± 6.8 Bq m^{-3} respectively whereas their geometric mean concentrations were 12.25, 18.41, 25.85 and 39.52 Bq m^{-3} respectively. The ^{220}Rn concentrations were found to vary between 5.56 – 33.33, 2.08 – 35.42, 1.37 – 56.25 and 6.18 – 61.11 respectively. The arithmetic mean concentrations with standard error were 16.46 ± 1.0, 12.33 ± 1.5, 19.67 ± 2.6 and 21.08 ± 6.8, respectively whereas their geometric mean concentrations were 15.85, 12.06,

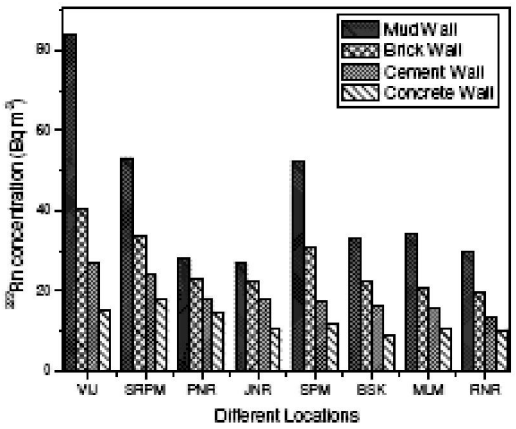

Figure 5 : Wall wise ^{222}Rn concentrations

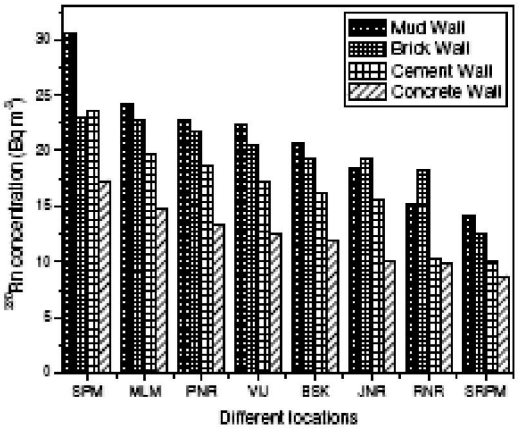

Figure 6 : Wall wise ^{220}Rn concentrations

Current Research Paper

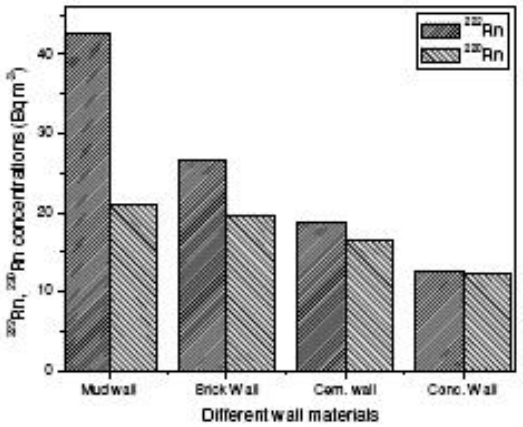

Figure 7 : ^{222}Rn, ^{220}Rn in different wall

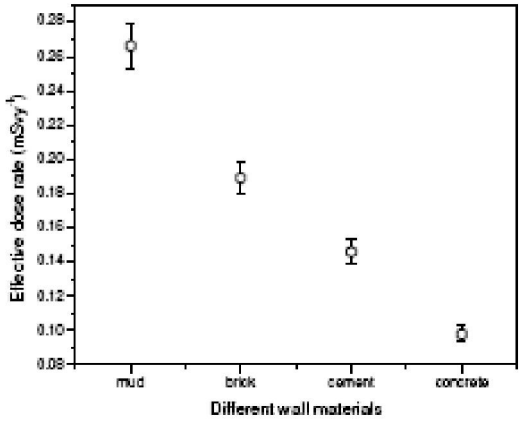

Figure 8 : Effective dose rates in different wall

19.37 and 20.51 respectively. The higher concentrations of ^{222}Rn and ^{220}Rn were observed in mud wall houses and lower concentrations were observed in houses with concrete walls of all the locations.

The concentrations are found to vary from wall to wall. The variation may be due to random distribution of radioactive rock species used ignorantly in the construction of houses[12]. Most of the walls of the houses in the city and surrounding area are constructed with cement and brick, and some of the houses had mud walls. In general the ^{222}Rn and ^{220}Rn concentration was found higher in mud wall houses than that in cemented wall houses. The ground floor allows more radon to diffuse inside the house because of higher porosity of material used. The emanation of radon is also higher from rocks and local stones. In addition, the mud wall houses have small doors and a small window, which remains closed for most of the time. Due to poor ventilation condition, the radon is accumulated inside the house and thus results in higher ^{222}Rn and ^{220}Rn concentration in mud wall houses than in concrete wall houses[13]. The higher concentrations of dose were seen in the houses of mud walls of all the locations and the lower concentrations were observed in houses with concrete walls of all the studied locations and are shown in Figure 8. The annual effective dose rate due to ^{222}Rn, ^{220}Rn and their progenies in different dwellings of concrete, cement, brick and mud walls were found to vary between 0.03 – 0.146, 0.112 – 0.187, 0.133 – 0.264 and 0.185 – 0.419 mSvy^{-1} respectively. The arithmetic mean dose with standard error were 0.098 ± 0.01, 0.146 ± 0.01, 0.189 ± 0.01 and 0.266 ± 0.02 respectively. The geometric mean dose rates were 0.090, 0.143, 0.184 and 0.258 respectively.

Floor wise variations and dose rates

The concentrations of ^{222}Rn and ^{220}Rn in different type of floorings of the houses of different locations and are shown in Figure 9-10.

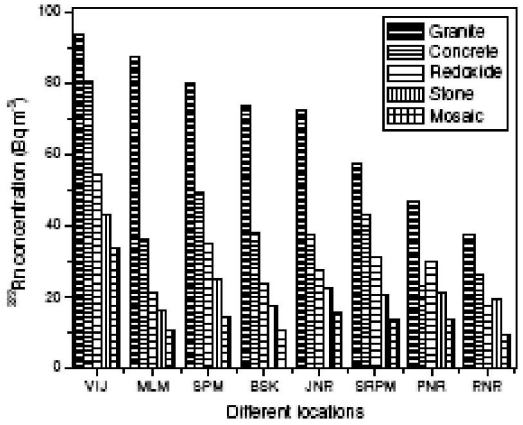

Figure 9 : Floor wise ^{222}Rn concentration

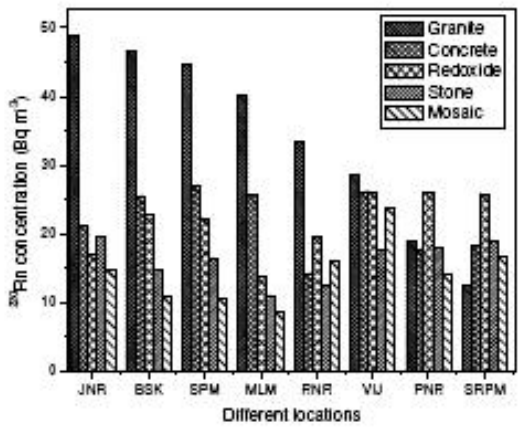

Figure 10 : Floor wise ^{220}Rn concentration

The higher concentrations ^{222}Rn and ^{220}Rn were observed in granite flooring houses and lower concentrations were observed in houses with mosaic flooring of all the locations and are shown in Figure 11. The ^{222}Rn con-

centrations in granite, concrete, red oxide, stone and mosaic flooring houses were found to vary between 36.84 – 100.00, 22.81 – 82.71, 13.88 – 57.89, 14.32 – 46.78 and 4.05 – 37.84 Bq m^{-3} respectively. The arithmetic mean concentrations of ^{222}Rn with standard error were 65.77 ± 8.4, 44.68 ± 5.6, 30.15 ± 3.9, 23.25 ± 2.9 and 15.32 ± 2.73 Bq m^{-3} respectively whereas their geometric mean concentrations were 60.38, 42.58, 28.58, 22.25 and 14.14 Bq m^{-3} respectively. The ^{220}Rn concentrations were found to vary between 6.18 – 72.92, 12.50 – 69.44, 1.37 – 61.11, 4.17 – 40.97 and 2.08 – 37.50 Bq m^{-3} respectively. The arithmetic mean concentrations with standard error were 30.28 ± 4.5, 25.86 ± 3.5, 21.64 ± 1.4, 16.05 ± 1 and 14.46 ± 1.6 Bq m^{-3} respectively, whereas their geometric mean concentrations were 27.51, 24.37, 21.17, 15.77 and 13.84 Bq m^{-3} respectively.

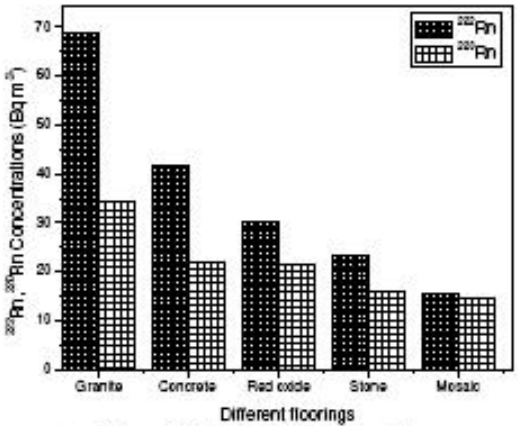

Figure 11 : ^{222}Rn, ^{220}Rn in different flooring

Granite is rich of radium and it may be the reason for higher concentration of radon in granite flooring houses. The materials used for construction of buildings are sufficiently porous and allow radon to enter into the indoor atmosphere[14]. The earlier studies have shown that there is a positive correlation between the exhalation rate and concentration in building materials[15].

Granite samples show higher radon exhalation rate than marbles. There is a positive correlation between radium content of granite with radon exhalation and its concentration. This trend is observed by several researchers[16-18]. Some of the huts had mud walls, bare flooring and the roof covered by the dry coconut leaves with poor ventilation. The exhalation from brick wall with cement plastering is high. It is observed that the Mosaic flooring houses show slightly less radon exhalation rate than cement flooring houses. Radon concentration in huts is lower than in concrete and mosaic flooring houses even though radon exhalation from bare flooring is higher than other types of floorings. This may be attributed to the possibility of out flow of air from huts through the coconut dry leaves. Further, the fumes emitted during cooking process either from the kerosene stove or fire wood will increase the air pressure inside dwellings. Radon exhalation in mud walls is less compared to the cemented walls. High exhalation of radon from concrete walls may be responsible for enhancement of concentration in cement and mosaic flooring houses, due to large extent of usage of these materials in construction. This may be due to the high radon concentration in the concrete floorings and also because of the existence of porous between the slabs that were sandwiched by cement for the floorings. Due to this radon could easily enter into the houses[19]. The cracks in the floor as a consequence of poor quality of materials used for construction favors the enhancement of radon concentration[20]. Sreenath Reddy et al.[21] and Vinaya Kumar et al.[22] have observed that the dwellings with mud floors have relatively higher dose and reports that the sub surface soil may be predominating source of indoor ^{222}Rn, ^{220}Rn for the environment of Hyderabad, India. This may be attributed to the rich content of ^{226}Ra and ^{232}Th in the local soil used for construction of mud walls. The radon levels in mud houses may be high due to emanation from ground surfaces and poor ventilation of the dwellings[23]. Radon concentrations in dwellings changes from place to place due to difference in geology and climate, in construction materials techniques and domestic customs. Although exposure for radon in tropical climates is unlikely to be of serious concern, keeping in view the radiological significance of radon, mapping of radon level in different parts of the country is helpful in defining the radon prone areas, if any, and evaluating the natural radiation exposures[24].

The variations of dose rate due to ^{222}Rn and ^{220}Rn in different floorings are shown in Figure 12. The annual effective dose due to ^{222}Rn, ^{220}Rn and their progenies in mosaic, stone, red oxide, concrete and granite floors of the houses of different locations were found to vary from 0.09 – 0.24, 0.11 – 0.25, 0.13 – 0.31, 0.17 – 0.41 and 0.19 – 0.48 $mSvy^{-1}$ respectively. The arithmetic mean concentration of dose with the standard error were 0.127 ± 0.01, 0.170 ± 0.01, 0.211 ± 0.02, 0.278 ± 0.04 and 0.373 ± 0.35 $mSvy^{-1}$ respectively.

The higher dose rates were observed in the granite floorings houses in all the studied locations and the lower concentrations were observed in mosaic floorings. The geometric mean concentrations were found to be 0.121, 0.165, 0.203, 0.269 and 0.355 $mSvy^{-1}$ respectively.

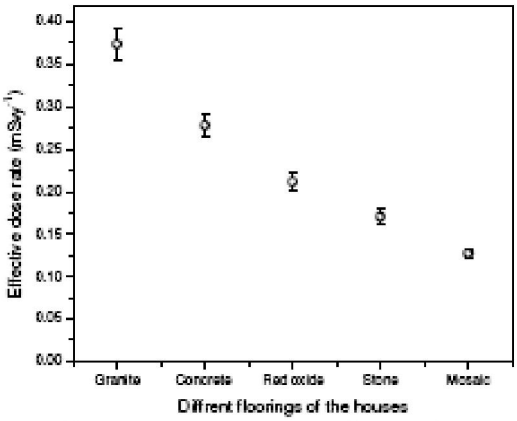

Figure 12 : Effective dose rates in different floorings

Room wise variations and dose rates

The concentrations of ^{222}Rn and ^{220}Rn in different rooms of the houses of different locations and are shown in Figure 13-14.

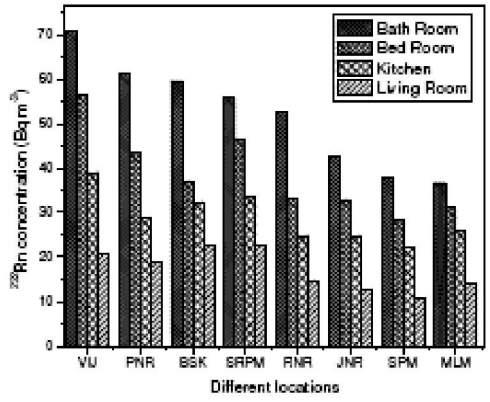

Figure 13 : Room wise ^{222}Rn concentration

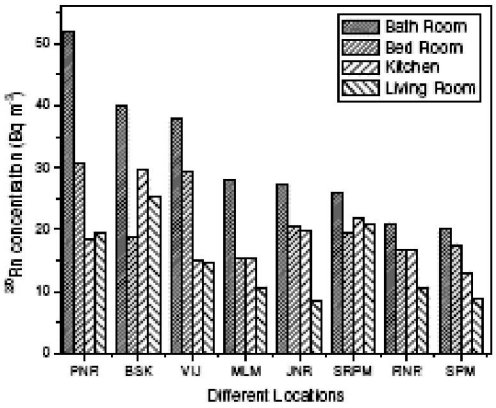

Figure 14 : Room wise ^{220}Rn concentration

Variations of indoor ^{222}Rn and ^{220}Rn concentrations in different rooms of houses are shown in Figure 15. The ^{222}Rn concentrations in bath room, bed room, kitchen and living room of the monitored houses were found to vary between 29.24 – 81.29, 24.98 – 58.48, 18.13 – 43.27, and 5.85 – 27.46 Bq m^{-3} respectively. The arithmetic mean concentrations with standard error were 52.16 ± 4.2, 38.59 ± 3.3, 28.90 ± 1.7 and 17.12 ± 1.4 Bq m^{-3} respectively whereas their geometric mean concentrations were 50.90, 37.64, 28.43 and 16.54 Bq m^{-3} respectively. The ^{220}Rn concentrations were found to vary between 13.89 – 63.89, 5.56 – 47.92, 6.25 – 61.11, and 6.11 – 31.94 Bq m^{-3} respectively. The arithmetic mean concentrations with standard error were 31.52 ± 3.5, 21.03 ± 1.7, 18.77 ± 1.7 and 14.855 ± 2.1Bq m^{-3} respectively whereas their geometric mean concentrations were 30.02, 20.39, 18.22 and 13.76 Bq m^{-3} respectively. The higher concentrations ^{222}Rn and ^{220}Rn were observed in bath room, bed room and lower concentrations were observed in living rooms of the houses of all the locations. One can clearly see in the Figure 15, that there is high concentration in bathroom compared to the other rooms in the houses. The differences were clearly present, bathroom was found to have higher ^{222}Rn concentration, kitchen ranked second, next bed rooms and living room the least. Bed rooms might be expected to be least ventilated, on the average based upon limited use patterns and bath rooms may receive some additional ^{222}Rn due to ^{222}Rn dissolved in water[25]. ^{222}Rn is shown to be released in spray from faucets or shower fixture[26,27]. Air in living rooms on the other hand is most readily diluted due to outdoor air blow. This can be correlated with concentrations of ^{222}Rn in water[27] and the activity of ^{226}Ra. However, Yadagiri Reddy et al.[28] have reported that the radon concentration varied from 17 to 311 Bq m^{-3} and progeny concentration varied between 0.1 to 20mWLwith an average of 62 ± 45 Bq m^{-3} and 4.7 ± 4.1 mWL, respectively. They have also reported the activity of ^{226}Ra from different zones and showed the bed rooms have relatively higher concentrations of ^{222}Rn and ^{220}Rn followed by kitchen, front room and hall. This may be due to less atmospheric pressure and less ventilation in the bed room and also depends on location of the houses for the environment of Hyderabad.

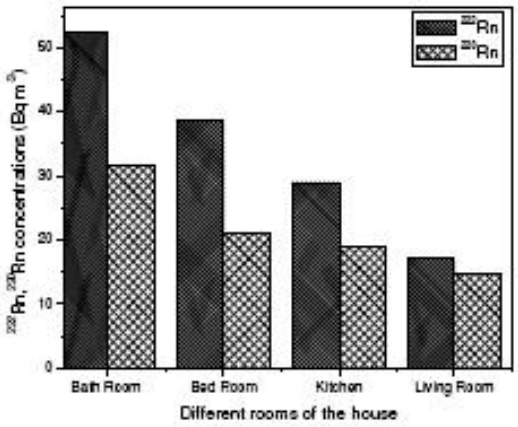

Figure 15 : ^{222}Rn, ^{220}Rn in different rooms

The variations of dose rate in different rooms of the houses are shown in Figure 16. The annual effective dose rate due to ^{222}Rn, ^{220}Rn and their progenies in living room, kitchen, bed room and bath room were found to vary between 0.009 – 0.21, 0.14- 0.32, 0.04 – 0.33 and 0.026 – 0.52 mSvy^{-1} respectively. The arithmetic mean dose with standard deviations are 0.11 ± 0.02, 0.206 ± 0.01, 0.201 ± 0.02 and 0.284 ± 0.05 mSvy^{-1} respectively. The higher dose rates were observed in bed room and bath rooms of all the studies locations. The observed geometric means of dose rates were 0.16, 0.22, 0.25 and 0.31 mSvy^{-1} respectively.

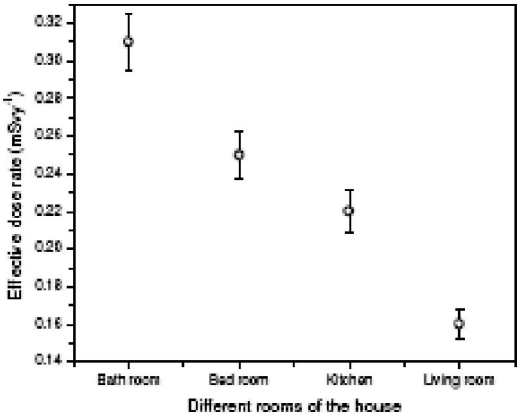

Figure 16 : Effective dose rates in different rooms

Volume wise variations and dose rates

The volumetric variations of ^{222}Rn and ^{220}Rn are shown in Figure 17. The higher concentrations of ^{222}Rn and ^{220}Rn were observed in lower volume room than in the higher volume room. The ^{222}Rn and ^{220}Rn concentrations in a dwelling of volume 30-310 m^3 ranged from 4 to 93 and 5 to 69 Bq m^{-3}, respectively. However, their progeny concentrations ranged from 0.015 to 2.45 and 0.012 to 0.80 mWL, respectively. It is also observed that the enhancement of volume by almost ten-fold reduces the concentration of ^{222}Rn to 23% and that of ^{220}Rn to 13% provided the rest of condition remains unaltered. It is interesting to note that the volume of room varies as geometric progression; there is no dependence on the concentrations in the same ratio. About 67% of monitored houses had volume 30 - 100 m^3, ^{222}Rn concentrations were above 30 with maximum 93 Bq m^{-3}. Whereas 32% of the dwellings had the volume 110 - 310 m^3 have shown the concentrations less than 20 Bq m^{-3}. For thoron it is 12 to 69 and less than 11.5 Bq m^{-3} respectively.

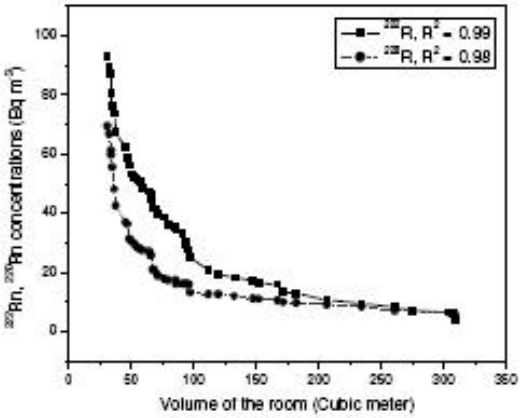

Figure 17 : Variation of ^{222}Rn, ^{220}Rn with volume

This clearly indicates that though the observations have been made almost for similar type of constructions, ventilation and lifetime of the houses, but as the volume of the room increases the concentrations reduces exponentially and it becomes almost constant above the volume of 150 cubic meters. The variation in the concentration follows the exponential decay with the regression coefficients for ^{222}Rn and ^{220}Rn are 0.99 and 0.98, respectively. The volumetric variations of dose rates are shown in Figure 18.

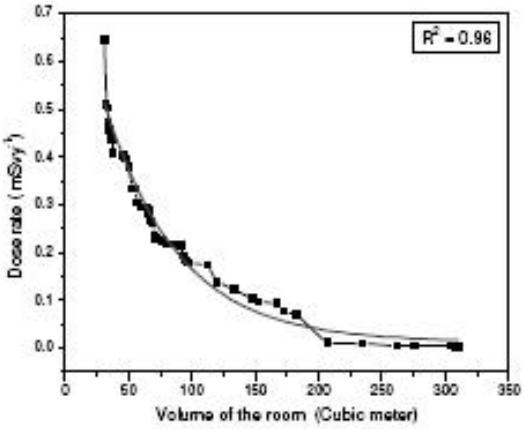

Figure 18 : Variation of dose rate with volume

The present work reveals that the dwellers of lower volume houses will expose themselves to the higher dose rates and is 4.4 times of the dose received in higher volume houses. It is recommended that the lower volume houses should have good ventilation to reduce the effective dose rate due to ^{222}Rn, ^{220}Rn and their daughters.

CONCLUSION

The higher value of annual effective dose rates in granite flooring house, bath room, mud wall houses and in winter season were found as 0.37, 0.31, 0.26 and 0.22 $mSvy^{-1}$ respectively. Among the higher dose concentrations the lower volume and granite flooring house inhabitants are exposed to higher dose than in winter season or mud wall houses or bath rooms of the studied locations. It is suggested to have higher volume rooms or well ventilated rooms and granite free houses to reduce the dose effect.

ACKNOWLEDGMENTS

The research work is sponsored by the University Grants Commission in the form of grants under the Research Funding Council for major research project, X Plan, UGC, New Delhi. The cooperation extended by all the residents is highly appreciated and the support extended by all the principals of government science college, Bangalore for allowing us to carry out the research work in the test room is highly acknowledged.

REFERENCES

[1] J.Porstendorfer; J.Aerosol Sci., **25(2)**, 219 **(1994)**.
[2] J.Porstendorfer, T.T.Mercer; Health Phys., **37**, 191 **(1979)**.
[3] Raghuveer, B.A.Lalgondar, S.Jayaram; Department of mines and geology, Bangalore, India, 272 **(1997)**.
[4] C.Ningappa, J.Sannappa, M.S.Chandrashekara, L.Paramesh; ESAIJ., **3(1)**, 11 **(2008)**.
[5] L.A.Sathish, K.Nagaraja, H.C.Ramanna, V.Nagesh, S.Shobha, S.Sundareshan, T.V.Ramachandran; ESAIJ., **4(5)**, 232 **(2009)**.
[6] E.Toth, F.Deak, C.S.Gyurkosza, Z.S.Kasztovsky, R.Kuczi, G.Marx, B.Nagy, S.Oberstedt, L.Sajo, P.Bohus, C.S.Sukosed, G.Toth, N.Vajda; Environ.Geol., **31**, 123 **(1997)**.
[7] UNSCEAR Rep, United Nations, New York **(1993)**.
[8] L.Sesana, E.Caprioli, G.M.Marcazzan; J.of Envir.Radio., **65**, 147 **(2003)**.
[9] M.Wilkening; Elsevier Science Publications, Netherlands, **1**, 100 **(1990)**.
[10] M.H.Magalhaes, E.C.S.Amaral, I.Sachett, Rochedo; J.of Envir.Radio., **67**, 131 **(2003)**.
[11] K.Nagaraja, B.S.N.Prasad, M.S.Madhava, M.S.Chandrashekara, L.Paramesh, J.Sannappa, S.D.Pawar, P.Murugavelu, A.K.Kamra; Radiat.Meas., **36**, 413 **(2003)**.
[12] J.Kumar, R.Malhotra, J.Singh, S.Singh; Nucl.Geophys., **6**, 573 **(1994)**.
[13] R.C.Ramola, R.B.S.Rawat, M.S.Kandari; Nucl.Geophys., **9**, 383 **(1995)**.
[14] M.L.Gaso, N.Segovia, S.Pulinets, A.Leyva, G.Ponciano, P.Pena; J.Appl.Sci., **5**, 1356 **(2005)**.
[15] J.Sannappa, M.S.Chandrashekara, L.Paramesh; Indoor Built Environ, **15**, 1 **(2006)**.
[16] Al-Jarallah; J.Env.Radioact., **53**, 91 **(2001)**.
[17] C.Papastefanou, M.Manolopoulou, S.Stoulos, A.Ioannidou, E.Gerasopoulos; Nat Hazards Earth System Sci., **1**, 159 **(2001)**.
[18] J.Sannappa, M.S.Chandrashekara, L.A.Sathish, L.Paramesh, P.Venkataramaiah; Radiat.Meas., **37**, 55 **(2003)**.
[19] J.Vaupotic; J.Radio Analytical Nucl.Chem., **247**, 291 **(2000)**.
[20] J.Singh, L.Singh, S.Singh, H.S.Virk; Radiat Meas., **19**, 415 **(1991)**.
[21] M.Sreenath Reddy, B.Sreenivasa Reddy, P.Yadagiri Reddy, Gopal Reddy, K.Rama Reddy; Environ.Geochem., **9**, 27 **(2006)**.
[22] K.Vinaya Kumar Reddy, Gopal Reddy, P.Yadagiri reddy, K.Rama reddy; Env.Geochem., **9**, 109 **(2006)**.
[23] K.Kant, R.P.Chauhan, R.S.Saini, K.Jindal, S.K.Chakravarthi; Environ Geochem., **9**, 35 **(2006)**.
[24] Rajesh Kumar, R.L.Patnaik, A.K.Shukla, A.H.Khan; Environ.Geochem., **9**, 84 **(2006)**.
[25] L.A.Sathish, J.Sannappa, L.Paramesh, M.S.Chandrashekara, P.Venkataramaiah; Environ.Geochem., **9**, 105 **(2006)**.
[26] T.F.Gessel, H.M.Prichard; 'The concentration of ^{222}Rn in tap water to indoor ^{222}Rn concentrations'. In: International Natural Radiation Environment-III, T.F.Gessel, H.M.Prichard, (Eds.), Springfield, 1347 **(1980)**.
[27] M.Wilkening; Health Phys., **51**, 427 **(1986)**.
[28] P.Yadagiri reddy, M.Sreenath reddy, K.Rama reddy; Env.Geochem., **9**, 16 **(2006)**.