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Study of Indoor Radon and Thoron Levels in Srirampura, Bangalore, India using Passive Detector Technique

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Abstract

Results of the measurement of indoor radon and thoron carried out in and around Srirampura, Bangalore, India using passive detector technique is presented. Measurements were carried out using twin cup radon-thoron dosimeter using small strips of 12 micron thick LR-115 Type II nuclear track detectors. Measurements were carried out in 60 dwellings for a period of one year on a quarterly time integrated quarterly cycle to see the seasonal variation. After the exposure period, the detectors were chemically analyzed using 2.5 N NaOH at 60^o C for a time of 90 minutes and the etched detectors were scanned by spark counter techniques. The estimated ^{222}Rn and ^{220}Rn levels in the studied locations showed the higher concentrations during winter season, in bath rooms, in concrete walls and in granite flooring houses. In this paper the author have made an attempt for the measurement of concentrations of indoor radon along with its distribution pattern based on construction material.

Key words: Radon, indoor exposure, dwellings, seasons.

Introduction

Radon and its decay products are the most important sources of natural radiation for the human exposure [1]. The detrimental health effect attributed to radon is the lung cancer. A statistically significant enhancement of its incidence for underground mine workers has been observed, but great attention should also be paid to radon exposure in workplaces and homes where in some cases of high radon concentrations are found. Since school buildings are workplaces of long occupancy time for students and staff, monitoring of indoor radon levels is of utmost importance for an adequate risk assessment [2]. In the past decades, systematic radon surveys in dwellings were carried out all over the world, but few data are available about the presence of radon in schools [3]. In Italy, at the beginning of 90s, a national survey was carried out for the measurement of the radon concentration in dwellings. Results in Campania region showed a mean value of 95 Bq m^{-3}, but it should be noted that 5.7% of the surveyed dwellings showed concentrations higher than 200 Bq m^{-3} and 0.4 % higher than 400 Bq m^{-3} [4]. Campaigns in schools were carried out only in the northern and central regions of Italy [5-7]. Some preliminary results about this type of survey are available [8].

In India there are no such data regarding area wise concentrations of ^{222}Rn and ^{220}Rn. Even though lifestyle and the type of house construction, topography and meteorological conditions prevailing in India are vastly different from those in western countries, it was felt that there was a need to obtain responsible reliable average value of population dose due to indoor radon to the population at large in Bangalore city. As a part of this, we have made measurements of indoor ^{222}Rn and ^{220}Rn concentrations in dwellings of Srirampura area of Bangalore City. Because of the pronounced seasonal variation in the indoor levels of ^{222}Rn and ^{220}Rn, it is necessary to make measurements over the entire period of the year to arrive at an average value of annual dose rate to the occupants of Bangalore city, Karnataka, India. This type of study strengthens the information stockpile for the specific area on radon studies in the globe. In this work we report the concentrations of ^{222}Rn and ^{220}Rn in dwellings and the analysis of main factors affecting indoor radon levels. In particular, the influence of the pattern of use of each kind of room on radon concentration.

Methods and Measurements

Solid State Nuclear Track Detectors (SSNTD)

The concentrations of indoor ^{222}Rn and ^{220}Rn levels are measured by using SSNTD, which are thin sheets of dielectric materials such as cellulose nitrate 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 methodology and the calibration procedures are available in the literature [9, 10].

Spark Counter

Spark Counter technique is applicable to plastic track detectors, which provides a convenient, economical and fast method for track counting. This technique was developed by Cross and Tommasino [11] and is discussed in detail by Garkani [12].

Results and Discussion

Floor wise variations

The variations of ^{222}Rn and ^{220}Rn levels in dwellings of different floorings covering all the four seasons of the calendar year are shown in Fig.1. The floorings of the houses are of different materials. They are sufficiently porous to allow radon to escape into the indoor atmosphere. The data shows the higher concentrations in granite flooring houses and lower in mosaic and stone flooring houses. Loose cement flooring houses show high ^{222}Rn exhalation rate than stone flooring houses. This may be due to low porosity and low diffusion coefficient in the stone flooring than in ordinary cement flooring houses. The data also reveals that the houses with red oxide and concrete floorings have shown the concentrations less than the granite flooring houses. This is may be due to the fact that granite contains higher activity concentrations of ^{226}Ra. The results reveal that the concentration increases linearly from mosaic to granite flooring with the regression coefficient greater than 0.95 for ^{222}Rn and ^{220}Rn respectively in all the cases. This can be seen in comparison with the exhalation rates measured for similar building materials [13]. Granite sample shows higher ^{222}Rn exhalation rate than mosaic and this may be because there is a positive correlation between the ^{226}Ra content of granite with the ^{222}Rn exhalation [14]. Mosaic flooring houses show slightly less ^{222}Rn exhalation rate than cement flooring houses. High radon exhalation from concrete walls may be responsible for increasing the concentration in cement than in mosaic flooring houses; the reason for the high concentrations in the concrete floorings is the porous floor concrete slab through which radon could easily enter the house [15]. The annual average concentrations of ^{222}Rn in granite, concrete, red oxide, stone and mosaic flooring houses were found to be 65.9, 52.0, 49.1, 45.1 and 35.5 Bq m^{-3} where as for ^{220}Rn they were 30.1, 18.5, 18.1, 16.3 and 15.8 Bq m^{-3} respectively. Higher concentrations were observed in granite flooring houses and lower in mosaic flooring houses. It is also reported that the radon exhalation rate was affected on by rainfall strongly, and it had a characteristic recovery curve within several days after the end of rain. Because the monitoring of radon exhalation rate by the grab sampling method is not performed in rainy days, the environmental impact evaluated with the monitoring result would be rather conservative as average [16].

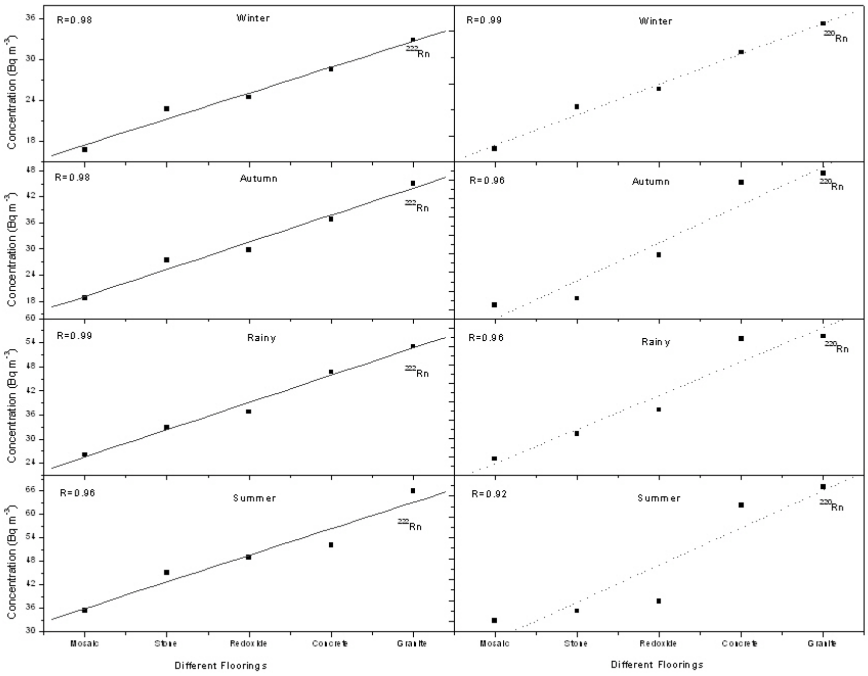

Figure 1: ^{222}Rn and ^{220}Rn in different floorings.

Season wise variations

The results of seasonal variations of ^{222}Rn and ^{220}Rn reveal the maximum concentrations during winter season and minimum during summer. The typical variations of ^{222}Rn and ^{220}Rn levels in different dwellings covering all the four seasons of the calendar year are shown in Fig. 2. The concentration of ^{222}Rn and ^{220}Rn were high during winter. This could be due to temperature inversion which can generally be expected to be in winter [17] and also houses are closed during this season most of the time to conserve heat energy. This leads to poor ventilation. The concentration gradually decreases and is lowest in summer. Turbulent transfer during summer causes low concentration of radon at lower atmosphere. The decrease of radon concentration and also exhalation from soil in rainy season has been observed. During rainy season soil becomes saturated with water and hence less concentration is exhaled [18]. The annual average concentrations of ^{222}Rn during winter, summer, rainy and autumn seasons were found to be 35.5, 16.8, 25.7 and 26.1 Bq m^{-3} where as for ^{220}Rn they were found as 21.0, 11.5, 18.1 and 19.9 Bq m^{-3} respectively. The typical seasonal variation of all the four different dwellings shows the higher concentrations in winter and lower in summer seasons. This usual trend of winter maximum and summer minimum were observed in all the dwellings are as observed by elsewhere [19, 20]. Wei et al [21] have done the similar type of studies and reports that the poor air tightness of the soil walls as well as wooden doors and windows are the reason for higher concentrations. The authors have also reports the mean ^{222}Rn concentration in the second period was 70% of that in the first period. However, both

^{220}Rn and its progeny concentrations were nearly the same in the two periods. It is considered as the different ventilation rates of the rooms in the two periods. The second survey performed in the summer and autumn, the ventilation rate is expected to be higher than that of the first survey covered the winter and spring. While the decay constant of ^{220}Rn is much larger than the ventilation rate, the change of ventilation does not affect ^{220}Rn concentrations [21]. Our results are quite similar to the observations made elsewhere [22, 23].

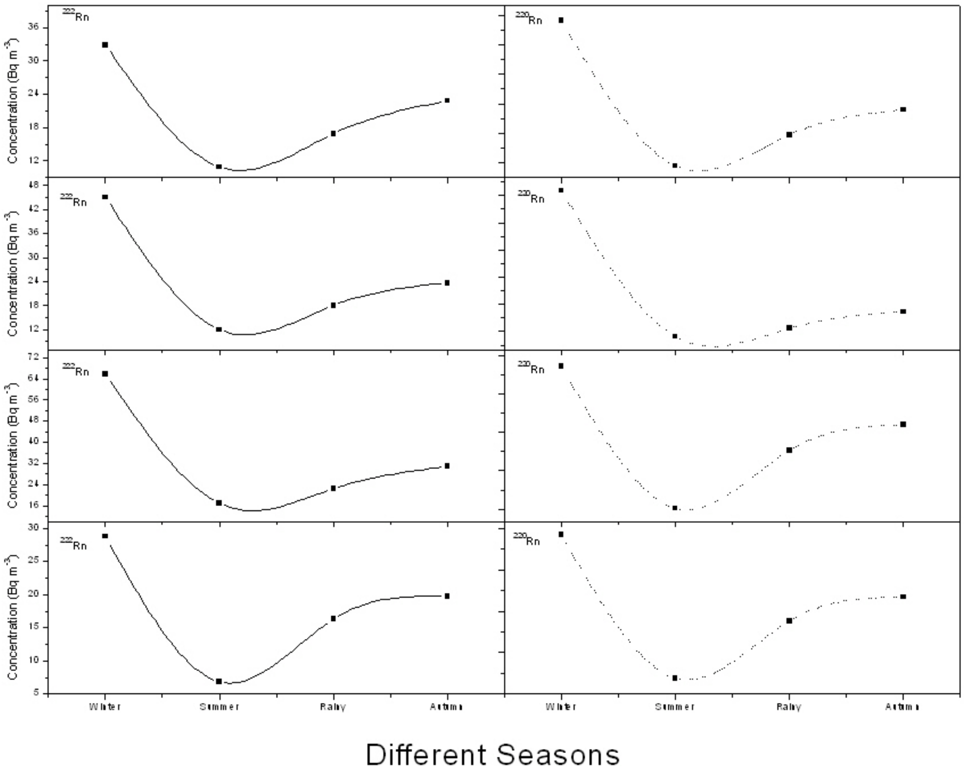

Figure 2: ^{222}Rn and ^{220}Rn in different seasons.

Wall wise variations

The concentrations of ^{222}Rn and ^{220}Rn levels in houses of various types of walls of the different dwellings are shown in Fig.3. The figure depicts that the concentrations were found to vary from wall to wall in all the studied houses. The variation is may be due to the random distribution of radioactive rock species used ignorantly while constructing the houses [24]. The annual average concentrations of ^{222}Rn in concrete, cement, brick and mud walls were found to be 52.0, 40.9, 27.4 and 18.7 Bq m^{-3} where as for ^{220}Rn they were 27.8, 20.1, 18.7 and 15.8 Bq m^{-3} respectively. The higher concentrations were observed in concrete wall houses. This is may be due the ^{222}Rn exhalation rate is higher in soil than in concrete. While building may contain several tons of concrete the contribution of this to indoor ^{222}Rn is relatively low because of low escape rate of ^{226}Ra. Samuelson [25] measured the ^{222}Rn exhalation rate in the walls and reported 20 Bq m^{-2} s^{-1} in Scandinavian dwellings and reports that the average values of porosity of the soil and building materials as 0.25 and 0.15 respectively [25]. However, the concentrations of radon gas in soils are controlled by the soils permeability to a certain extent. The radon evidence suggests that these soils and sediment rocks are acting as local reservoirs for radon. Radon is also known to concentrate at the surface outcrop of geological faults [26] enhances the higher concentrations in concrete walls.

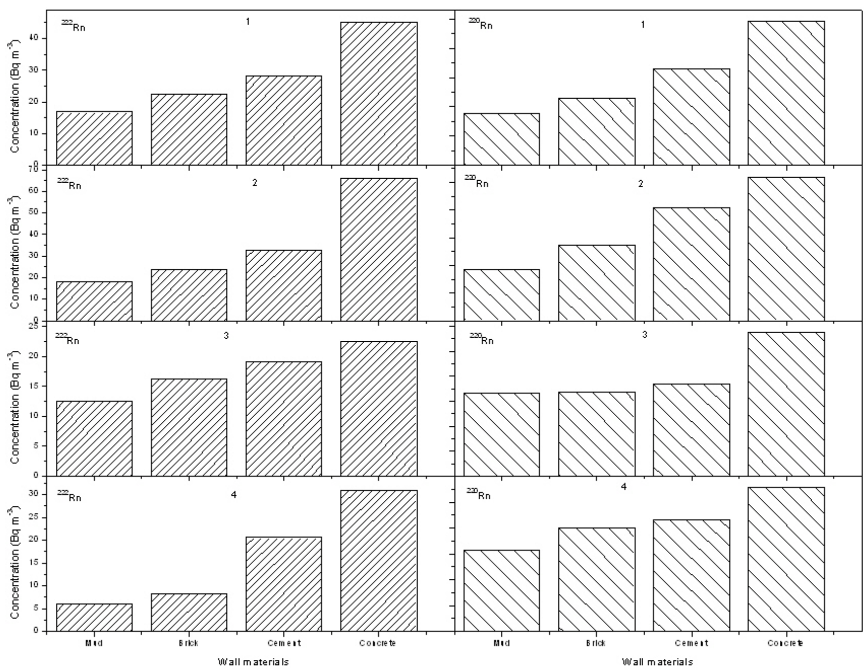

Figure 3: ^{222}Rn and ^{220}Rn in different walls.

Room wise variations

The variations of ^{222}Rn and ^{220}Rn levels in dwellings of different rooms are shown in Fig.4.

The result shows that the concentrations reduce linearly from bath room to open room with the regression coefficient above 0.96 in all the studied dwellings for both ^{222}Rn and ^{220}Rn respectively. This may be due to the better air exchange rate in the living room than in the bath room and bed room of all houses. It is observed that the bathroom was found to have higher concentration. Bed rooms ranked second, next kitchen and open/living room last. This is may be due to the fact that the 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. Radon is shown to be released in spray from faucets or shower fixture [27] strengthens our results of higher concentrations in bath rooms of all the studied houses. Air in living rooms on the other hand is most readily diluted due to outdoor air blow. The mean concentrations of ^{222}Rn and ^{220}Rn in bath room, bed room, kitchen and the open/living rooms were found to be 67.8, 49.1, 33.3 and 24.5 Bq m^{-3} and 52.0, 25.0, 18.5 and 15.2 Bq m^{-3} respectively. In the studies [28] it is reported that the value of ^{222}Rn concentration in the indoor air near granite quarries varies from 55 to 300 Bq.m^{-3} with a median of 155 Bq.m^{-3} and its progeny varies from 0.24 to 19.6 mWL with a median of 8.4 mWL. In Bangalore City, the concentration of radon varies from 18.4 to 110 Bq.m^{-3} with a median of 45 Bq.m^{-3} and its progeny varies from 1.62 to 11.24 mWL with a median of 4.15 mWL. Higher concentrations of ^{222}Rn and its progeny were observed in granite quarries compared with Bangalore City. The main reason for the higher indoor ^{222}Rn concentration is due to the types of the bedrock underneath the earth [28]. The concentration of ^{222}Rn mainly depends on the activity of ^{226}Ra present in soils and rocks and the types of building materials used. The activity of ^{226}Ra varies in granitic regions of Bangalore rural district from 42.0 to 163.6 with a median of 112.8 Bq.kg^{-1}.

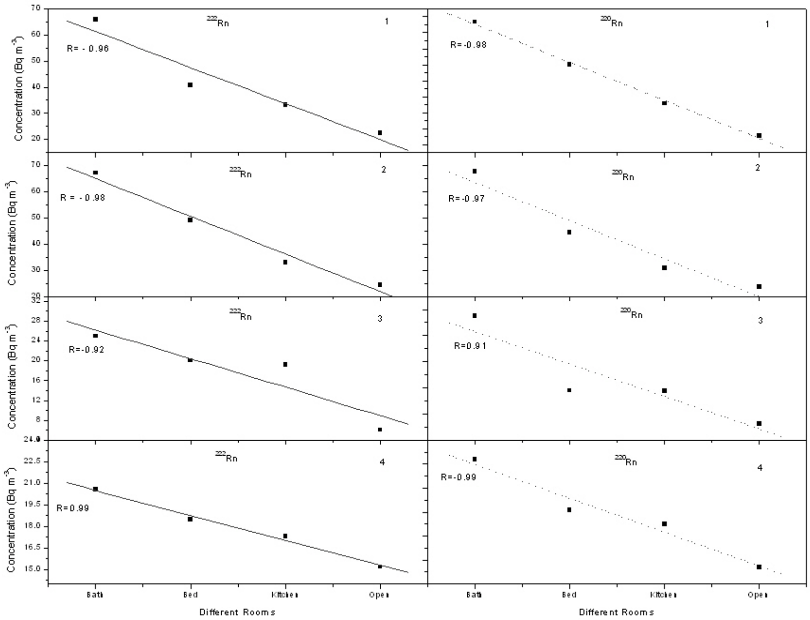

Figure 4: ^{222}Rn and ^{220}Rn in different rooms.

The obtained data range between 4.2 and 65.9 Bq m^{-3}, showing an arithmetic mean of 23.2 and 15.1 Bq m^{-3} for ^{222}Rn and ^{220}Rn respectively. The reference values i.e. the levels above which actions are suggested to reduce the ^{222}Rn concentration recommended by European Commission for future and existing dwellings: 200 and 400 Bq m^{-3}, respectively [29] and by the International Commission on Radiological Protection: 500 Bq m^{-3} for workplaces [2]. This level for workplaces is adopted by the

Italian law [30]. The concentration levels are well within the action level prescribed by ICRP [2].

Conclusions

It is evident from our studies that the concentration levels of ^{222}Rn and ^{220}Rn in dwellings depend on various factors such as soil beneath, local geology, the house construction materials, microclimatic parameters and last but not the least life style in the dwelling since higher concentration in the poor ventilated rooms has been observed. Therefore it is suggested that the residential rooms must be well ventilated and free from ^{222}Rn rich materials to reduce the health hazard effects of ^{222}Rn. Indoor concentration depend also on radon exhalation rate of the flooring and ventilation condition. Higher concentrations of both ^{222}Rn and ^{220}Rn have been observed where the exhalation rate is more. It is obvious that the concentrations are maximum during winter and minimum in summer. This behavior can be attributed to the fact that during these months because of high temperature during summer the doors and windows are kept open most of the time and electric fans are used for cooling purpose but during winter the doors are closed to conserve heat effect. In conclusion, this work has posed the bases for the realization of a network that will allow to mapping the environmental radioactivity in Bangalore region and, more importantly, that will contribute to diffusion of a more complete scientific culture about radioactivity.

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References

[1] UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), 2000. “Sources and Effects of Ionizing Radiation”. Report to the General Assembly, with Annexes. United Nations, New York.

[2] International Commission on Radiological Protection (ICRP), 1993. “Protection against Radon-222 at Home and at Work”, ICRP Publication, vol. 65. Pergamon Press, Oxford, pp. 1–262.

[3] IAEA (International Atomic Energy Agency), 2003. “Radiation protection against radon in workplaces other than mines”, IAEA Safety Report Series No. 33, (Vienna: IAEA).

[4] Bochicchio, F., Campos-Venuti, G., Piermattei, S., Nuccetelli, C., Risica, S., Tommasino, L., Torri, G., Magnoni, M., Agnesod, G., Sgorbati, G., Bonomi, M., Minach, L., Trotti, F., Malisan, M.R., Maggiolo, S., Gaidolfi, L.,

Giannardi, C., Rongoni, A., Lombardi, M., Cherubini, G., D'Ostilio, S., Cristofaro, C., Pugliese, M., Martucci, V., Crispino, A., Cuzzocrea, P., Sansone Santamaria, A., Cappai, M., 2005, "Annual average and seasonal variations of residential radon concentration for all the Italian regions", Radiat. Meas., 40, pp. 686–694.

[5] Malanca, A., Fava, R., Gaidolfi, L., 1998, "Indoor radon levels in kindergartens and play-schools from the province of Parma", J. Environ. Radioact., 40, pp. 1–10.

[6] Gaidolfi, L., Malisan, M.R., Bucci, S., Cappai, M., Bonomi, M., Verdi, L., Bochicchio, F., 1998, "Radon measurements in kindergartens and schools of six Italian regions", Radiat. Prot. Dosim., 78, pp. 73–76.

[7] Giovani, C., Cappelletto, C., Garavaglia, M., Scruzzi, E., Peressini, G., Villalta, R., 2001, "Radon survey in schools in north-east Italy", Radiat. Prot. Dosim., 97, pp. 341–344.

[8] Pugliese, M., Roca V., Sabbarese, C., Venoso, G., Gialanella, L., 2006, "Radon Survey in Twenty Schools of Campania Region (Southern Italy) Carried out from Students in the Frame of a Project on the Study of the Environmental Radioactivity: Preliminary Results", Second European IRPA Congress on Radiation Protection. May 15–19, Paris, France.

[9] Mayya, Y.S., Eappen, K.P., and Nambi, K.S.V., 1998, "Methodology for mixed field inhalation dosimetry in monazite areas using a twin cup dosimeter with three track detectors", Radiat. Prot. Dosim., 77, pp. 177-184.

[10] Eappen, K.P., and Mayya Y.S., 2004, "Calibration factors for LR-115 (type II) based radon thoron discriminating dosimeter", Radiat. Meas., 38, pp. 5–17.

[11] Cross, W.G., and Tommasino, L., 1970, "Rapid reading technique for nuclear particle damage tracks in thin foils", Radiation Effects., 5, pp. 85–89.

[12] Garkani, D.A., 1989, "Spark Counter for Alpha Particle Registration", in Proceedings of International Workshop on Radon Monitoring in Radioprotection, Environmental Radioactivity and Earth Sciences. Eds L. Tommasino, G. Furlan, H. A. Khan and M. Monnin (Singapore: World Scientific), pp. 164–170.

[13] Sathish, L.A., Sannappa, J., Paramesh, L., Chandrashekara, M.S. and Venkataramaiah, P., 2006, "Studies on the concentrations of radon/thoron and their progeny in houses of different types of floorings in Mysore city", Env. Geochem., 9, pp. 105-108.

[14] Al-Jarallah, M., 2001, "Radon exhalation from granite used in Saudi Arabia", J. Environ. Radioact., 53(1), pp. 91–98.

[15] Vaupotic, J., Kobal, I., and Planinic, J., 1998, "Long-term radon investigation in four selected kindergartens in different geological and climate regions of Slovenia", J Radioanal. Nucl. Chem., 238, pp. 61–66.

[16] Ishimori, Y., Ito, K., and Furuta, S., 1998, "Environmental effects of radon and its progeny from uranium waste rock piles": part 1 and 2, in: A. Katase, M. Shimo (Eds.), Proc. 7th Tohwa Univ. Int. Sym. on Radon and Thoron in the Human Environment, 23–25 October 1997, World Scientific, Fukuoka, Japan, pp. 282–293.

[17] Sathish, L.A., Sannappa, J., Paramesh, L., Chandrashekara, M.S., and Venkataramaiah, P., 2001, "Studies on indoor radon/thoron and their progeny levels at Mysore city, Karnataka state", Ind. J Pure and App. Phys., 39, pp.738-745.

[18] Abu- Jarad, F. and Fremlin, J.H., 1984, "Seasonal variation of radon concentration in dwellings", Health Phys., 46, pp. 1126-1129.

[19] Ramachandran, T.V., Muraleedharan, T.S., Shaikh, A.N., and Subba Ramu, M.C., 1989, "Seasonal variation of indoor radon and its progeny concentration in dwellings", Atmos. Environ., 24 A (3), pp. 639-643.

[20] Vaupotic, J., Sikovec, M., and Kobal,I., 2000, "Systematic indoor radon and gamma-ray measurements in Slovenian schools", Health Phys., 78, pp. 559–562.

[21] Wei, M., Zhuo, W., Luo, Y., Furukawa, M., Chen, X., Yamada, Y., Lin, D., and Jian, Y., 2005, "Radon and thoron in Yongding Hakka Earth Building in Fujian Province of China", International Congress Series., 1276, pp. 309– 310.

[22] Virk, H.S., and Sharma, N., 2000, "Indoor radon/thoron survey report from Hamirpur and Una districts, Himachal Pradesh, India", Appl. Radiat. Isotopes., 52, pp. 137–141.

[23] Virk, H.S., Sharma, N., and Bajwa, B.S., 1999, Environmental radioactivity: A case study in Himachal Pradesh, India", J Environ. Radioact., 45 *(*2), pp. 119-127.

[24] Singh, J., Singh, L., Singh, S., and Virk, H.S., 1991, "Seasonal variation study of radon pollution at radioactive sites", Nucl. Tracks and Radiat. Meas., 19, pp. 415-416.

[25] Samuelson, C., Person, P. B. R., and Holen, E, 1981, "Measurement of ^{222}Rn and ^{220}Rn daughters in various Scandinavian Environment", Proceedings of 2nd Symposium on Natural Radiation Environment, pp. 575-583.

[26] Gavin, G., David, G., John, G., Chris,H., Sue, McLaren.,Brian, P., Richard mani B., Graeme, B., Antony, D., Paul, P., and Tim, R., 2005, "The potential risk from ^{222}Rn posed to archaeologists and earth scientists: reconnaissance study of radon concentrations, excavations, and archaeological shelters in the Great Cave of Niah, Sarawak, Malaysia", Ecotoxi. and Environ. Safety., 60, pp. 213–227.

[27] Gessel, T.F., and Prichard, H.M., 1980, "The concentration of ^{222}Rn in tap water to indoor ^{222}Rn concentrations", Int Natural Radiation Environment-III, Gessel T F, Prichard H M, eds Springfield VANTIS, DOECONF, 780422, pp.1347-1363.

[28] Ningappa, C., Sannappa, J., and Karunakara, N., 2008, "Study on radionuclides in granite quarries of Bangalore rural district, Karnataka, India", Radiat. Prot. Dosim., 131**(**4), pp. 495-502.

[29] European Commission (EC), 1990, "Commission recommendation of 21-2-1990 on the protection of the public against indoor exposure to radon" (90/143/Euratom). Off. J. Eur. Comm., L80, pp. 26–28.

[30] D. Lgv 241/2000. Decreto Legislativo 26 maggio 2000, n. 241, Gazzetta Ufficiale n. 203 Suppl. Ordinario, August 31, 2000 (in Italian).