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Full Length Research Paper

Measurement of radon concentration inside houses in Tafila Province, Jordan

O. Abu-Haija[1]*, B. Salameh[1], A. W. Ajlouni[1], M. Abdelsalam[1] and H. Al-Ebaisat[2]

[1]Applied Physics Department, Tafila Technical University, Tafila-Jordan.
[2]Chemistry Department, Tafila Technical University, Tafila-Jordan.

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The scope of this paper is to present a brief study related to the investigations we have already made at three districts of Tafila province, which is located in the south part of Jordan and where the most important hot spa and phosphate mines are located. The main concern in these investigations is to measure the indoor radon concentration levels by means of CR-39 detectors installed in randomly selected houses during winter season. The exposure time started from December 2008 and lasted for ninety days. After exposure, the detectors were etched in a KOH solution at 70°C for 8 h. The obtained average values of indoor radon concentration in the three different districts were ranged from 20.45 to 32.41 Bq/m^3. It was found out that the Ayma district possesses the highest radon concentration. Meanwhile, the district of Aina Al-Badah possesses the lowest.

Key words: Indoor radon, CR-39, passive dosimeter, exposure time.

INTRODUCTION

Radon is a radioactive noble gas that is formed as natural deposits of uranium throughout the earth's crust decay. As radon decay products are inhaled, they can mutate the cells in the lungs. These alterations can increase the potential for getting lung cancer (ICRP, 1987). Moreover, a radon gas is considered to be the second leading cause of lung cancer behind smoking. It turned out that a large part of natural dose to human population comes from radon (^{222}Rn) and its progeny (UNSCEAR, 2000). This health risk comes from the fact that the radon gas and its airborne daughters can seep up from the ground and build up in enclosures like dwellings. As a result, nationwide measurements of radon concentration levels inside dwellings (indoor) have received numerous interests from research professionals and are continuously presented all over the world (NRC, 1999). It is also of great importance to assess the exposure to (^{222}Rn) and its progeny in houses and areas of high ^{222}Rn levels for the purposes of quality control, radioactivity monitoring of building materials and for correction measures recommendations. Therefore we believe that it is crucially important to perform a measurement on the indoor radon concentration levels in a large number of randomly selected houses in different locations of Tafila province in Jordan since the indoor radon levels depend on many factors like the geological nature of the site under study, the nature of the soil, the meteorological conditions, the social habits of the dwellers and the porosity as well as the density of the wall material. Most of the dwellings in the study area and its surrounding are without any compliance to regulatory standards and are typical for one family having four to five rooms. The dwellings surveyed were of different types, but were mainly made of stones with cement. Xerochreptic soil constitutes more than 73% of this region with high stone content in the soil. The prevalent kinds of stone in the study area are limestone, sandstone, crushed and Marl. Moreover, a higher ventilation rate was exercised during the daytime inside the dwellings surveyed since doors and windows were open most of the day, in turn this can circulate the air in the dwellings and introduce a fresh air.

It is interesting to mention that many authors studied the indoor radon concentration levels in Jordan. Among them Al-Kofahi et al. (1992) have obtained radon concentration levels in the city of Irbid. Abumurad et al. (1997) have been made a comprehensive study of radon levels in Jordanian dwellings in all Jordan cities during an

*Corresponding author. E-mail: oabuhaija@ttu.edu.jo. Tel: +962 7 99027889. Fax: +962 3 2250002.

Table 1. Number of collected dosimeters (No.) from each location, and radon concentrations in each group of dwellings that form the areas. *C* is the average concentration and σ is the standard deviation.

Region	No.	Min. conc. (Bqm^{-3})	Max. conc. (Bqm^{-3})	*C*(Bqm^{-3})
Al'is	30	9.66	66.90	25.99 ± 3.93
Ayma	30	9.52	102.01	32.41 ± 4.65
Aina al-badah	30	7.44	54.43	20.45 ± 2.53

autumn season. Similar study has been made by Khatibeh et al. (1997) on a measurement of indoor radon concentration levels in some cities of Jordan. In addition, Kullab et al. (2001) has been studied the seasonal variation of radon-222 concentration levels inside and outside specific location in Jordan. Recently, Abumurad et al. (2008) have been made a comprehensive serious radon survey in an area (Abumurad et al., 2008) second in population after the capital of Jordan (Amman), which is located in the north part of Jordan. Very recently, Ya' qoub et al. (2009) have been measured the indoor radon concentration in dwellings of As-Salt region, the middle part of Jordan. No attempts have been made to perform a comprehensive study on a measurement of the indoor radon concentration levels in different locations (Al'is, Ayma and Aina Al_Badah) of Tafila province in Jordan during winter season, 2009.

MATERIALS AND METHODS

The measurement of the indoor radon concentration using CR-39 detector has been carried out. CR-39 detector is a convenient detecting device since it is sensitive to alpha particle with energies varied from about 0.1 to more than 20 MeV. We used what so-called long time-integrated passive radon dosimeters of closed can technique containing CR-39 solid state track detectors. The structure of these passive radon dosimeters had been described elsewhere (Al-Bataina et al., 1997). Following this technique, a total of thirty dosimeters were prepared and distributed in three locations (Al'is, Ayma and Aina Al_Badah) in Tafila province. In each dwelling, at least two detectors were placed, one in the living-room and one in a bedroom. The detector was kept on the top of a cabinet at different height above the ground. The exposure time of the detectors started from December 2008 and lasted for ninety days. After exposure, the detectors then collected and chemically etched using 30% solution of KOH in water bath with controlled electric heater for eight hours at fixed temperature of 70℃. After etching process took place, the detectors were washed by distilled water and then dried out. The number of tracks per cm^2 occurred in each detector was determined by means of an optical microscope. To link the obtained track density with radon concentration, the dosimeters were previously calibrated in the School of Physics and Space Research at Birmingham University, England. The radon concentration (activity density) measured by one detector, in units of Bq/m^3, is given by Al-Bataina et al. (1997),

$$C = \frac{C_o \; t_o \; \rho}{\rho_o \; t}$$

where C_o is the radon concentration of the calibration chamber (90 kBq/m^3), t_o is the calibration exposure time (48 h), ρ is the measured track number density per cm^2 on the CR-39 detectors inside the dosimeters used in this study, ρ_o is the measured track number density per cm^2 on those of the calibrated dosimeters (3.31×10^4 $tracks/cm^2$) and t is the exposure time (2160 h).

RESULTS AND DISCUSSION

Table 1 shows the number of dosimeters collected from the main groups of dwellings and the minimum and maximum concentrations of radon 222 in the dwellings of each group measured in Bq/m^3. The table also shows the average concentration (C) of radon 222 for each location in the survey. The average concentration for each location was calculated by multiplying the individual concentrations (dosimeter readings) for that location with the corresponding frequencies for each concentration, and then the sum of the products was divided by the total number of dosimeters. It can be seen in this table that the average concentration in the Tafila province ranges from 20.45 to 32.41 Bq/m^3. The Aymah area is characterized by the highest average of radon concentration level (32.41 Bq/m^3), while the Aina Al_Badah area is characterized by the lowest one (20.45 Bq/m^3). This is properly due to the large number of houses with many openings; occupied by big families. Such a factor may induce good air circulation which may reduce the indoor radon concentration level. The overall average of the measured indoor radon concentration level inside dwelling of Tafila province is found to be 26.28 Bq/m^3. From the tabulated data in Table 1, it is clear that the difference between the minimum and maximum concentrations of radon level in the dwellings of Aymah is very high. This large variation in radon concentrations inside these dwellings is mainly due to the difference in the ventilation methods used and the difference in the dwelling heights. The fluctuation in the measurements of the radon concentration level in the other two areas can be explained in the same manner.

Table 2 shows the results of radon concentration levels in different regions in Jordan along with the present study. It is noticeable that result of our study is lower than the average radon concentration in Jordanian dwellings in all studied regions. For the purpose of comparison of radon levels in different regions in Jordan and the study region some factors have to be considered. Tafila Province lies in the south part of Jordan and during winter time has a relatively high wind speed. It is also characterized by large houses with many openings,

Table 2. Radon concentration levels (arithmetic mean value) in different regions in Jordan.

Region	Indoor radon concentration, C (Bqm^{-3})	Reference
Tafila Province	26.28	Present study
As-Salt	111	Ya' qoub et al. (2009)
Irbid	44	Abumurad et al. (2008)
Al-Ruseifa	386.2	Kullab et al. (2001)
Tafila	47.28	Abumurad et al. (1997)
Tafila	50	Khatibeh et al. (1997)
Ajloun	52	Khatibeh et al. (1997)
Amman	43	Khatibeh et al. (1997)
National average of Jordan	48	Abumurad et al. (1994)

occupied by big families. In addition, it is traditional to exchange many visits between neighbors. These factors may induce good air circulation which may reduce the indoor radon concentration levels and explain why regions in the middle and North of Jordan have high radon levels in comparison with Tafila province.

The highest radon level recorded by Kullab et al. (2001) was about 386.2 Bq/m^3 in AL-Ruseifa region. The reason for that might be due to the fact that most houses in this region were built on lands that used to be phosphate mines. Ya' qoub et al. (2009) explained the raising in the radon concentration levels in their study due to lack of ventilation. Since the majority of participants in their survey are employees, which implies that their dwellings are kept closed during day time when they are outside the house. Our result is seen to fall below the previous measured value of Abumurad et al. (1997). This is mainly due to the fact that the studied period was not the same since they performed their measurements during the autumn season, while we conducted the measurements during the winter season. Another comparison can be made between our result and that of Khatibeh et al. (1997). Again, our result appears to be less than their result by a factor of one half. This can be explained from the fact that the number of houses used in their study was less than the number of houses in the present study. When comparing the results obtained here with the results obtained by Abumurad et al. (1994), we see that the obtained result in this study is lower by about 55%. The observed variations of radon concentrations among various regions can be attributed to many factors like geological structure of the sites, the various types of building materials used for the construction of the houses, the heating systems and ventilation rates, and the aging effect on the building as well as the social habits of the dwellers.

Conclusion

In this work, radon concentration levels in a large number of randomly selected dwellings in Tafila province are reported. The overall average of radon concentration level inside dwelling of Tafila province was 26.28 Bq/m^3. Although this work had been done during winter season, this average value is still much lower (almost half) than that of the residential houses measured previously during the autumn season (Abumurad et al. 1997; Khatibeh et al., 1997). In addition, the result of the national average of Jordan (Abumurad et al., 1994) is twice that in the present study. Therefore, we strongly recommend that better ventilation rate to these houses must be considered to keep low radon concentration level. Additional studies should be made during the other seasons of the year, where the ventilation of various dwellings is different.

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