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ARTICLE

Radon Concentration and Lung Cancer Risk in Bashika District

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Abstract: In this work, the indoor radon concentration level and lung cancer risks have been measured in Bashika district, east of Mosul city-Iraq, during the summer season, by using time integrated passive radon dosimeters containing CR-39 plastic track detectors. These measurements were carried out in the sitting room of ten dwellings built by plaster for an exposure time of 60 days. The radon concentration in these dwellings ranges from (18.32-54.87) $Bq.m^{-3}$with an average of (33.44 $Bq.m^{-3}$), which lies below the acceptable radon levels (50-150) $Bq.m^{-3}$ recommended by the International Commission of Radiation Protection (ICRP). The average value of the PAEC was 3.61×10^{-3} in working level (WL) and the average value of potential alpha energy concentration (PAEC) in working level month per year (WLM/Y) was 0.14. The average absorption effective dose equivalent for a person living in homes for which the investigation was done was found to be ($0.79 mSv.y^{-1}$). In the recent report (ICRP), the recommended action levels of radon in dwellings should be within the range of (3-10 mSv). It is observed that the average lung cancer cases per year per 10^6 persons were found to be 14.31.
Keywords: CR-39; Radon-222 concentration; AEDE; PAEC.

Introduction

The three isotopes of radon ^{219}Rn, ^{220}Rn and ^{222}Rn are radioactive gases with half- lives of 3.96s, 55.6s and 3.825d, respectively. These isotopes are produced by decay of the natural radio nuclides ^{235}U, ^{232}Th and ^{238}U. ^{222}Rn can be considered to be of the most dangerous radioactive elements in the environment, because of its short half-life. Its character as a noble gas allows it to spread through the atmosphere [1]. The main natural sources of indoor ^{222}Rn level are soil, building materials (sand, rocks, cement, … etc.), water born transport and natural energy sources like gas, coal, … etc, which contain traces of ^{238}U [1,2]. The indoor radon concentration depends mainly on radon exhalation from surrounding materials. ^{222}Rn and its airborne daughters can cause a significant internal health hazard (for example lung cancer), especially when uranium or radium content in the soil is high or when radon and its daughters are concentrated in enclosed areas and in particular in dwelling areas. Several reports have appeared in the literature, demonstrating that residential ^{222}Rn may be responsible for 7% of lung cancer in Germany, 4% in Netherlands, 20% in Sweden and (10-15) % in the United States [3].

Concentration of ^{222}Rn gas in dwelling areas has been reviewed and summarized by the United Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [4]. The data is available for over 20 European countries and shows that the average ^{222}Rn concentration varies widely from < 25 $Bq.m^{-3}$ in the Netherlands, the United Kingdom and Cyprus, to over 100 $Bq.m^{-3}$ in Estonia, Finland, Sweden, Luxembourg, the Czech Republic, Hungary and Albania. For many countries, the variation in indoor ^{222}Rn levels within the country is enormous, and individual dwellings with ^{222}Rn gas concentrations above 10000 Bq/m^3 have been found in Finland, Norway, Sweden,

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Belgium, Germany, Switzerland, the United Kingdom, the Czech Republic and Spain [4, 5].

In a recent multi-year survey conducted on Guam by the local Environmental Protection Agency (EPA), indoor ^{222}Rn levels exceeded the U.S. EPA air quality standard of 148 Bq/m^3, m~40% of all buildings tested. By the mid 1990s, it was widely publicized that radon was the second leading cause of lung cancer after smoking. Shortly thereafter, the U.S. EPA estimated that indoor radon exposures account for approximately 21,000 lung cancer deaths annually in the U.S. This represents about 14% of all U.S. lung cancer deaths. The number of lung cancer cases reported for each village between 1993 and 2007 ranged from 5-159 and were tightly correlated with village population size (r = 0.95) [6].It can be concluded that lung cancer rate may show a negative correlation with natural radon concentration [7]. Measurement of indoor ^{222}Rn is rather important, because the radiation dose of humans constitutes more than 60% of the total equivalent dose of annual exposures of humans, including exposure from natural sources [6, 8]. Several techniques have been used to measure the concentration of ^{222}Rn and its daughters. Solid state nuclear track detectors, such as LR-115 and CR-39, have been widely used for the measurement of time integrated radon levels in dwellings under different conditions [9, 10].

The present study aims to measure some important parameters, such as the indoor ^{222}Rn concentration in dwellings of Bashika district, the potential alpha energy concentration, the absorption effective dose exposure and the lung cancer cases per year per 10^6 persons. These evaluations can help in establishing a reference level of activity concentration from which any further increase in those levels for any reason could be detected.

Experimental Procedure

This study assesses the indoor ^{222}Rn concentration in dwellings of Bashika district situated in the east of Mosul city in Iraq. The dwelling spaces under study were in general buildings with cement bricks, with a concrete and iron structure. The walls of the dwellings are often covered with gypsum board and several of these materials are expected to contribute significantly to sources of indoor ^{222}Rn.

The passive ^{222}Rn dosimeter (as in Fig. 1) is a closed chamber into which ^{222}Rn diffuses and is composed of a plastic cup of 7 cm in diameter and 4.6 cm in depth. A circular hole of sponge with an area of (2x2) cm^2 and a thickness of 0.5 cm is sealed to the interior surface of the lid. The design of the chamber ensures that aerosol particles and thoron (^{220}Rn) are deposited on the sponge from outside and ^{222}Rn, among other gases, diffuses through it to the sensitive volume of the chamber. The cup contains a CR-39 alpha track detector fixed to the bottom by double-side cello-tape.

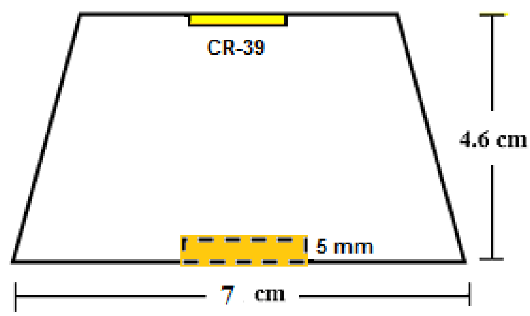

FIG. 1. Irradiation chamber

The measurements were carried out in the sitting room of the dwelling for an exposure time of 60 days during the summer season (August) of 2007. The detectors were collected and chemically etched using the aqueous solution of 6.25 N of NaOH at a temperature of 70 ^{o}C for 4 hours. After etching, the detectors were rinsed in distilled water and cleaned. An optical microscope with a magnification of X400 was used to count the number of tracks per cm^2 in each detector.

The calibration process for the dosimeter of this type and dimension was done by [3]. The concentration of ^{222}Rn (C_{Rn}) in units of Bq/m^3 was determined by measuring the track density (ρ) of the exposed detector inside the cup according to the following relation [11]:

$$\frac{c_o\, t_o}{\rho_o} = \frac{c_{Rn}\, t}{\rho} \; ; \qquad (1)$$

where c_0 is the concentration during the calibration process which equal to 90 kBq/m^3, ρ_o is the track density on the calibrated dosimeters which is equal to 96768 tracks/cm^2, t_o is the exposure time for calibrated dosimeters which is equal to 48 hours and t is the exposure time which is equal to 60 days.

Our aim is to find the following parameters:

1- (PAEC) in working level (WL) of radon daughters estimated according to the following equation [1, 3]:

$$C_a = \frac{F\, C_{Rn}}{3700}. \quad (2)$$

First find the concentration of ^{222}Rn, so the equivalent equilibrium concentration *EEC* of radon is deduced as in the equation: $EEC = F \times C_{Rn}$.

F is the equilibrium factor which is equal to 0.4 indoor, *EEC* times 0.01 is the *PAEC* in (*WLM*), while $WLMY^{1}$ is equivalent to working level *WL* times factor 40.

2- The absorption effective dose equivalent (*AEDE*) is estimated by using the dose conversion factor of 5.5 mSv/*WLM* [1, 12].

$$\left. \begin{aligned} & AEDE\ (mSv\ /\ y) = \\ & \quad (5.5\ mSv\ /WLM\ ) * (WLM\ \ /\ y\ ) \end{aligned} \right\} \quad (3)$$

3- Lung cancer cases per year per 10^6 persons are estimated by using the risk factor lung cancer induction of $18\times10^{-6}\ mSv^{-1}$ [1, 12].

$$\left. \begin{aligned} & \text{Lung cancer cases per year per } 10^{6} \text{ persons} \\ & = AEDE\ (mSv\ /\ y\ ) * 18 * 10^{-6}\ \ (mSv^{\ -1}) \end{aligned} \right\} \quad (4)$$

Results and Discussion

Table 1 summarizes the track density ρ (tracks/cm^2), the radon concentration C_{Rn} (Bq/m^3), the potential alpha energy concentration *PAEC* (*WL*), the absorption effective dose equivalent *AEDE* (*mSv*.y^{-1}) and the lung cancer cases per year per 10^6 persons in different dwellings in Bashika district. Fig. 2 shows the radon concentration in dwellings with the location number in Bashika district. The analysis of the measured values of radon concentration shows that there is only one dwelling with a value of more than 50 Bq/m^3, six dwellings with values between (30-49) Bq/m^3 and three dwellings with values less than 30 Bq.m^{-3}. The lowest radon concentration was measured in dwelling no.5 which is 18.32 Bq/m^3 and the highest was in dwelling no.7 which is 54.87 Bq/m^3. It is believed that the reason behind the high ^{222}Rn level in dwelling no.7 (Bartilla root) is due to the presence of uranium, where its average content in Bartilla soil was found to be 5.27 ppm [13]. The average radon concentration for all the studied dwellings was 33.44 Bq/m^3, which lies below the acceptable ^{222}Rn limits of (50-150) Bq/m^3 recommended by the ICRP. The ICRP refined this recommendation in 2014 in Publication126. The commission now "strongly encourages national authorities to set a national derived reference level that is as low as reasonably achievable in the range of 100-300 Bq/m^3, taking the prevailing economic and societal circumstances into account" [14]. This is because exposure to radon earlier in life increases the risk of developing lung cancer during lifetime. The Canadian radon guideline recommends that remedial measures be undertaken in a dwelling whenever the average annual radon concentration exceeds 200 Bq/m^3 in the normal occupancy area, and the higher the radon concentration, the sooner remedial measures should be undertaken [15]. The ^{222}Rn concentration levels in Bashika district are lower than those found in other regions in Iraq (northern of Baghdad), like Erbil governorate (44 Bq/m^3) [1]. The variation in radon concentrations is fundamentally related to the type of construction, ventilation rate, size and age of the building. The average ^{222}Rn concentration was found to be lower than those measured by other works in other countries (see Table 2) [16]. The potential alpha energy concentration (*PAEC*) levels range between (1.98-5.92) × 10^{-3} *WL* with an average value of 3.61×10^{-3} *WL*. The average absorption effective dose equivalent for a person living in one of the homes for which the investigation was done was found to be 0.79 mSv/y. In the recent report of the ICRP, the recommended action levels of radon in dwellings should be within the range of (3-10) *mSv* [17]. On the basis of this ICRP recommendation, it has been observed that the dwellings monitored for indoor ^{222}Rn concentration show values below the action levels. According to our estimations, the ^{222}Rn induced lung cancer risk for dwellings in Bashika district ranges from 7.83 to 23.47 with an average of 14.31 per 10^6 persons.

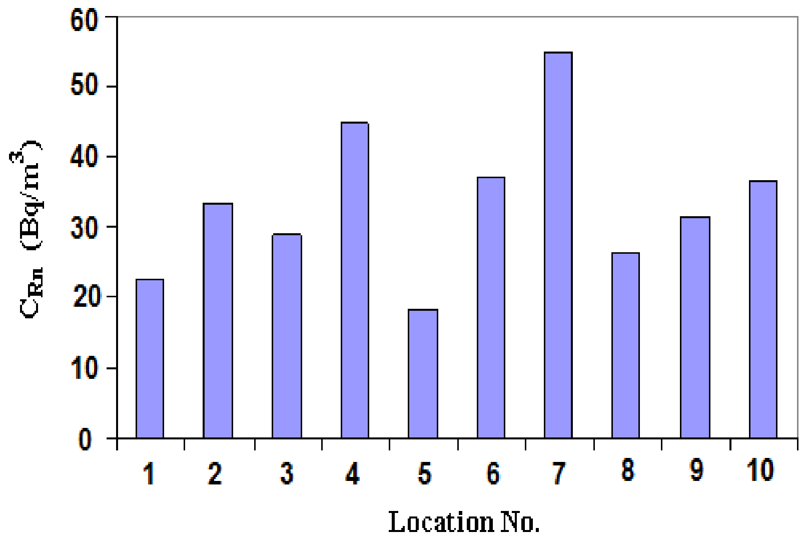

FIG. 2. Histogram of radon concentration in dwellings versus location number.

TABLE 1. Radon concentration, potential alpha energy concentration, absorption effective dose equivalent and lung cancer cases in Bashika district

No.	Location	ρ Tr./cm^2	C_{Rn} Bq/m^3	PAEC WL x10^{-3}	PAEC [(a)] WLM/y	AEDE mSv/y	Lung Cancer Cases /10^6 person
1	Oil Station	732	22.693	2.45	0.09	0.53	9.70
2	Rass Al-Aien	1074	33.29	3.59	0.14	0.79	14.25
3	Al-Islaam Cartier	930	28.83	3.11	0.12	0.68	12.27
4	Bashika Center	1442	44.70	4.83	0.19	1.06	19.11
5	Al-Kaba Cartier	591	18.32	1.98	0.07	0.43	7.83
6	Al-Fathlya Root	1200	37.20	4.02	0.16	0.88	15.94
7	Bartilla Root	1770	54.87	5.92	0.23	1.30	23.47
8	Al-Rabee Cartier	849	26.32	2.84	0.11	0.62	11.28
9	Al-Shabak Cartier	1020	31.62	3.42	0.13	0.75	13.57
10	Bahzany	1180	36.58	3.95	0.15	0.86	15.64
	Average	1078.8	33.45	3.61	0.14	0.79	14.31

(a) PAEC (WLM/Y) = PAEC (WL) × 40 taken from refs. [1, 16].

TABLE 2. Arithmetic mean of radon concentrations in dwellings in various European countries based on UNSCEAR [4, 18]

Country	C_{Rn} (Bq/m^3)	Country	C_{Rn} (Bq/m^3)
Denmark	53	Hungary	107
Finland	120	Poland	41
Sweden	108	Romania	45
Belgium	48	Slovakia	87
France	62	Italy	75
Germany	50	Spain	86
Switzerland	70	Bashika (Iraq)	34
Australia	11	Korea	53
Italy	70	Uk	20
USA	46		

Conclusions

As the ^{222}Rn induced lung cancer risk for dwellings in Bashika district ranges from 7.83 to 23.47 with an average of about 14.31 per10^6 persons, this implies that people who live in these dwellings are subjected to a relatively low risk factor for radon induced lung cancer.

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