Assessment of Indoor Radon Concentration in Dwellings in Iraqi Kurdistan Using CR-39 Dosimeters

Najeba FS* and Mohamad SJ

School of Physics,
Universiti Sains Malaysia,
11800 USM, Penang, Malaysia

*Corresponding author e-mail: najebafarhad@yahoo.com
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ABSTRACT: The effect of indoor radon radiation on the fertility of women living in 30 spatial dwellings in three governorates in Iraqi Kurdistan was investigated. The radon concentrations in kitchens were measured using 60 CR-39 detectors. The level of radiation of alpha particles was evaluated depending on the track density of the particles. Also, the indoor radon progeny and concentration of radon varied depending on the type of dwelling, ventilation, and geological formation. The results show that radon concentration was high in Sedakan city and low in Dukan city. The levels of radon in the kitchen of the dwellings ranged between 99.947 Bq m^{-3} and 360.112 Bq m^{-3}, with an average activity of 187.215 Bq m^{-3}. The radon progeny concentration WL varied between 10.805 Bq m^{-3} and 38.931 Bq m^{-3}. The indoor radon levels in few dwellings were above the recommended limits of the US Environmental Protection Agency. The distribution of indoor radon concentration in Iraqi Kurdistan was high in many houses and this could pose a health risk or affect women fertility.

Keywords: CR-39NTDs, dwelling, fertility of women, indoor radon, kitchen, radon concentration

Introduction

Radon (^{222}Rn) is a noble, naturally radioactive gas that originates from the decay of uranium in soils and rocks. It is odourless, colourless, tasteless, and requires special equipment to handle. Many factors affect the amount of radon emitted in a house, such as the rocks upon which the house is built upon and the amount of soil or other materials that cover the radon-emitting rocks. When radon is emitted from the soil, it enters the building through openings that permits air to flow, such as cracks within walls, junctions between floors and ceilings, plumbing chases, as well as chimney flues. The radon concentration in the atmosphere varies depending on the place, time, meteorological condition, and height above ground (Ahmad, 2007).

The problem of indoor radon emission has attracted considerable attention worldwide. Nationwide radon surveys and case-control studies on the association of residential radon with cancer risk have been conducted in many countries. Human exposure to radon and its daughters comprises more than 50% of the total dose from natural sources. Therefore, the measurement of indoor radon is significant.

Atmospheric ^{222}Rn concentration is directly linked to the inhalation of its short-lived daughters, which are deposited in respiratory organs if deeply inhaled (Asumadu-Sakyi *et al*., 2011). Radon and alpha particles have many effects on the body. The decay products of ^{222}Rn ($t_{1/2}$ = 3.82 days) are polonium 218 (^{218}Po, $t_{1/2}$ = 3.05 min.), lead 214 (^{214}Pb, $t_{1/2}$ = 26.8 min.), bismuth (^{214}Bi, $t_{1/2}$ = 19.7 min), and polonium 214 (^{214}Po, $t_{1/2} = 1.6 \times 10^{-4}$ s), as shown in (Figure 1).

In this present work, indoor radon alpha activities were measured in houses in Iraqi Kurdistan. The measurements were performed in kitchens because these locations were where women spent most of their time. Dosimetry CR-39 alpha-sensitive solid-state (SS) plastic nuclear track detectors (NTDs) in air-filled cups were used. The use of this device is the most reliable and time-saving procedure for estimating the equivalent concentrations of radon and its daughters under different environmental conditions (Mansour *et al.*, 2005). The health effects of radiation on the fertility of the women were evaluated.

Building characteristics

The studied dwellings were made of clay bricks, cement, sand, iron, marble, mud (mixed with wood), and concrete. Most of them were covered with gypsum. Several of these materials have significantly contributed to the indoor radon emission. Most dwellings only had one door and one window each. The windows were usually closed with many not functional. The ventilation conditions were poor (Narula *et al*., 2009) as there were no exhaust fans.

CR-39 NTDs

The CR-39 technique was used to determine alpha particles and radon concentrations. This technique has been previously used to study indoor radon levels in different dwellings. CR-39 SS NTD was diglycol carbonate ($C_{12}H_{18}O_7$). The NTDs comprised rectangular films with dimensions of about 1.5 cm^2 × 1 cm^2 and 700 μm thick. The sensitivity of CR-39 enabled it to register low-energy alpha particles (Nsiah-Akoto *et al*., 2011).

Chamber design

A 2.1 cm in diameter and 10.5 cm long chamber was used. The opening of the container was covered with a permeable cling film. The design of this type of radon detector ensures that only radon diffuses into the sensitive volume of the chamber, and that all aerosols and radon decay products were kept outside (Obed *et al.,* 2011).

Methodology

Experimental

Indoor ^{222}Rn concentrations in the kitchen of 30 houses were studied. The chamber technique was used. The chamber was 2.1 cm in diameter and 10.5 cm long. A typical CR-39 dosimeter with dimensions of 15.0 mm × 10.0 mm × 0.7 mm was used. The physical appearances and structural materials of the studied kitchen rooms did not differ significantly.

Two detectors were placed inside each house (total of 60 detectors). The detector was positioned flat at the bottom of a plastic container and affixed with a small piece of tape or glue. A circular hole 0.8 cm in diameter was bored in the middle of the cover, was closed by a thin soft sponge about 0.5 cm thick (Mansour *et al*., 2005). The detector was protected by the sponge from dust, but allows for radon gas diffusion into the bottom of the cans. This design ensures that all aerosols and radon decay products are kept outside and only radon diffuses into the sensitive volume of the chamber (Mansour *et al*., 2005). All detectors were placed at a height of about1.5 cm (Rafique *et al.,* 2010) from the ground of each kitchen and left undisturbed for 60 days.

Detector etching and scanning

The detectors were collected after 60 days and separately etched with a 6.25 N NaOH solution at 70 ± 0.5 °C for eight hours to enhance the damaged tracks (Rahmana *et al.,* 2011). During etching, the temperature was kept constant with an accuracy of ± 0.5 °C. The detectors were taken out from the etching solution and immediately rinsed with distillated water.

The track densities were then registered on the CR-39 and determined using an optical microscope (Rahmana *et al.,* 2011). To measure the radon concentration associated with the track density per square centimeter, an optical microscope at 400× magnification and 70 fields was used to scan each detector. Before counting the tracks, the areas of the fields of view were determined. During the scanning process, these areas were kept constant throughout the counting (Leghrouz *et al*., 2011).

Measurement of indoor radon concentration and annual effective dose

The background was corrected prior to the calculation of the track densities and concentrations of indoor radon gas (in Bq/m^3) as reported Saad *et al.* (2010). The indoor radon concentrations (Bq/m^3) were the average value of two detector strips. To estimate the annual effective dose received by the population, the annual absorbed dose was expressed in the unit mSv/y as indicated by Sathish *et al.* (2008).

Cancer cases per year per million per person (CPPP) were also determined by the conversion ion factor for CPPP, 18 × 10^{-6} mSv^{-1}·y. The radon progeny concentration WL was calculated using a formula in literature (Mansour *et al.,* 2005). The results are summarized in Table 1 and the data analyses are shown in Figure 2 to Figure 4.

Results and discussion

Indoor radon levels can be determined by different parameters, such as atmospheric conditions, seasonal situations (ventilation and soil emission), local geology, building features (type of building material, ceiling height, and house orientation), and the habits of the occupants. Generally, the large variations in indoor radon activity among the different dwellings in these localities can be explained by the different ventilation rates, nature of the soil underneath, and particularly, geological considerations.

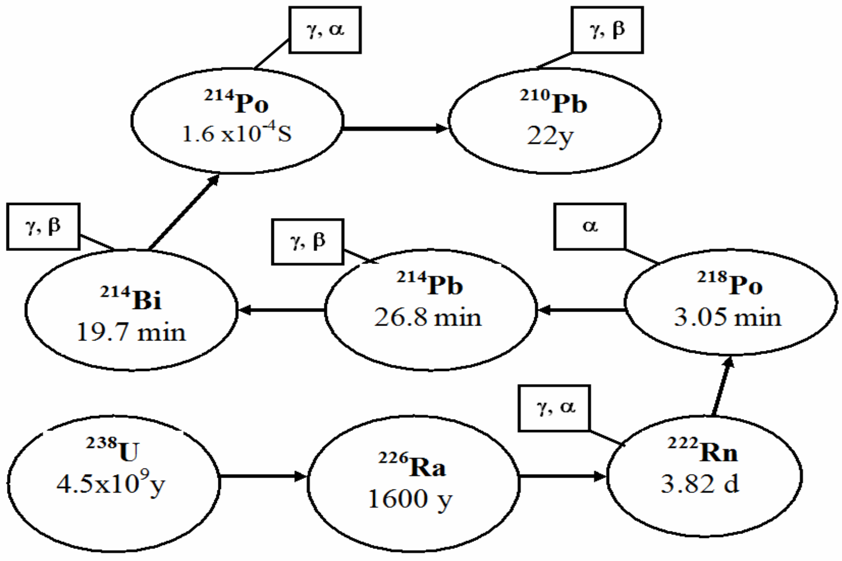

Figure 1: The decay products of ^{222}Rn

Table 1: Evaluation and assessment indoor radon concentration in chicken room in Iraqi Kurdistan region

N	Location	Age/year	Con. (Bq/m^3)	A ED (mSvy^{-1})	WL (m Bq/m^3)	CPPP (mSvy^{-1})
1	Taqtaq	41	107.664	2.7131	11.6393	48.8358
2	Koya	34	181.158	4.5661	19.5846	82.1898
3	Khalakan	25	172.476	4.3464	18.6460	78.2352
4	Rania	42	329.136	8.2942	35.5822	149.2956
5	Said sadiq	41	143.231	3.6094	15.4844	64.9692
6	Halabjay taza	30	240.118	6.0509	25.9709	108.9162
7	Kfry	28	105.546	2.6597	11.4103	47.8746
8	Sedakan	34	360.112	9.0748	38.9310	163.3464
9	Takea	33	145.655	3.6705	15.7464	66.0690
10	Shekhan	35	220.563	5.5582	23.8446	100.0476
11	Chanchamal	45	137.195	3.4573	14.8318	62.2314
12	Darbandikhan	34	231.651	5.8376	25.0433	105.0768
13	Penjween	42	267.662	6.7451	28.9364	121.4118
14	Erbil center	29	123.534	3.1130	13.3550	56.0340
15	Bardarash	36	353.754	8.9146	38.2436	160.0463
16	Deana	33	249.671	6.2917	26.9914	113.2506
17	Khurmal	31	304.654	7.6773	32.9355	138.1914
18	Zaweta	30	170.123	4.2870	18.3916	77.1660
19	Halabjay kon	47	341.552	8.6071	36.9245	154.9278
20	Qaladza	36	261.511	6.5909	28.2714	118.7820
21	Arbat	35	125.429	3.1608	13.3436	56.8944
22	Harer	32	193.157	4.8675	20.8818	87.6150
23	Kalar	27	139.300	3.5103	15.0594	63.1854
24	Dukan	26	99.947	2.5186	10.8050	45.3348
25	Shaqlawa	32	155.473	3.9179	16.8078	70.5222
26	Sharawany	43	130.973	3.3005	14.1592	59.4090
27	Suaymania	38	124.457	3.1363	13.4548	56.4534
28	Chwarqurna	39	182.156	4.5903	19.6925	82.6254
29	Rawanduz	27	263.101	6.6301	28.4433	119.3418
30	Dihuk	28	146.821	3.6999	15.8725	66.5982

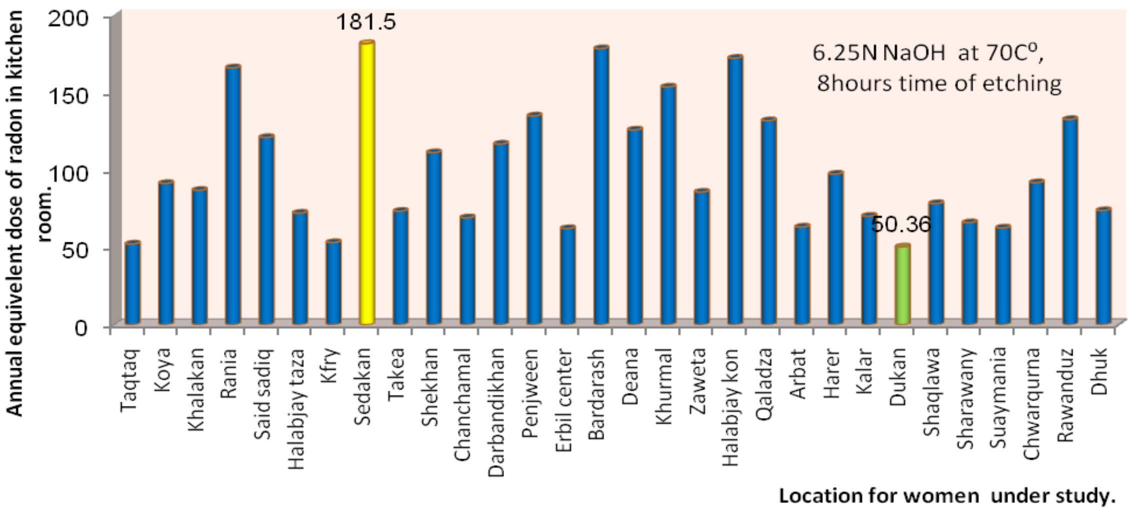

Figure 2: Relationship the annual equivalent dose of radon in the air in kitchen room for women with location under study

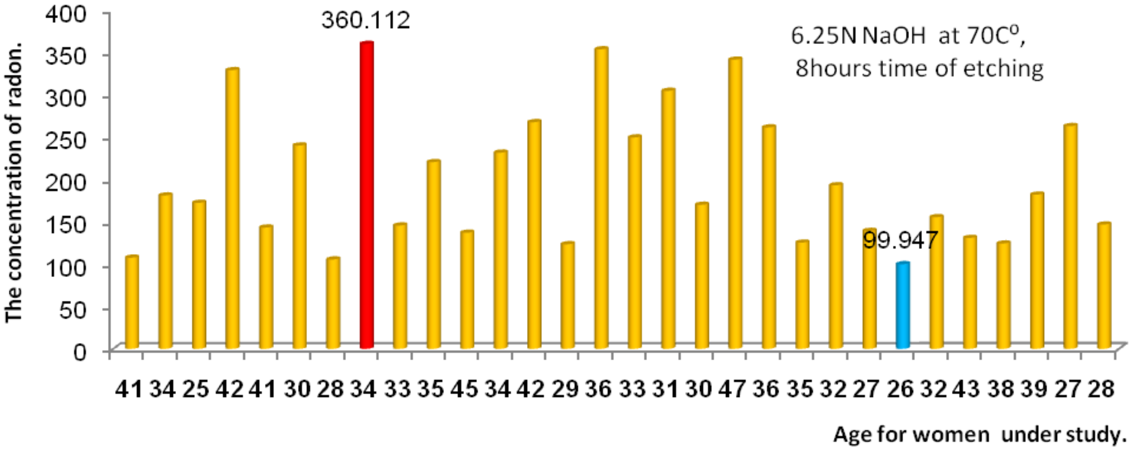

Figure 3: Relationship the age for women with the concentration of radon gas in kitchen room under study

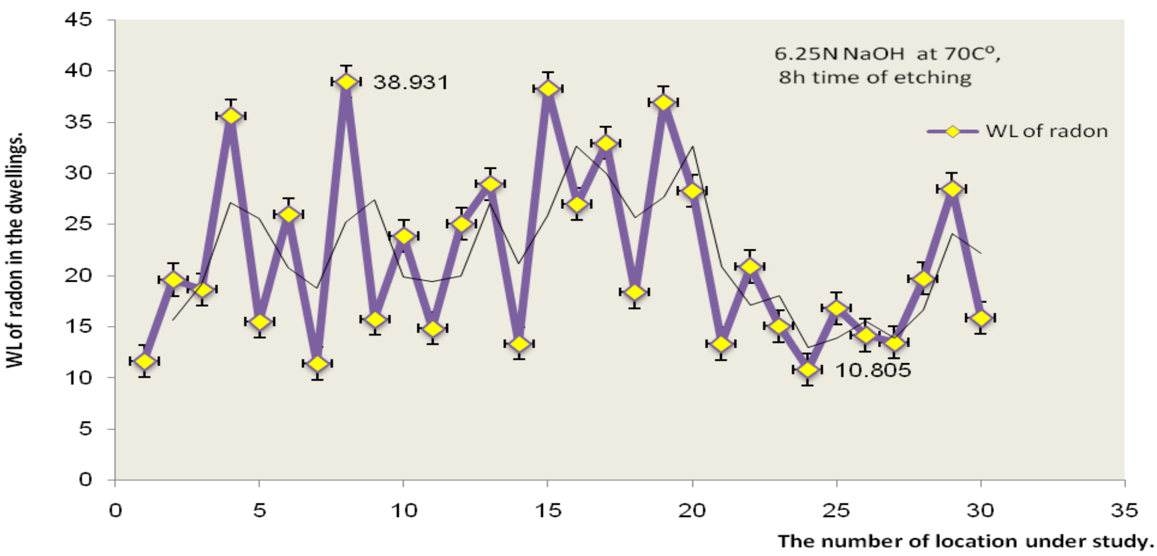

Figure 4: The WL of radon gas in the kitchen room as a function of location under study in Kurdistan Iraq

Indoor radon activity concentrations were measured in the kitchen of 30 dwellings in the Kurdistan Iraqi region, and the results are listed in Table 1. The radon concentration was found to be high in Sedakan city and low in Dukan city. The radon levels in the kitchens varied from 99.947 Bqm^{-3} to 360.112 Bq m^{-3}, with an average activity value of 187.215 Bq m^{-3}. The indoor radon levels WL varied from 10.805 Bq m^{-3} to 38.931 Bq m^{-3}.

The indoor radon levels were within the acceptable limits of the International Commission on Radiological Protection. However, the levels in a few dwellings were above the recommended limits of the US-Environmental Protection Agency (EPA). The US-EPA states that immediate intervention is required only if the Radon (^{222}Rn) concentration is higher than 190 Bq m^{-3} (the standard level is between 40 and 190 Bqm^{-3}. No intervention is required if the radon level is below 40 Bq m^{-3}, indicating that this level is safe for occupancy (Zunic and Miljevic, 2009).

The highest annual effective doses calculated in 20 mL of female urine samples was 9.0748 $mSvy^{-1}$ in Sedakan city, and the lowest annual effective dose was 2.518 $mSvy^{-1}$ in Dukan city. The annual mean effective dose was 5.1633 mSv in the kitchen that had the limit of the recommended action level, i.e., 3–10 $mSvy^{-1}$ (Narula *et al.*, 2009). The highest radon concentration levels were found in kitchens with the poorest ventilation (one door and one window).

Conclusion

The distribution of indoor radon concentration in Iraqi Kurdistan is high in many houses, and it affects the fertility of the women residing there. In Sedakan city, the highest radon concentration and annual effective dose calculated in 20 ml of female urine samples were 360.112Bq m^{-3} and 9.0748 $mSvy^{-1}$, respectively. In Dukan city, the lowest radon concentration and annual effective dose in 20 ml of female urine samples were 99.947 Bq m^{-3} and 2.518 $mSvy^{-1}$, respectively. The high levels of uranium in some regions pose danger to public health. Most health risks came from the alpha particles that were deposited in the body. Therefore, the environment needs to be as secure and safe as possible. Unfortunately, the high levels of uranium in some regions endanger the health of the public.

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