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Hazards Assessment of Radon Exhalation Rate and Radium Content in the Soil Samples in Iraqi Kurdistan Using Passive and Active Detecting Methods

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***Abstract*—**This study aims to assess the environmental hazards from radon exhalation rate in the soil samples in selected locations in Iraqi Kurdistan, using passive (CR-39NTDs) and active (RAD7) detecting method. Radon concentration, effective radium content and radon exhalation rate were estimated in soil samples that collected at the depth level of 30 cm inside 124 houses. The results show that the emanation rate for radon gas was variation from location to other, depending on the geological formation. Most health risks come from emanation of radon and its daughter due to its contribution for indoor radon, so the results showed that there is a linear relationship between the ratio of soil and indoor radon concentration ($C_{Soil\ Rn222}/C_{indoor\ Rn222}$) and the effective radium content in soil samples. The results show that radon concentration has high and low values in Hajyawa city and Er. Tyrawa Qr, respectively. A comparison between our results with that mentioned in international reports was done.

***Keywords*—**Radon, CR-39NTDs, RAD7, Soil, Iraqi Kurdistan.

I. INTRODUCTION

RADON is a naturally occurring radioisotope. Radioactivity is, and always has been a part of the earth. Radon-222 is one of the elements in the long radioactive decay chain from uranium-238. The elements above radon in the chain are relatively long-lived and of less concern for radiation exposure, but radon and the elements immediately following it in the chain are short-lived and therefore more hazardous [1].Whereas the predecessors to radon in the chain are solids and will not migrate far from their place in the soil, radon is a gas and can migrate through a few feet of earth, depending on the soil porosity. Radon in the outside air is diluted rapidly, but if it enters through a basement floor and is trapped in a tight house, it can reach high concentrations, and therefore, more hazardous appear for poor ventilation rate [2].

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Radon can diffuse through rocks and soil, can move from one place to the other and can leak out in the atmosphere from the soil. So the distribution of radon in soils has been related to geological controls in terms of its generation and migration; uranium content in bed rocks and soils influence production, and the soil characteristics (including the soil moisture and permeability) control the transportation of radon [3]. Radium and uranium contents of soil generally reflect that of the bedrock from which the soil materials have originated due to weathering processes. Homes located in areas with higher permeable soil and bedrock, with higher volume of soil under or surrounding the houses, and over bed rocks having crack zones, deep-seated faults and fractures that provide effective avenues for radon migration may have increased radon concentrations [4]. The purpose of this study was to assess the radon concentration, radon exhalation rate and the radium content in soil samples in selected areas in Iraqi Kurdistan using passive and active techniques type CR-39 NTDs and RAD7 respectively to quantify the radon activity of soil samples.

Sampling Schemes

The study sites are covered most parts of Iraqi Kurdistan. This region contains the uranium deposits in the entire belt, and a lot of infertility and cancers (blood, breast and prostate cancer) prevail. This region is largely mountainous with a population of currently around 4, 500,000 million. The 16 areas study sites were selected in this region.

II. EXPERIMENTAL PROCEDURES

A. Samples Collection

Soil samples (1Kg) were collected under the depth 30 cm inside the (garden) homes in selected areas in Iraqi Kurdistan that have different ratio of men infertility, the data of men infertility were collected via collecting personal data from 1999 to 2009 in the "Infertility Care and I.V.F center, Erbil-Iraqi Kurdistan, Date: 1st June 2009"

B. Sample Preparation

The samples first sieved in a mesh sieve, and then dried in a hot air oven at a temperature of 110±0.1°C for 24 hours and their bulk densities were determined. All the samples had nearly same densities (i.e. 1.*05927*g.cm^{-3}). These samples (each weighing 299. 35g) were then put into PVC containers of volume (282.6 cm^3). Each sample made 10 cm thick layer having surface area 28.26 cm^2 in the container.

C. Etching and Scanning Process

CR-39 track detector sizes are (10×15×0.5) mm^3 from the INTERCAST EUROPE SRL Company. A barrier is installed inside radon dosimeters at a distance of 7 cm from the surface of the samples. And the dosimeters were calibrated in previous work [5].

The cylindrical container was sealed and the samples were stored for 60 days. After the exposure, CR-39 detectors were etched in 6N NaOH at 70C^o for 9h, and then the detectors were washed in distilled water. To determine the track density per cm^{2,} ^{optical} microscope at 400X, 55 fields were used for scanning each detector, as shown in Fig.1.

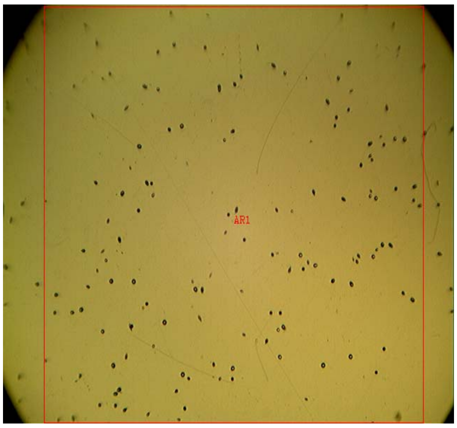

Fig. 1 Scanning of Alpha track density {track/ (23565.289μm^2 per 60 day)

III. The Measurements

A. Radon Concentration (Bq.m^{-3})

Average radon concentration in the soil samples is calculated using the following formula [6];

$$C_{Rn}(Bq.m^{-3}) = \frac{\rho_{Rn}}{K_{(Rn)}.t} \qquad (1)$$

where ρ_{Rn} is the radon track density (track/cm^2) , $K_{(Rn)}$ is the calibration factor for radon (=0.2315 track. cm^{-2}. d^{-1}/ Bq.m^{-3}) which is calibrated in previous work [5], and this factor depended on the detector efficiency for detect alpha particles, which are emitted from radon and its progeny [7], and t is the exposure time (=60 days).

B. Radon Exhalation Rate

The ratio of the cup volume to the sample volume must exceed 10 in order to consider the back diffusion process negligible. So, in this study the radon exhalation rate affected by the back diffusion process, because the volume of the cup volume less than the sample volume. Therefore, the process of the back diffusion has to be taken into consideration. Back diffusion parameter (β) can be defined as [8];

$$\beta = \frac{\lambda_{Rn} \times p \times V_s}{V} \; ; p = 1 - \frac{V_d}{V_w} \qquad (2)$$

where λ_{Rn} is the decay constant of radon (7.5 × 10^{-3} h^{-1}), V is the effective volume (197.82×10^{-6} m^3) inside the container, Vs is the volume of soil sample, p is the porosity of soil porous material, V_w and V_d are the volumes of wet and dry sample, respectively.

The exhalation rate of radon in soil samples was determined in terms of surface area $E_{s\,(Rn)}$ and mass $E_{m\,(Rn)}$, using the following formula [9, 10]:

$$E_{s(Rn)} = \frac{CV(\lambda_{Rn} + \beta)}{ATe}; E_{m(Rn)} = \frac{CV(\lambda_{Rn} + \beta)}{MTe} \qquad (3)$$

where, , M is the mass of the sample, A is the surface area of the sample, and C represents the integrated radon exposure (Bq.m^{-3}.h), and is defined as:

$$C = \frac{T_{rack}}{d.K_{(Rn)}} \times t \qquad (4)$$

T_{rack} and d represent the measured track density and the number of exposure days.
In the Eq. 3, Te is the effective exposure time (=1306.66h) which is related with the actual exposure time t(=1440 h) and is defined as.

$$\left[Te = t + \frac{1}{(\lambda_{Rn} + \beta)} \left\{ \exp^{-(\lambda_{Rn}+\beta)t} - 1 \right\} \right] \qquad (4)$$

C. Radium Content

The effective radium content of the soil samples C_{Radium} was calculated by using the following relation [11]:

$$C_{Radium} = C_{Rn}(Bq.m^{-3}) \times \frac{hA}{TeM} \qquad (6)$$

where h is the distance between the detector and the top of the soil sample (7×10^{-2}m).

IV. Results And Discussion

The values of radon concentration ($Bq.m^{-3}$), radon exhalation rates and the radium content in soil samples was in selected location in Iraqi Kurdistan are listed in Table I.

TABLE I RESULTS RADON CONCENTRATION, RADON EXHALATION RATE AND THE EFFECTIVE RADIUM CONTENT IN SOIL SAMPLES IN IRAQI KURDISTAN, AND THE RATIO OF MEN INFERTILITY

location name	Indoor radon concentration $C_{indoor\ Rn222}$ ($Bq.m^{-3}$) [ref. 3]	Soil radon concentration $C_{soil\ Rn222}$ ($KBq.m^{-3}$)/1 month (CR-39)NTDs	Soil radon concentration $C_{soil\ Rn222}$ ($Bq.m^{-3}$)/ 1hr(RAD7)	Radium content in soil samples Ra ($Bq.Kg^{-1}$)	$C_{soil\ Rn222}$/ $C_{indoor\ Rn222}$	Radon Exhalation rate Ea ($Bq.m^{-2}.h^{-1}$)	Radon Exhalation rate Em ($mBq.kg^{-1}.h^{-1}$)
Su. Mamustayan	175.91±38.21	13.33±5.33	907± 186	9.47±4.21	75.77	7.522±2.35	710.14±235.63
Su.Qlyasan	185.91±38.21	12.045±4.67	688±120	8.55±3.33	64.79	6.797±2.43	641.73±217.31
Hajyawa	**125.31±37.62**	**24.855±14.31**	**1720 ±50.1**	**27.65±11.2**	**198.34**	**14.02±7.11**	**1324.12±672.6**
Chwarquma	126.96±43.33	18.378±9.1	1700± 83.9	13.05±6.2	144.75	10.37±3.51	979.09±433.8
Ranya	142.16±40.42	17.948±9.86	1370 ±119	12.75±6.49	154.39	10.12±3.54	956.15±521.8
Er. Mamustayan Qr.	128.45±41.33	11.03±4.84	642±50	7.83±3.51	85.86	6.22±2.11	587.54±198.5
Er. Nawros.Qr	210.33±62.36	13.183±5.67	1120 ±212	9.36±3.22	62.67	7.439±3.43	702.31±201.7
Er. Tayrawa.Qr	162.82±37.87	**10.063±4.02**	**622±75**	**7.15±4.63**	**61.80**	**5.67±2.31**	**536.09±188.7**
Shawes	165.63±38.26	11.424±8.32	772±66.4	8.11±4.71	111.24	6.44±4.22	608.59±408.3
Koya	128.34±35.87	11.68±3.21	1090 ±58.6	8.29±2.28	59.84	6.59±1.89	622.23±155.8
Darartwo	238.4±76.54	12.16±5.44	989.5±152	8.63±2.86	53.75	6.86±3.09	647.81±212.8
Suran	209.44±43.58	12.824±4.89	1026±43	9.11±3.11	61.23	7.23±3.21	683.18±203.7
Bnaslawa	**239.65±77.32**	12.02±4.55	811±44.4	8.54±3.07	53.42	6.78±3.51	640.35±211.7
Akre	237.61±66.11	17.533±7.32	1099±102.1	12.45±4.64	73.79	9.89±4.65	934.05±406.1
Kelak	**95.11±34.75**	13.04±6.04	898 ±22	9.26±4.31	141.49	7.35±3.78	694.69±223.4

One observed that the radon concentration had high and low values in the location of Hajyawa (16.56% from whole values) and Er. Tyrawa (3.27% from whole values) respectively, because the geological formation of the locations was different, and this is clear in Fig.2.

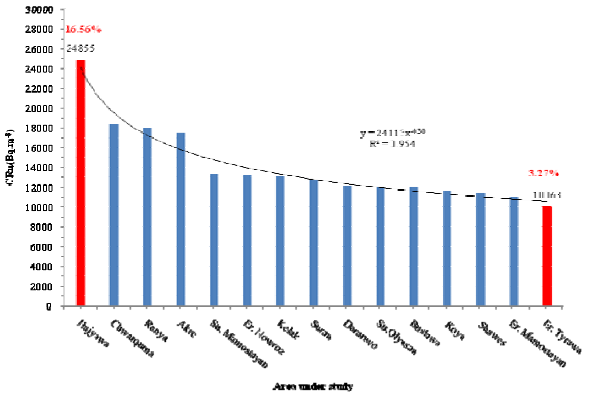

Fig. 2 Un-uniform distribution of soil radon concentration in the selected locations

In Fig.3, one observed that there is a linear relationship a good correlation (R=0.656) between an effective radium content in the soil samples and the ratio of soil radon to indoor radon ($C_{Soil\ Rn222}$/ $C_{indoor\ Rn222}$). This mean that, soil radon is a main source of indoor radon, then it can be reach to high concentrations. The positive part in this relation is an indication for the role of ventilation rate to decrease indoor radon. Therefore, more hazardous appears for poor ventilation rate.

A good correlation (R=0.779) has been observed between the results of the passive and active detector for measure radon concentration in the soil samples in Fig.4. Slop of the linear relation is 10.12; this is due to the long and short measurements. For CR-39NTDs the measurements were for 1 month, and for RAD7 the measurement was for 1 hour.

A comparison between our results about soil radon concentration, radon exhalation rate and effective radium content in soil samples in some location in Iraqi Kurdistan with that reported in other references [12,13] has been done.

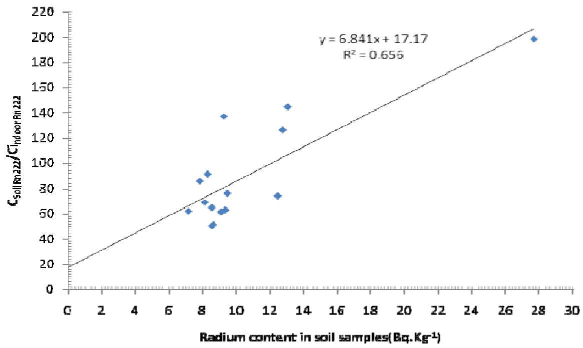

Fig. 3 Variation ratio of soil to indoor radon concentration with the radium content in soil samples.

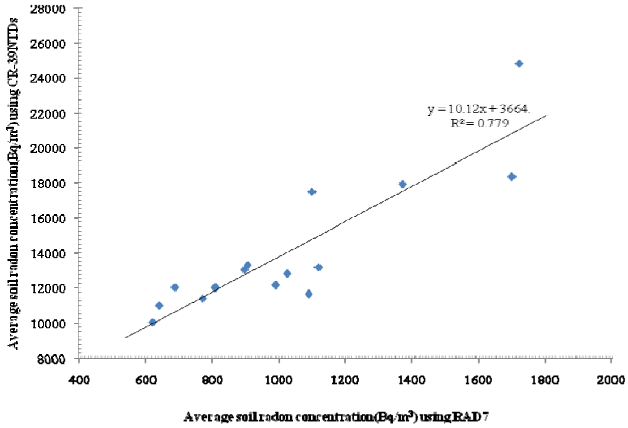

Fig. 4 Linearity between two active and passive detectors for measure radon concentration in Bq/m^3.

V. Conclusions

The results of the present work indicate that the area under investigation has a different ratio of radon concentration for both methods. A good correlation between the results of the passive and active detector for measure radon concentration in the selected soil samples has been demonstrated that the efficiency of our detector type CR-39NTDs was in high efficiency. This is approved that the real value of radon concentration can be gotten from long measurements using NTDs instead of short measurements.

Radon exhalation rate and effective radium content in the r soil samples has been estimated. And the level of soil radon concentration was a good correlation with the level of indoor radon concentration inside the bedroom, except in some houses in some locations, due to their ventilation rate.

As well as, the ratio of soil radon concentration was higher than indoor radon concentration, the average soil radon concentration by passive detecting method and indoor radon concentration were ($15.638\pm7.38 KBq.m^{-3}$) and ($171.47\pm47.3 Bq.m^{-3}$) respectively. Ignoring other sources of radon in dwellings, one can say that every 1000 $Bq.m^{-3}$ in soil air contributes about 9.11 in selected dwellings air of Iraqi Kurdistan, and this is agreement with the results in references [14]. And these values are considered to be at a typical level for the soil samples from Iraqi Kurdistan.

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