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A NEW APPROACH FOR MEASURING INDOOR RADON, THORON AND THERE PROGENIES USING CR-39 AND LR-115 SSNTDS

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ABSTRACT

We develop a new method to measure alpha- and beta-activities per unit volume of indoor air due to radon, thoron and their progenies using LR-115 type II and CR-39 solid state nuclear track detectors (SSNTDs). In the present study we fuond in Al-bradhia Region in Basrah Governorate (Iraq), the value of radon concentrations ranges from 42 $Bq.m^{-3}$ to 178 $Bq.m^{-3}$ with an average value of 107 $Bq.m^{-3}$ with standard deviation 38 $Bq.m^{-3}$. The value of thoron concentrations ranges from 2 $Bq.m^{-3}$ to 15 $Bq.m^{-3}$ with an average value of 9 $Bq.m^{-3}$ with standard deviation 3 $Bq.m^{-3}$.

KEYWORDS: Indoor Radon, Thoron, CR-39 Detector, LR-115 Type II Detector

INTRODUCTION

According to the UNSCEAR Report 2000, the world mean of annual effective dose due to the inhalation of radon, thoron and their decay products is estimated to be 1.2 mSv. This value corresponds to a half of the total of natural radiation exposure. In general, indoor radon concentration and the occupancy factor are larger than those of outdoor environments. It has been widely from many surveys that the dose due to indoor radon is much larger than that due to outdoor (UNSCEAR, 2000).

The protection from radon has become important in dwellings and workplaces. Radon monitoring in the dwellings and workplaces has started all over the world and still continuing in some countries. Thoron, an isotope of radon produced in thorium disintegration series, was neglected earlier because of its shorter half life (55.6 s). But later thoron progeny was also found to be hazardous and thoron was included in the dose estimations (Godaymi and Al-Khalifa, 2014).

Knowledge on the distribution of radon and thoron in the dwellings and workplaces is useful in estimating the inhalation dose due to them. On the other hand, the indoor life is mainly divided into dwelling and office lives. (K. Vinay Kumar Reddy et al. 2012).

Although radon and thoron are chemically inert and electrically uncharged, when the resulting atoms, called radon and thoron progeny, are formed, they are electrically charged and can attach themselves to tiny dust particles (aerosols) in indoor air and gets traped in the tracia bronchial system during inhalation there. Alpha particles from the decay of radon and thoron progeny irradiating the bronchial tissues. It is constitutes a significant radiation hazard to human lungs and occurrence of lungs cancer and that are deposited in the lungs cannot reach any other organs, so it is likely that lung cancer is the only potential important cancer hazard posed by radon in indoor air (BEIR-VI 1999 and Mohd Zubair et al, 2011).

Method of the Study

In the present study to measure indoor radon and thoron concentration, we used a method based on using two track detectors having different sensitivities CR-39 and LR-115 (M. Amrane et al., 2013, A.F. Hafez and M.A. Naim, 1992). Film track detector (LR-115 type II) is a cellulose nitrate ($C_6H_2O_9N_2$) film of 12 μm thickness manufactured by Kodak Path, France. The CR-39 SSNTD (500 μm thick) is the diglycol carbonate ($C_{12}H_{18}O_7$) supplied by Pershore Mouldings Ltd., UK. These plastics films of size ~ 1.5 cm×1.5 cm were fixed on glass slides and then these slides were mounted on the walls of different dwellings at a height of about 2m from the ground level with their sensitive surfaces facing the air in bare mode, taking due care that there was nothing to obstruct the detectors. For the present study where the observation were taken from October to December, 2013. After an exposure time of 3 months, detector films were removed and etched in a NaOH solution (2.5N at 60°±1 C for 120 min for LR-115 type II films and 6.25N at 70°±1 C during 7 h for the CR-39 detectors) in a constant temperature bath. Then these SSNTDs were washed, dried and scanned under a binocular microscope for track density measurements.

An unexposed film of the LR-115, CR-39 was also etched and scanned for the determination of background track density of the film. This background track density was subtracted from the observed value of the readings.

For our experimental etching conditions, the residual thickness of the LR-115 type II film is 5 μm which corresponds to the lower ($E_{\min}$ =1.6 MeV) and upper ($E_{\max}$ = 4.7MeV) energy limits for registration of tracks of alpha particles in LR-115 type II films. All α-particles that reach the LR-115 SSNTD with a residual energy situated between 1.6 and 4.7MeV are registered as bright track-holes. The CR-39 SSNTD is sensitive to all α-particles reaching its surface under an angle smaller than its critical angle of etching (M. A. Misdaq and A. Chaouqi, 2013).

Theoretical Approach

Let radionuclide distributed homogeneously throughout detection volume or effective volume in front of the detector. Let *dV* be an elementary volume situated at a distance r from a point O on the surface element *ds* of the detector (figure.1).

In spherical coordinates;

$$dV = r^2 \sin\theta \, dr \, d\theta \, d\phi \tag{1}$$

The Solid Angle *dΩ* between *dV* and *ds* is Defined as

$$d\Omega = \iint_{x\,y} \frac{\cos\theta}{r^2} ds \tag{2}$$

Let dN_i represent the number of α-particles i-th with an energy $E_{\alpha i}$ emitted from the radioactive nuclei during the exposure time d*t* in *dV* emitted in the direction of *ds* is defined as:

$$dN_i = A_{\alpha i} \, dV \, dt \, \frac{d\Omega}{4\pi} \tag{3}$$

Where $A_{\alpha i}$ is the activity of the i-th radionuclide

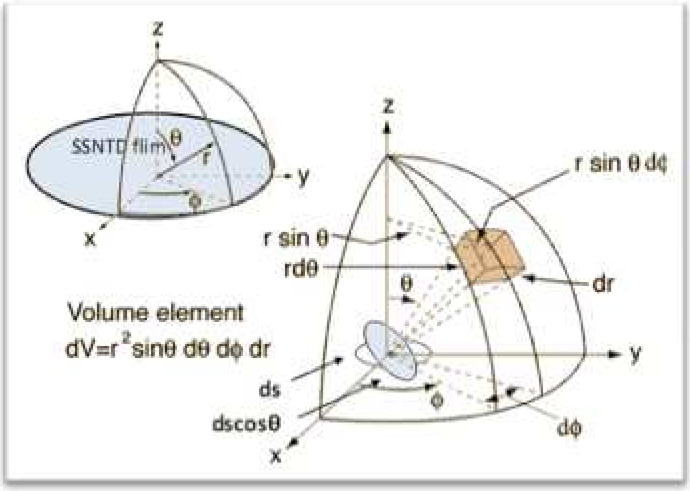

Figure 1: Radio Nuclides in Detection Volume in Spherical Coordinate

N_i can now be defined as the total number of α-particles that reach the detector surface

$$N_i = A_{\alpha i} \iint_{x\,y} ds \int_0^{2\pi} \int_\theta \int_r \frac{r^2 \sin\theta \cos\theta \, d\theta \, d\phi \, dr}{4\pi r^2} \int_0^T dt \quad (4)$$

The numbers of α-particles i with an energy $E_{\alpha i}$ emitted in the volume dV which reach and are registered on the LR-115 SSNTD per unit area and unit exposure time is given by:

$$\rho_i^{LR} = A_{\alpha i} \int_0^{2\pi} \int_0^{\grave{\theta}_c} \int_{R_{min}}^{R_{max}} \frac{r^2 \sin\theta \cos\theta \, dr \, d\theta \, d\phi}{4\pi r^2} \quad (5)$$

$$\rho_i^{LR} = \frac{1}{4} A_{\alpha i} \sin^2 \grave{\theta}_c \left[R_{max} - R_{min}\right]$$

$$\rho_i^{LR} = \frac{1}{4} A_{\alpha i} \sin^2 \grave{\theta}_c \, \Delta R \quad (6)$$

Assuming a secular equilibrium between radon and their corresponding daughters, the density of tracks, due to the α-particles of the radon group, registered on the LR-115 SSNTD is given by:

$$\rho_T^{LR} = \frac{1}{4} \Delta R \, sin^2 \grave{\theta}_{ci} \sum_{i=1}^{3} \mathrm{A_{ci}} \, B_i \quad (7)$$

Where B_i is the branching ratio, $\grave{\theta}_c$ it the crtical angle of eaching for LR-115 type II.

Similarly the density of tracks, due to the α-particles of the thoron group, registered on the LR-115 SSNTD is

$$\rho_T^{LR} = \frac{1}{4} \Delta R \, sin^2 \grave{\theta}_{ci} \sum_{i=1}^{4} \mathrm{A_{ci}} \, B_i \quad (8)$$

The global density of tracks, due to the α-particles of the radon and thoron groups registered on the LR-115 type II SSNTD is then equal to

$$\rho_G^{LR} = \rho_T^{LR}(^{222}Rn) + \rho_T^{LR}(^{220}Rn)$$

$$\rho_G^{LR} = \frac{1}{4} \Delta R \, sin^2 \grave{\theta}_{ci} \left(\sum_{i=1}^{3} \mathrm{A_{ci}} \, B_i + \sum_{i=1}^{4} \mathrm{A_{ci}} \, B_i\right) \quad (9)$$

The numbers of α-particles i with an energy $E_{\alpha i}$ emitted in the volume dV which reach and are registered on the CR-39 SSNTD per unit area and unit exposure time are respectively given by

$$\rho_i^{CR} = A_{\alpha i} \int_0^{2\pi} \int_0^{\theta_{ci}} \int_0^{R_i} \frac{r^2 \sin\theta \cos\theta \, dr \, d\theta \, d\phi}{4\pi r^2} \quad (10)$$

$$\rho_i^{CR} = \frac{1}{4} A_{\alpha i} R_i \sin^2 \theta_{ci} \quad (11)$$

Assuming a secular equilibrium between radon and their corresponding daughters, the density of tracks, due to the α-particles of the radon group, registered on the CR-39 SSNTD is given by

$$\rho_T^{CR} = \frac{1}{4} \sum_{i=1}^{3} A_{\alpha i} R_i B_i \sin^2 \theta_{ci} \quad (12)$$

Similarly the density of tracks, due to the α-particles of the thoron group, registered on the LR-115 SSNTD is

$$\rho_T^{CR} = \frac{1}{4} \sum_{i=1}^{4} A_{\alpha i} R_i B_i \sin^2 \theta_{ci} \quad (13)$$

The global density of tracks, due to the α-particles of the radon and thoron groups registered on the LR-115 type II SSNTD is then equal to

$$\rho_G^{CR} = \rho_T^{CR}(^{222}Rn) + \rho_T^{CR}(^{220}Rn)$$

$$\rho_G^{CR} = \frac{1}{4} \sum_{i=1}^{3} A_{\alpha i} R_i B_i \sin^2\theta_{ci} + \frac{1}{4} \sum_{i=1}^{4} A_{\alpha i} R_i B_i \sin^2\theta_{ci} \quad (14)$$

The activities of a *i-th* nucleus A_{ci} and its *(i + 1)th* daughter $A_c(i+1)$ of the radon and thoron series are related by (Planinic et al., 1997)

$$A_c(i+1) = M(i+1) A_c(i) \quad (15)$$

Where:

$$M(i+1) = \frac{\lambda(i+1)}{\lambda(i+1) + f(i+1) D_a + (1 - f(i+1)) D_u + V} \quad (16)$$

Where $\lambda(i+1)$(S^{-1}) is the disintegration constant of the $(i+1)$th daughter. Using the following commonly (assumed) parameter values: $f(i+1)$ is the ratio of the concentration of the $(i+1)$th daughter attached on aerosols to the total concentration of the attached and unattached radon or thoron daughters, f_1=0.9, f_2=f_3=1 , D_a=7.5×$10^{-5}$$s^{-1}$ (=0.27 h^{-1}) is the deposition rate of the attached radon and thoron decay products, D_u = 8.33× 10^{-3} s^{-1} (=30 h^{-1}) (Planinic et al., 1997) is the deposition rate of the unattached radon and thoron decay products, and V(h^{-1}) is the ventilation inside a room which is measured by using a CO_2 tracer gas method. Values of the *f(i+1)*, λ(i+1) and M(i+1), parameters for radon and thoron progenies are given in Table 1.

The ventilation rate were varied in ranges 0.2 - 2.1 h^{-1} (D. Nikezic and K.N. Yu, 2010), with the following steps: the ventilation rate was varied with steps of 0.1 up to 1 h^{-1} which is normal ventilation rate (Mohd Zubair et al., 2011) or balanced ventilation with heat recovery, to observe the effects of air exchange on the ratio of radon or thoron progenies $M(i+1)$ to the parent nuclide.

Table 1: Values of the *λ (i+1)*, *f (i+1)* and *M(i+1)*
(For Different Ventilation Rates) Parameters for Radon and Thoron Decay Products

	Radon Decay Products				Thoron Decay Products			
	^{218}Po	^{214}Pb	^{214}Bi	^{214}Po	^{216}Po	^{212}Pb	^{212}Bi	^{212}Po
$\lambda(i+1)$ (s^{-1})	3.8×10^{-3}	4.3×10^{-4}	5.86×10^{-4}	4200	4.4	1.8×10^{-5}	1.9×10^{-4}	1.9×10^{6}
$f(i+1)$	0.9	1.00	1.00	1.00	0.9	1.00	1.00	1.00
$M(i+1)V=1\ h^{-1}$	0.76	0.55	0.62	1.00	1.00	0.05	0.35	1.00
$M(i+1)V=0.9\ h^{-1}$	0.77	0.57	0.64	1.00	1.00	0.05	0.37	1.00
$M(i+1)V=0.8\ h^{-1}$	0.77	0.59	0.66	1.00	1.00	0.06	0.39	1.00
$M(i+1)V=0.7\ h^{-1}$	0.78	0.62	0.69	1.00	1.00	0.06	0.41	1.00
$M(i+1)V=0.6\ h^{-1}$	0.78	0.64	0.71	1.00	1.00	0.07	0.44	1.00
$M(i+1)V=0.5\ h^{-1}$	0.78	0.67	0.73	1.00	1.00	0.08	0.47	1.00
$M(i+1)V=0.4\ h^{-1}$	0.79	0.70	0.76	1.00	1.00	0.09	0.51	1.00
$M(i+1)V=0.3\ h^{-1}$	0.79	0.73	0.79	1.00	1.00	0.10	0.55	1.00
$M(i+1)V=0.2\ h^{-1}$	0.80	0.77	0.82	1.00	1.00	0.12	0.59	1.00
$M(i+1)V=0.1\ h$	0.80	0.81	0.85	1.00	1.00	0.15	0.65	1.00
$M(i+1)V=0.0\ h$	0.81	0.85	0.89	1.00	1.00	0.19	0.72	1.00

The moderate ventilation rate for dwelling is about (0.6 h^{-1}), while dwelling with ventilation rate (<0.3 h^{-1}) is low ventilation rate.

Combining equations (9), (14) and (15), we get :-

Combining equations (9), (14) and (15), we get :-

$$\rho_G^{CR} = \frac{1}{4} A_c\left({}^{222}Rn\right)\Big[\Big(R_1B_1 sin^2\theta_{c1} + M({}^{218}Po)R_2B_2 sin^2\theta_{c2} + M({}^{214}Po)M({}^{214}Bi)M({}^{214}Pb)M({}^{218}Po)\ R_3B_3 sin^2\theta_{c3}\Big) + \frac{A_c({}^{220}Rn)}{A_c\left({}^{222}Rn\right)}\Big(R_1B_1 sin^2\theta_{c1} + M({}^{216}Po)R_2B_2 sin^2\theta_{c2} + M({}^{212}Bi)M({}^{212}Pb)M({}^{216}Po)R_3B_3 sin^2\theta_{c3} + M({}^{212}Po)M({}^{212}Bi)M({}^{212}Pb)M({}^{216}Po)\ R_4B_4 sin^2\theta_{c4}\Big)\Big] \tag{17}$$

$$\rho_G^{LR} = \frac{1}{4}\Delta R\ sin^2\theta'_c\ A_c\left({}^{222}Rn\right)\Big[\Big(B_1 + M({}^{218}Po)B_2 + M({}^{214}Po)M({}^{214}Bi)M({}^{214}Pb)M({}^{218}Po)\ B_3\Big) + \frac{A_c({}^{220}Rn)}{A_c\left({}^{222}Rn\right)}\Big(R_1B_1 + M({}^{216}Po)B_2 + M({}^{212}Bi)M({}^{212}Pb)M({}^{216}Po)B_3 + M({}^{212}Po)M({}^{212}Bi)M({}^{212}Pb)M({}^{216}Po)\ B_4\Big)\Big] \tag{18}$$

By combining Eqs. (17) and (18) we obtain:-

$$\frac{\rho_G^{CR}}{\rho_G^{LR}} = \left[\frac{\begin{pmatrix} R_1B_1\sin^2\theta_{c1} + M(^{218}Po)R_2B_2\sin^2\theta_{c2} \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po) \quad R_3B_3\sin^2\theta_{c3}) \end{pmatrix} + \frac{A_c(^{220}Rn)}{A_c(^{222}Rn)} \begin{pmatrix} (R_1B_1\sin^2\theta_{c1} + M(^{216}Po)R_2B_2\sin^2\theta_{c2} \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)R_3B_3\sin^2\theta_{c3} \\ M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po) \quad R_4B_4\sin^2\theta_{c4} \end{pmatrix}}{\Delta R\sin^2\theta'_c \begin{pmatrix} \begin{pmatrix} B_1 + M(^{218}Po)B_2 \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po) \quad B_3 \end{pmatrix} \\ + \frac{A_c(^{220}Rn)}{A_c(^{222}Rn)} \begin{pmatrix} B_1 + M(^{216}Po)B_2 \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)B_3 \\ M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po) \quad B_4 \end{pmatrix} \end{pmatrix}} \right] \tag{19}$$

Measuring ρ_G^{CR} and ρ_G^{LR} track density one can evaluate the $A_c(^{220}Rn)/A_c(^{222}Rn)$ ratio [Eq. (20)] and consequently the $A_c(^{222}Rn)$ and $A_c(^{220}Rn)$ alpha-activities [Eq. (17)] as well as the activities of the radon [$A_c(^{218}Po)$, $A_c(^{214}Pb)$, $A_c(^{214}Bi)$, $A_c(^{214}Po)$] and thoron [($A_c(^{216}Po)$, $A_c(^{212}Pb)$, $Ac(^{212}Bi)$, $A_c(^{212}Po)$] decay products [Eqs. (15)] in a given room.

$$\frac{A_c(^{220}Rn)}{A_c(^{222}Rn)} = \frac{\left[\frac{\rho_G^{CR}}{\rho_G^{LR}} \Delta R\sin^2\theta'_c \begin{pmatrix} B_1 + M(^{218}Po)B_2 \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po) \quad B_3 \end{pmatrix} - \begin{pmatrix} R_1B_1\sin^2\theta_{c1} + M(^{218}Po)R_2B_2\sin^2\theta_{c2} \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po) \quad R_3B_3\sin^2\theta_{c3}) \end{pmatrix} \right]}{\left[\begin{pmatrix} (R_1B_1\sin^2\theta_{c1} + M(^{216}Po)R_2B_2\sin^2\theta_{c2} \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)R_3B_3\sin^2\theta_{c3} \\ M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po) \quad R_4B_4\sin^2\theta_{c4} \end{pmatrix} - \frac{\rho_G^{CR}}{\rho_G^{LR}} \Delta R\sin^2\theta'_c \begin{pmatrix} B_1 + M(^{216}Po)B_2 \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)B_3 \\ M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po) \quad B_4 \end{pmatrix} \right]} \tag{20}$$

RESULTS AND DISCUSSION

Table two contains concentrations of radon gas, which has been measured according to our method (^{222}Rn) and in method ($^{222}Rn^*$) described in details in our previous work (Al- khalifa and Abood, 2014).

Alpha- and beta-activities per unit volume due to radon, thoron and their decay products have been measured inside various dwelling rooms in Basrah Governorate-Iraq. Data obtained are shown in Tables 2 and 3. For the present study where the observation were taken from October to December, 2013. The significant value of radon activity varies from 42 $Bq.m^{-3}$ to 178 $Bq.m^{-3}$ with an average value of 107 $B.qm^{-3}$ with standard deviation 38 $B.qm^{-3}$. The significant value of thoron activity varies from 2 $Bq.m^{-3}$ to 15 $B.qm^{-3}$ with an average value of 9 Bqm^{-3} with standard deviation 3 $B.qm^{-3}$.

We notice that alpha- and beta-activities due to the radon and its progeny are higher than those due to thoron and its daughters for the dwelling rooms studied. This is due to the fact that radon has a higher half-life (3.825 d) than thoron (55.6 s). Beta activities coming from the decay of ^{214}Bi and ^{214}Po in radon decay series. Evidence indicates that the equivalent radiation dose from thoron (^{220}Rn) and its progeny is about 5%-30% of that due to ^{222}Rn and its progeny (R. Sivakumar, 2010).

Results show higher indoor radon levels and radon effective does especially in kitchen as compared to other locations. High values of radon activity may be due to use of water and cooking gas in kitchen. Gas, whether natural or from oil, comes from ground and contain so many radioactive elements. Radon concentration was found to be lowest in bed room. High values of radon activity in other rooms in some dwellings may be due to ventilation conditions or the type of building materials. For dwelling consist from two floors, radon and thoron activity concentration in the ground floor is much higher than the first floor and must be mainly due to radon and thoron exhalation from soil under the dwellings.

The action level for radon activity should be in the range 200-300 Bq.m^{-3} (ICRP, 2009). The measured values are below the recommended ICRP action levels.

Table 2: Indoor Radon and Thoron Concentration

No.	Room	ρ_G^{LR} (T.cm^{-2}.d^{-1})	ρ_G^{LR} (T.cm^{-2}.d^{-1})	^{222}Rn (Bq.m^{-3})	^{220}Tn (Bq.m^{-3})	^{222}Rn* (Bq.m^{-3})
1	kitchen	11.25	35.08	165	10	167
1	Reception room	9.07	28.31	132	9	134
1	Bed room	10.77	33.61	157	10	159
1	First floor	6.17	19.29	89	8	91
2	kitchen	12.27	38.31	178	14	182
2	Reception room	11.88	37.12	172	14	176
2	Bed room	11.97	37.34	175	12	177
3	kitchen	8.05	25.11	118	8	119
3	Reception room	5.24	16.5	71	11	78
3	Bed room	7.39	23.12	105	10	109
4	kitchen	7.62	23.95	105	14	113
4	Reception room	12.39	38.73	178	15	183
4	Bed room	9.53	29.79	137	12	141
5	kitchen	8.68	27.15	124	12	128
5	Reception room	8.72	27.3	124	12	129
5	Bed room	7.34	22.93	106	8	109
5	First floor	5.14	16.08	73	7	76
6	kitchen	11.10	34.57	164	9	164
6	Reception room	11.10	34.62	162	10	164
6	Bed room	6.47	20.09	98	2	96
6	Fist floor	5.55	17.31	81	5	82
7	kitchen	5.89	18.41	85	7	87
7	Reception room	4.97	15.47	73	4	73
7	Bed room	5.79	18.15	82	8	86
8	kitchen	8.32	25.98	121	8	123
8	Reception room	6.02	18.89	85	9	89
8	Bed room	5.55	17.52	73	14	82
8	First floor	4.40	13.81	61	8	65
9	kitchen	6.14	19.06	93	3	91
9	Reception room	5.48	17.12	79	7	81
9	Bed room	5.97	18.69	85	8	88
10	kitchen	9.36	29.28	133	12	138
10	Reception room	5.79	18.16	81	9	86
10	Bed room	5.29	16.56	76	7	78
11	kitchen	7.10	22.16	104	7	105
11	Reception room	4.97	15.55	70	7	73
11	Bed room	4.14	12.91	60	4	61
11	First floor	2.90	9.057	42	3	43
	Average			107	9	110
	Max.			178	15	183
	Min.			42	2	43
	S.D.			38	3	38

Table 3: Radon and Thoron Progenies

No.	Radon Progenies				Thoron Progenies			
	^{218}Po (Bq.m^{-3})	^{214}Pb (Bq.m^{-3})	^{214}Bi (Bq.m^{-3})	^{214}Po (Bq.m^{-3})	^{216}Po (Bq.m^{-3})	^{212}Pb (Bq.m^{-3})	^{212}Bi (Bq.m^{-3})	^{212}Po (Bq.m^{-3})
1	129	84	60	60	10	0.69	0.32	0.32
1	103	67	48	48	9	0.61	0.28	0.28
1	123	80	57	57	10	0.72	0.33	0.33
1	69	45	32	32	8	0.53	0.24	0.24
2	138	90	65	65	14	0.95	0.44	0.44
2	134	87	63	63	14	0.95	0.43	0.43
2	136	89	64	64	12	0.81	0.37	0.37
3	92	60	43	43	8	0.54	0.25	0.25
3	55	36	26	26	11	0.76	0.35	0.35
3	82	53	38	38	10	0.70	0.32	0.32
4	82	53	38	38	14	0.96	0.44	0.44
4	139	90	65	65	15	1.07	0.49	0.49
4	107	69	50	50	12	0.81	0.37	0.37
5	96	63	45	45	12	0.82	0.38	0.38
5	97	63	45	45	12	0.82	0.38	0.38
5	83	54	39	39	8	0.59	0.27	0.27
5	57	37	27	27	7	0.49	0.22	0.22
6	128	83	60	60	9	0.60	0.27	0.27
6	127	82	59	59	10	0.72	0.33	0.33
6	77	50	36	36	2	0.15	0.07	0.07
6	63	41	30	30	5	0.37	0.17	0.17
7	66	43	31	31	7	0.46	0.21	0.21
7	57	37	27	27	4	0.27	0.13	0.13
7	64	42	30	30	8	0.59	0.27	0.27
8	95	62	44	44	8	0.58	0.26	0.26
8	66	43	31	31	9	0.66	0.30	0.30
8	57	37	27	27	14	0.95	0.44	0.44
8	48	31	22	22	8	0.53	0.25	0.25
9	72	47	34	34	3	0.19	0.09	0.09
9	61	40	29	29	7	0.47	0.21	0.21
9	66	43	31	31	8	0.57	0.26	0.26
10	104	68	49	49	12	0.87	0.40	0.40
10	63	41	30	30	9	0.64	0.29	0.29
10	59	38	28	28	7	0.48	0.22	0.22
11	81	53	38	38	7	0.48	0.22	0.22
11	55	36	26	26	7	0.50	0.23	0.23
11	47	31	22	22	4	0.29	0.13	0.13
11	33	21	15	15	3	0.20	0.09	0.09

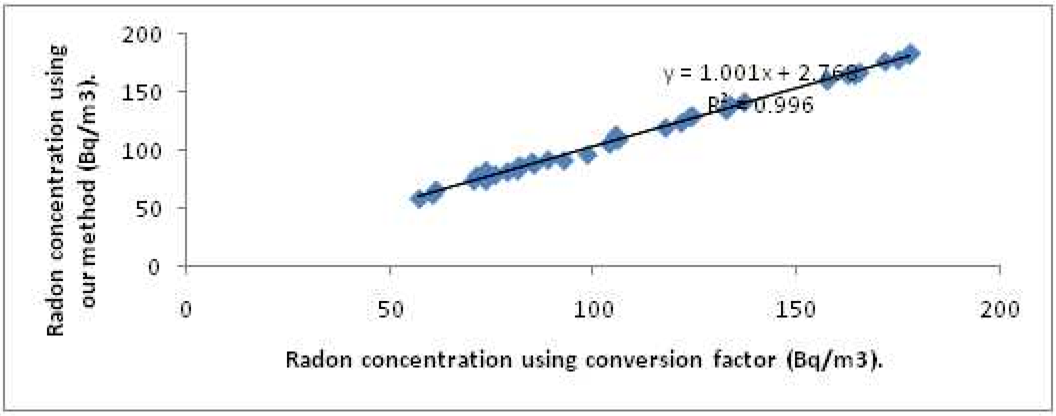

Figure 2: Correlation between the Radon Gas Measurements by the Two Method

CONCLUSIONS

From figure two, we notice a good correlation between indoor radon gas concentration obtained by our method and method described in details in our previous work (Al- khalifa and Abood, 2014). In this new approach one can measure the activities of radon, thoron and there progenies (^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po, ^{216}Po, ^{212}Pb, ^{212}Bi and ^{212}Po). Using CR-39 and LR-115 type II SSNTDs one can evaluate the concentration of radon, thoron and their corresponding decay products in various dwellings without needing calibration factors. From the present work it has been concluded that the radon levels in running dwelling are found to be lower than the action levels recommended by (ICRP, 2009).

REFERENCES

1. A.F. Hafez and M.A. Naim. Plastic nuclear track detection methods for estimation of thorium to uranium ratio in thick natural materials. Nuclear Instruments and Methods in Physics Research B69 (1992) 373-381.

2. BEIR-VI Committee on health risks of exposure to radon-National Research Council (1999) Health effects of exposure to radon; National Academy Press, Washington DC.

3. D. Nikezic and K.N. Yu (2010), Long-term determination of airborne concentrations of unattached and attached radon progeny using stacked LR 115 detector with multi-step etching, Nuclear Instruments and Methods in Physics Research A 613 245–250.

4. ICRP, International Commission on Radiological Protection (1993). protection against radon-222 at home and at work, ICRP publication 65, Ann. ICRP 23(2).

5. Isa Jasem al-klifa & Hussam Najem Abood (2014), Indoor radon levels and the associated effective dose rate determination at the shatt-alarab distract in the Basrah Governorate- iraq, International Journal of Research in Applied Natural and Social Sciences, Vol. 2, Issue 3, 117-122.

6. K. Vinay Kumar Reddy, M. Sreenath Reddy, Ch. Gopal Reddy, P. Yadagiri Reddy, K. Rama Reddy. Spatial and vertical distribution of radon and thoron in a typical Indian dwelling. J. Radioanal Nucl Chem (2012) 292:1089–1092.

7. M. A. Misdaq and A. Chaouqi, ^{222}Rn and ^{220}Rn concentrations measured in bottled sweet drinks and their residual gases and resulting radiation doses to the consumers, American Journal of Environmental Protection, 2013; 2(3):

95-102

8. M. Amrane, L. Oufni, B. Manaut, S.Taj. Measurements of ^{222}Rn, ^{220}Rn and Their Decay Products in the Environmental Air of the Errachidia Area (Morocco) Using SSNTDs, Energy and Environmental Engineering 1(2):62-67, 2013.
9. Mohd Zubair , M Shakir Khan, Deepak Verma, ssessment of indoor radon, thoron and their decay products in the surrounding areas of Firozabad, Uttar Pradesh, India Archives of Applied Science Research, 2011, 3 (1):77-82.
10. Planinic, J., Radolic’, V., Faj, Z., Suveljak, B.(1997). Radon equilibrium factor and aerosols. Nucl. Instrum. Methods A 396, 414–417.
11. R. Sivakumar (2010), A study on radon and thoron progeny levels in dwellings in South India, Iran. J. Radiat. Res.; 8 (3): 149-154.
12. S. A. L GODAYMI and I. J. M AL-KHALIFA. Radon and thoron concentrations mesurements in local produced and imported dry legumes in Iraqi markets using SSNTDs technique, International Journal of Applied and Natural Sciences (IJANS), Vol . 3, Issue 4, July 2014, 67-74.
13. UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation: Sources and Effects of Ionizing Radiation (2000), Vol.1.United Nations, New York.