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Indoor Radon Concentration Measurement in Selected Factories in Northern and Central Iraq

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Abstract

In this work, the outdoor radon concentration level and lung cancer risks have been measured in selected locations in northern and central Iraq during the summer season 2012 by using time integrated passive radon dosimeters containing LR-115 Type II plastic track detectors. These measurements were carried out in the factories for an exposure time of 60 day. The radon concentration in these factories ranges from (36.36 – 125.10) $Bq.m^{-3}$ with an average of (59.93$Bq.m^{-3}$), which within the acceptable radon levels (50-150) $Bq.m^{-3}$ recommended by the International Commission on Radiological Protection (ICRP). The average absorption effective dose equivalent for a person living in factories for which the investigation were done was found to be (1.425$mSv.y^{-1}$). It is observed that the average lung cancer per year per 10^6 person was found to be 25.654.

Keyword: LR-115 Type II nuclear track detectors; Radon concentration; AEDE; PAEC.

1. Introduction

The radon isotopes are produced from the decay of the natural radio nuclides (^{235}U), (^{232}Th) and (^{238}Rn) mainly because of their short half-life are not as important as (^{222}Rn). (^{222}Rn) can be considered to be of the most dangerous radioactive elements in the environment. Its character as a noble gas allows it to spread through the atmosphere [1].

The main natural sources of indoor are soil, building materials (sand, rocks, cement, etc), water born transport, natural energy sources like (gas, coal, etc) which contains traces of(^{238}U) [1, 2]. The indoor radon consecration depends mainly on radon exhalation from surrounding materials. (^{222}Rn) and is 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 the radon and its daughters are concentrated in enclosed area and in particular in dwelling. Several reports have appeared in literature demonstrating that residential radon 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 gas been reviewed and summarized by the UNSCEAR, data available for over 20 European countries and these show that average radon 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 radon levels within the country is enormous, and individual dwellings with radon gas concentrations above (10000 $Bq.m^{-3}$) have been found in Finland, Norway, Sweden, Belgium, Germany, Switzerland, the united kingdom, the Czech republic and Spain [4, 5].

Measurement of indoor radon is rather important because the radiation dose to human constitutes more than 60% of the total dose, including that from the natural sources [6]. Several techniques have been used to measure radon and

is daughters concentration. Solid state unclear 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 [7-12].

The present study aims to measure some important parameters such as the outdoor radon (^{222}Rn) concentration in selected factories, the potential alpha energy concentration, the absorption effective dose exposure and the lung cancer cases per year per 10^6 person. These evaluations can help in stabling a reference level of activity concentrations from which any further increase in those levels for any reason could be detected.

2. Experimental procedure

This study assesses the indoor radon concentration in selected factories in northern and central Iraq. LR-115 Type II nuclear track detector sheets of active layer 12 μm thick were used. These sheets were cut into small pieces of $1.5 \times 1.5 cm^2$ area each. The sheets were stored under normal laboratory conditions, and then suspended in ceilings for two months in places under study (exposed in Bare mode). The track density so obtained was converted into the units of Bq m^{-3} of radon concentration using the calibration factor determined by Subba Ramu *et al.* (1988) and assuming an equilibrium factor of 0.4 between radon progeny and radon [13], the detectors were collected and chemically etched using solution of 2.5 N of NaOH at temperature of (60 ^oC) for 2 hours. After etching, the detectors were rinsed in distilled water and cleaned. An optical microscope with a magnification of 400X was used to count the number of tracks per cm^2 in each detector.

Figure 1 shows the calibrations curve for radon standard samples and track density. Radon concentration in the samples was measured by comparing between track density registered on the detectors and that of the standard derived from equation 1 [14]. LR-115 detectors were positioned in direct contact with the outdoor air at several specific locations in Iraq for 60 days as shown in (Figure 2). During exposure, alpha particles emitted by radon, thoron and their progenies bombarded the detectors.

$$C_x = \rho_x . (C_s/\rho_s) \quad (1)$$

Where ρ_x and ρ_s are the induced fission track densities for unknown sample and standard solution (in tracks/mm^2) respectively, while C_x and C_s denote the uranium concentration for unknown sample and standard solution (in μg/l) [15].

The following parameters were deduced from technique:

1- The Potential Alpha Energy Concentration (PAEC) in Working Level (WL) of radon daughters is estimated using the following equation [1, 16].

$$C_d = F\, C_{Rn}/3700 \quad (2).$$

Where F is the equilibrium factor and equal to 0.4 and C_{Rn} is the activity concentration of radon in Bq.m^{-3}.

2- The Absorption Effective Dose Equivalent (AEDE) is estimated by using the dose conversion factor 5.5 mSv/WLM [1, 17].

$$AEDE\ (mSv.y^{-1}) = (5.5 mSv/WLM) \times (WLM/y) \quad (3)$$

3- The lung cancer per year/10^6 person is estimated by using the risk factor lung cancer induction 18×10^{-6} mSv^{-1} [1, 17].

$$\text{Lung cancer per year par } 10^6 \text{ person} = AEDE\ (mSv.y^{-1}) \times 18 \times 10^{-6}\ (mSv^{-1}) \quad (4)$$

3. Results and discussions

The results of the radon concentration in air samples of factories were given in Table (1) and it was observed that they varied from 36.36 Bq/m^3 in North Fertilizer Plant factory to 125.10 Bq/m^3 in Phosphate factory, the result shows that the average radon concentration in samples from the phosphate factories (highest) is a factor of 2.59 higher than that from the ceramic factory (lowest), similarly the average radon concentration in samples from the MST (Ministry of Science and Technology) is a factor of 2.24 higher than the average radon concentration in samples from the ceramic factory, and the average radon concentrations in samples from the glasses, ceramic, detergent chemicals, North Oil, Mishraq Sulphur , and North Fertilizer Plant factories are similar to each other.

This illustrates that the phosphate factories and MST had radon levels higher than other factories in this study, but it is acceptable because it lies within the radon levels recommended by the international commission on radiological protection (ICRP), and the average radon concentration for all factories (except phosphate) also within the acceptable radon levels (50 - 150) Bq/m^3 recommended by the international commission on radiological protection (ICRP) [18].

Table (2) is summarized the value of radon concentration C_{Rn} (Bq/m^3), the potential alpha energy concentration PAEC (WL), the absorption effective dose exposure AEDE (mSv.y-^{1}) and the lung cancer per year per 10^6 person. The values of radon concentration for all locations ranged from (36.31 to 125.10) Bq/m^3 with the average value of 59.93 Bq/m^3, the highest value of potential alpha concentration (PAEC) levels in the phosphate factory 13.5 mWL with average value of 12.2 mWL, likewise MST had an average value of potential alpha concentration (PAEC) levels of more than 10 mWL. While most of the factories had average value of potential alpha concentration (PAEC) levels less than 5 mWL, the lowest value 3.9 mWL and average value of 6.5 mWL was evident for all locations. The absorption effective dose exposure equivalent ranged from (0.864 to 2.975) mSv.y^{-1} with an average value of 1.43 mSv.y^{-1}. The report (ICRP) recommended that action levels of radon should be within a range of (3-10 mSvy^{-1}) [19, 12]. According to this study, the radon induced lung cancer risk ranged from (15.56 to 53.56) per million persons, with an average of about 25.65 per million persons, the phosphate factory and MST had similar value of the radon induced lung cancer risk per year at more than 40 per million persons, but all the other factories had ≤ 20 per million persons.

4. Comparison with some other results

Table 3 shows a comparison of average values of the radon concentration in Bq/m^3 for some countries. The results in this study were in agreement with data available in another study for Jordan and less than other findings in Pakistan, India, Spain and north Iraq but greater than findings in Hong Kong, Italy, Japan Canada and south Iraq.

5. Conclusion

The higher radon concentrations in air samples were 125.10 Bq/m^3 from Phosphate factorie, and the minimum concentrations 36.36 Bq/m^3 from North Fertilizer Plant, the average radon concentration in samples from phosphate factories (highest) and MST is a factor of (2.59 and 2.24) higher than from ceramic factory (lowest). These average radon concentrations in samples from all factories except Phosphate factory are close to each other.

The radon induced lung cancer risk was measured ranges from (15.56 to 53.56) per million persons, with an average of about 25.65 per million persons. Therefore the Phosphate factory is the most dangerous than all factories at this study.

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Table 1: Average, maximum and minimum radon concentration in samples (Bq/m^3)

Locations	**No. of Samples**	**Average radon concentration**	**Maximum radon concentration**	**Minimum radon concentration**
Phosphate factory	10	112.69	125.10	97.13
Glasses factory	10	44.67	46.59	42.25
Ceramic factory	10	43.51	46.39	39.93
Detergent Chemicals	4	45.04	49.48	37.52
North Oil	6	47.97	50.44	43.31
Mishraq Sulphur	6	43.68	49.19	38.48
North Fertilizer Plant	10	44.27	50.35	36.36
MST	5	97.53	103.49	91.53

Table 2: summarized the measurement of radon concentration, the potential alpha energy concentration, the absorption effective dose exposure and the lung cancer cases per year per 10^6 person.

Sample Code	C_{Rn} (Bq/m^3)	PAEC (mWL)	AEDE (mSv.y^{-1})	Lung Cancer/10^6 person
Phosphate factory	112.69	12.2	2.68	48.244
Glasses factory	44.67	4.8	1.062	19.124
Ceramic factory	43.51	4.7	1.035	18.627
Detergent Chemicals	45.04	4.9	1.071	19.282
North Oil	47.97	5.2	1.141	20.536
Mishraq Sulphur	43.68	4.7	1.039	18.700
North Fertilizer Plant	44.27	4.8	1.053	18.952
MST	97.53	10.5	2.320	41.753

Table 3: A comparison of radon concentration in air in Bq/m^3 for some countries

Country		C_{Rn} (Bq/m^3)	PAEC (mWL)	AEDE (mSv/y)	Ref.
Iraq		103.98	17.2	2.47	Battawy and Hussein
		13.53 - 51.176	--	--	Al-Gaim *et al.*
Jordan		33.28	--	--	AL-Kofahi *et al.*
		29.3 to 99.7	--	--	Abumurad *et al.*
Hong Kong		48 ±32	5.2 ±5.1	--	Yu *et al.*
Brazil		5 - 200	--	--	Magalhaes *et al.*
Italy		5 - 15	--	0.12	Magalhaes *et al.*
Japan		6.1	--	0.45	Oikawa *et al.*
India	Taj Mahal	213	--	1.3 - 4.4	Kumar *et al.*
	Punjab	84.93 - 128.53	--	1.45 - 2.19	Badhan *et al.*
	Garhwal and Kumaun	11 - 191	--	--	Ramola
	western Haryana	76 - 115.46	--	--	Kansal *et al.*
Spain		above 400	--	--	S ánchez, *et al.*
Canada		41.9	--	--	Chen *et al.*
Iraq		59.93	6.5	1.43	Present study

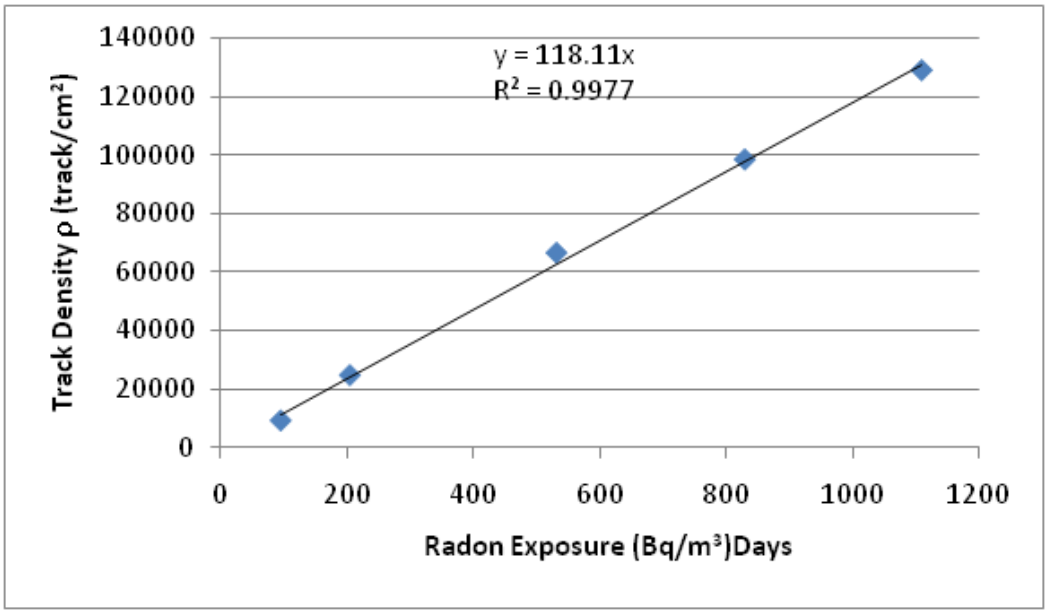

Figure 1: The relation of radon concentration and track density in standard samples.

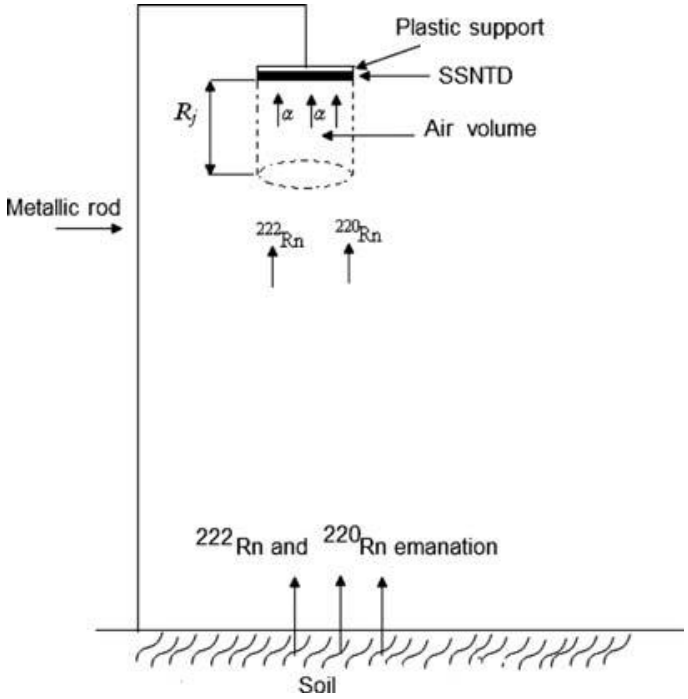

Figure 2: Arrangement of the LR-115 detector of (1.5×1.5) cm^2 placed in the outdoor air. The distance between the detectors and the ground level is 2.5 m.

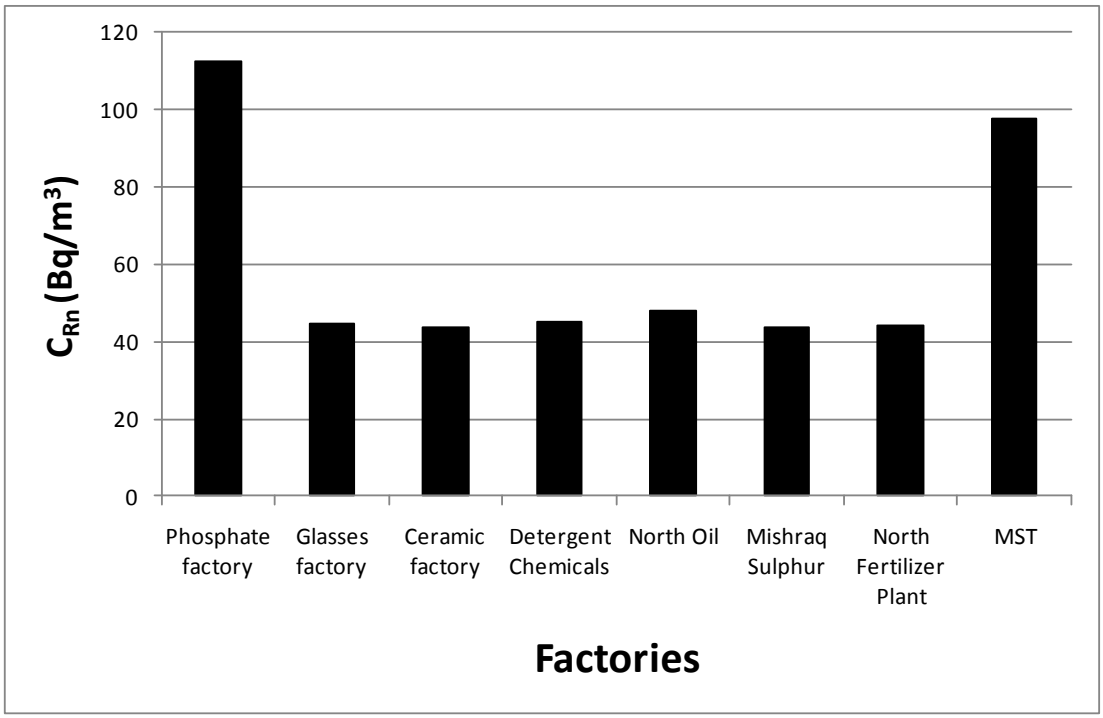

Figure 3: shows the histogram of radon concentration in factories