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Lung dose determined due to inhalation of radon gas from building materials used in Al-Shatra city, Dhi-Qar Governorate, Iraq

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► ***Short report***

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ABSTRACT

Background: Inhaling radon is the most common way that humans are exposed to this radioactive gas. Radon can seep into buildings and homes, where it can accumulate to levels that can be harmful to human health. According to the World Health Organization, radon is the second most common cause of lung cancer. ***Materials and Methods:*** The radon concentrations, effective dosage and lung dose were assessed in construction building materials of sand, cement, and bricks in Al-Shatra City, Dhi-Qar Governorate, Iraq using solid state nuclear track detector CR-39. ***Results:*** The average radon concentrations in sand were 92.766 ± 46.518 Bqm^{-3}, while in bricks was 198.256 ± 87.64 Bqm^{-3} and cement was 69.897±46.903 Bqm^{-3}. According to this study, there was difference in the concentrations of radon, and the largest amount was found in the bricks. An annual effective dose was 2.34 $mSvy^{-1}$, 4.99 $mSvy^{-1}$ and 1.76 $mSvy^{-1}$ for sand, bricks and cement, respectively. On the other hand, the lung dose was determined to be 3.71, 7.92 and 2.795 for sand, bricks and cement respectively. ***Conclusion:*** The concentrations of radon gas in building materials were consistent with recommended by the International Commission on Radiological Protection (ICRP) 200-300 Bqm^{-3} except the bricks materials.

INTRODUCTION

Radiation can be present in building materials due to the natural occurrence of radioactive elements such as uranium, thorium, and potassium in the earth's crust. These elements can be found in soil, rocks, and building materials. Some types of building materials, such as granite countertops and natural stone tiles, have been found to emit high levels of radiation due to their natural composition. Exposure to radiation from building materials can be a concern, especially in buildings where people spend a lot of time, such as homes and workplaces [1, 2]. Due to the presence of uranium (U-238), thorium (Th-232), and their decay products in the minerals, they are classified as radioactive materials stands for Naturally Occurring Radioactive Material 'NORM' [1]. Increased human activities, such as the extraction of oil and gas and burning of coal, produce more radiation than in a normal condition [2]. Radon (^{222}Rn a daughter of ^{238}U) is the most common in NORMs, with ^{222}Rn accounting for over half of the global effective dosage to the people [3]. Radon is one of the most prevalent indoor air pollutants, nonetheless, a lot research on radon exposure have been undertaken since the majority of people are utterly unaware of the danger [4]. Radon is a colorless, odorless radioactive gas produced by the disintegration of naturally existing uranium in the earth's crust [5]. The dosage received from the presence of radon in the air is connected to the inhalation of its short-lived daughters, which are often deposited in the lungs. Radon daughters release alpha particles, which can stick to the bronchial and pulmonary epithelium [6, 7].

Three radon isotopes, in fact actinon (^{219}Rn), thoron (^{220}Rn) and ^{222}Rn are members from ^{235}U, ^{232}Th and ^{238}U, respectively. ^{222}Rn, which has a longer half-life, is 3.82 days and its longest than other isotopes of thoron and actinon are 55.6 and 3.96 seconds, respectively [8]. Natural radioisotopes, primarily radionuclides from the ^{238}U and ^{232}Th decay series are found in various levels in building materials [9, 10]. There are many studies on radon diffusion have been estimation of various building construction materials and effects of grain size on radon diffusion in building materials gravel, cement, sand, etc. [6, 10]. According to these studies, the risk of lung cancer grows linearly with long-term radon exposure, with no indication of a cancer-free threshold with what was recommended by the ICRP 200-300 Bqm^{-3} [11]. Overall, radon is a unique and potentially dangerous substance because of its invisible and odorless nature, as well as its ability to seep into buildings and accumulate to harmful levels without being noticed. As well as, the most important indictor in this studied is the increase of the lung cancer in the Dhi-Qar Governorate based on the reported from hospitals. In this study, the concentration of radon gas has calculated in building materials samples, including sand, bricks and cement, by CR 39 nuclear track detector the current study in this area is recent and has not been discussed before.

MATERIALS AND METHODS

Study area

Dhi-Qar Governorate is one of the southern governorates of Iraq, with 46° 11' 34'' to 46° 8' 42'' E latitude, and 31° 23' 45'' to 31° 26' 16'' N longitude. It is surrounded by five governorates: Qadisiyah and Wasit to the north, Basra to the south, Maysan to the east and Muthana to the west. The governorate is divided into five administrative divisions: Nasiriyah is the center of the governorate, Al Shatra, Suq Al-Shuyoukh, Al-Rifai, and Al-Jabayish (12). Al-Shatra is selected as because of the large number of diseases and congenital malformations that the region witnessed recently, especially after 2003, when it was exposed to military operations, between 1991 and 2003, a study area to collect the samples and measure the radon in building materials.

Collected and prepared samples

A total of 34 samples of sand, bricks and cement were collected from construction materials from different places in Al-Shatra, Dhi-Qar Governorate, Iraq. All samples collected then dried in a thermal oven at 110 °C, after that they were crushed carefully. Ten gram for each sample in a tight tube, with size 10 cm high and 3.5 cm in diameter were stored for two months. CR-39 nuclear track detector (Tasl Company, UK) with thickness of 500 µm was used. The dimensions of detectors are (1.5×1.5) cm^2. After two months all detectors were collected from tube then chemically etched with 6.25 N of NaOH solution at 70 °C for 6 hours. After that, the detectors were cleaned with distilled water (13). The microscope with a magnification of 400X was used to count the tracks.

Calculation

The density of the tracks (ρ_{RN}) for each detector was estimated by equation (1) (12).

$$\rho_{Rn} = \frac{N_{avg}}{A} \quad (1)$$

Where; N_{avg} is represents the mean of the tracks, and A is area of view field visible under the microscope.

The concentrations of radon C_{Rn} (Bqm^{-3}) were calculated using the equation (2) (14).

$$C_{Rn} = \frac{\rho_{Rn} - B_{Rn}}{KT} \quad (2)$$

Where; B_{Rn} is tracks density without sample (background). K is the calibration factor K =0.02607 track.cm^{-2} /Bq.m^{-3}.d (14) and T is exposure time (60 days).

The Annual Effective dose (AED) has been determined using the equation (3) (15).

$$AED = C_{Rn} \times F \times H \times D \times L_f \quad (3)$$

Where; C_{Rn} concentrations of radon (Bqm^3), F is the equilibrium factor and equal to (0.4), H is the occupancy factor which is equal to (0.8), D is the dose conversion factor which is equal to 9×10^{-6}mSv. Bq^{-1}.h^{-1}.m^{-3}, and L_f is the time in hours in one year 8760 h y^{-1} (15).

Finally, the Dose rate to lung was estimated using the equation (4) (3, 15).

$$D_{lug} = 0.04 \times C_{Rn} \quad (4)$$

Statistical analysis

Statistical significance was applied by Pearson correlation for all the analysis of samples indicted as average ± standard deviation of mean value. P<0.001 was considered significant. As well as, the Tukey's honestly significant difference test, Tukey's HSD was used to test difference among the sample.

RESULTS

The results of radon concentrations in 34 samples of sand, brick and cement materials are presented in table 1. The results were ranged from 51.068±21.193 Bqm^{-3} to 118.214±44.981 Bqm^{-3}, with an average of 92.766±46.518 Bqm^{-3} for sand. While, the concentrations of radon in the brick material, it is ranged from 95.51±68.21to 273.31±106.13 Bqm^{-3} with an average of 198.25±87.64 Bqm^{-3}. On the other hand, the concentrations of radon in cement, it is ranged from 34.045±9.63 Bqm^{-3} to 108.75±77.73Bqm^{-3}, with an average of 69.897±46.90 Bqm^{-3}. On the other side, the annual effective dose has ranged from 1.288 to 2.982 msvy^{-1} with an average of 2.34 mSv y^{-1} for sand. While for bricks the annual effective dose is ranged from 2.4 to 6.89msv y^{-1} with an average is 4.99mSv y^{-1}. On the other hand, the annual effective dose of cement was ranged from 0.85to 2.74 mSvy^{-1}, with an average of 1.76 mSv y^{-1}. Moreover, the average dose of lung 3.71msv y^{-1}, 7.92 mSv y^{-1} and 2.795 mSv y^{-1} for sand bricks and cement respectively. From figure 1, the proportion of bricks was 55%, sand 26% and cement 19%. The proportion have been indicted the radon concentration of bricks is highest than the concentrations of sand and cement.

In order to understand the correlation between the samples being studied, statistical analysis was employed, with a significance level of P<0.001. Tukey's HSD test was utilized to investigate

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differences between the samples, as demonstrated in table 2. The Pearson correlation coefficient showed a weak correlation between the concentration of sand, bricks, and cement, with no significant differences observed among the samples. However, based on the results of Tukey's statistical analysis, there was strong significance between sand and bricks, while no significance was found between cement and either sand or bricks. Furthermore, the brick samples exhibited strong significance with both sand and cement. The cement sample showed a strong correlation with brick, but not with sand. Based on these statistical findings, it can be concluded that the brick samples had a significant correlation with other samples due to their composition of sand and cement.

Table 1. Radon concentration, annul effective dose and lung dose for sand, bricks, cement and Statistical descriptive collected from Al-Shatra, Iraq.

Sample	Concentration (Bq.m^{-3})	Annul effective dose (AED) msvy^{-1}	Dose lung (D_{lung}) msvy^{-1}
Sand	51.07 ± 11.19	1.288	2.042
	105.92 ± 23.52	2.672	4.236
	69.98 ± 18.781	1.765	2.799
	118.21 ± 24.98	2.982	4.728
	117.27 ± 25.24	2.958	4.69
	87.95 ± 17.99	2.218	3.518
	108.76 ± 21.29	2.743	4.35
	96.46 ± 21.59	2.433	3.858
	110.65 ± 24.78	2.791	4.425
	77.548 ± 20.81	1.956	3.101
	76.60 ± 19.55	1.932	3.064
Average	92.77 ± 21.52	2.34	3.71
Bricks	256.29 ± 25.77	6.46	10.25
	273.31 ± 22.13	6.89	10.93
	189.14 ± 21.76	4.77	7.56
	193.87 ± 19.61	4.89	7.75
	234.54 ± 25.25	5.91	9.38
	212.79 ± 26.95	5.36	8.51
	212.79± 26.95	5.36	8.51
	166.45 ± 22.44	4.19	6.65
	172.12 ± 19.34	4.34	6.88
	216.57 ±20.8	5.46	8.66
	170.23 ± 16.83	4.29	6.8
	95.51 ± 23.21	2.4	3.82
Average	198.26 ± 27.64	4.99	7.92
Cement	39.72 ± 12.53	1.002	1.588
	58.63 ± 15.56	1.47	2.345
	71.87 ± 18.75	1.81	2.874
	108.75 ± 27.73	2.74	4.35
	88.89 ± 19.59	2.24	3.555
	53.91 ± 12.69	1.35	2.156
	34.05 ± 9.63	0.85	1.361
	73.77 ± 17.03	1.86	2.95
	72.82 ± 27.34	1.83	2.912
	66.2 ± 15.36	1.67	2.648
	100.24 ± 27.78	2.52	4.009
Average	69.98 ±26.90	1.76	2.795

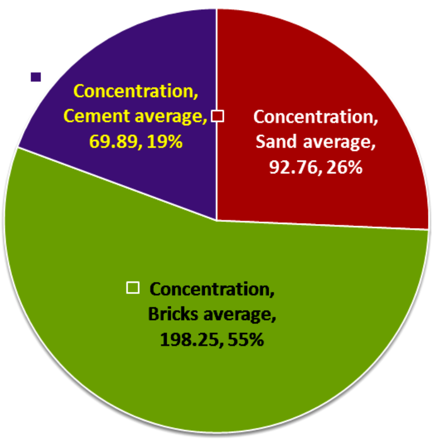

Figure 1. The concentration proportion of sand, bricks and cement.

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Table 2. Statistical significance was applied Pearson Correlation and the Tukey's significant difference test (Tukey's HSD) was used.

Pearson Correlation				
		Concentration 1	Concentration 2	Concentration 3
concentration	Pearson Correlation	1	-0.090	0.325
	Sig. (2-tailed)		0.792	0.329
	N	11	11	11
concentration	Pearson Correlation	-0.090	1	-0.484
	Sig. (2-tailed)	0.792		.131
	N	11	12	11
concentration	Pearson Correlation	0.325	-0.484	1
	Sig. (2-tailed)	0.329	0.131	
	N	11	11	11

Tukey HSD						
(I) concentration of radon	(J) concentration of radon	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
sand	bricks	-106.701545*	13.903255	.000	-140.92008	-72.48301
	cement	22.870000*	14.202284	256	-12.08450	57.82450
bricks	sand	106.701545*	13.903255	.000	72.48301	140.92008
	cement	129.571545*	13.903255	.000	95.35301	163.79008
cement	sand	-22.870000	14.202284	256	-57.82450	12.08450
	bricks	-129.571545*	13.903255	.000	-163.79008	-95.35301

*. The mean difference is significant at the 0.05 level.

DISCUSSION

Almost the samples used in Al-Shatra originated from the quarries south of Zubair, Basra, which was subjected to military operations in the wars of 1991-2003. In addition, brick samples are collected from quarries and at great depths to which radon may leak from the rocks, as well as the region contain large oil reserves that may increase the presence of radon concentration. However, radon concentration is lower than the acceptable limit from ICRP action levels 200–300 Bq.m^{-3} as recommended [11]. Depending on the results, the bricks concentrations have been seen to be higher than other samples. Moreover, the annual effective dosage has been within than recommended 3-10 msvy^{-1} the (ICRP) [11]. The results have been compared with other studied of different countries as seen in table 3.

Table 3. Radon concentrations for sand, bricks and cement were compared with other studies.

Country	Radon concentration Bqm^{-3}			References
	Sand	Bricks	Cement	
Malaysia	-----	192.1±75.4	28.4±5.7	4
Kurdistan, Iraq	480.71±4.52	314.15±5.12	344.21±3.76	17
Benghazi, Libya	----	172±5.8	------	18
U.K	69	106	23	19
Sudan	234± 55	190±50	202± 58	20
Dhi-Qar, Iraq	92.76±46.51	198.25±87.64	69.89±46.90	Present study

The results of Malaysia, United Kingdom and Libya have been lower than the current study, while the concentration of Iraqi Kurdistan is higher than the concentration of radon in building materials. In addition to, the concentration of radon in Sudan is higher concentration of sand and cement than the present study [16-20]. The difference concentration of radon is due to the difference geology of the materials. In general, radon concentrations are within the safety level (ICRP) [11]. Based on these statistical findings, it can be concluded that the brick samples had a significant correlation with other samples due to their composition of sand and cement.

CONCLUSIONS

The radon concentration of brick material is highest of sand and cement. Moreover, the results of radon concentration are slightly below the allowable level recommended by ICRP. On the other hand, the annual effective dose was within the permissible limit, but the lung dose was in some brick samples higher than the permissible level recommended by the ICRP. It can be inferred from the results that prioritizing radon exposure and its associated health risks is necessary to safeguard public health and reduce the occurrence of cancer. The Pearson correlation coefficient showed a weak correlation between the concentration of sand, bricks, and cement, with no significant differences observed among the samples. Based on these statistical findings, it can be concluded that the brick samples had a significant correlation with other samples due to their composition of sand and cement.

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discussion of the presented results.

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