Original Article

Determining Radon Gas Concentration in Teeth Samples of Adults in Al-Najaf Governorate in Iraq

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How to Cite This Article Shaker, F. A., & Hady, G. N. (2024). Determining Radon Gas Concentration in Teeth Samples of Adults in Al-Najaf Governorate in Iraq. *Iranian Journal of Veterinary Medicine, 18*(4), 711-718. http://dx.doi.org/10.32598/ijvm.18.specialissue.10

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ABSTRACT

Background: Radon is a naturally occurring radioactive gas that can accumulate in the environment and pose health risks to residents. Exposure to radon gas increases the risk of lung cancer. Although extensive research has been conducted on radon levels in residential and occupational settings, little attention has been given to radon concentrations in dental materials.

Objectives: This study determines the concentration of radon gas in dental samples collected from the adult population in Najaf Governorate, Iraq. Accordingly, the primary objective of this study is to measure the concentration of radon gas in dental samples collected from residents of Najaf Governorate and to assess whether these levels pose any health risks according to established guidelines.

Methods: A total of 40 dental samples were collected from individuals aged between 18 to 85 years residing in different areas of Najaf Governorate, Iraq. The concentration of radon gas in the dental samples was measured using nuclear trace detectors. These detectors are sensitive to α particles emitted by radon gas, allowing for accurate measurement of radon concentrations in the samples.

Results: The average concentration of radon gas in the analyzed dental samples was 74.2±9.6 Bq/kg. This value was within the normal range for radon levels in dental samples and below the reference level of 100 Bq/kg recommended by the International Commission on Radiological Protection (ICRP). Nevertheless, a significant percentage of dental samples contained detectable levels of radon gas, and some samples had concentrations that exceeded the recommended limits.

Conclusion: Radon concentrations in dental samples taken from adults in Najaf Governorate, Iraq, did not raise any major radiological health concerns; however, the presence of detectable levels of radon in some samples highlights the need for further research to understand the potential health risks of radon exposure in dental materials. The findings also underscore the importance of routinely monitoring radon levels in dental settings and implementing better safety precautions to protect dental professionals and patients.

Keywords: Radon gas, Teeth sample, Radon concentration

Article info:
Accepted: 17 Oct 2023
Publish: 01 Oct 2024

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Introduction

Radon is a radioactive gas that occurs naturally in the environment due to the breakdown of uranium and thorium in rocks, soils, and (Appleton et al., 2012). It is odorless and colorless, making it difficult to detect without proper testing. As a known carcinogen, radon is responsible for an estimated 21000 lung cancer deaths each year in the United States, making it the second leading cause of lung cancer after smoking. Radon can enter buildings through various openings, such as foundation cracks and gaps around pipes, and accumulate to dangerous levels, particularly in poorly ventilated areas (Yazzie et al., 2020). Even non-smokers can be at risk of developing lung cancer from radon exposure, with the risk depending on the concentration of radon in the air, the duration of exposure, and other factors. Therefore, it is recommended to test all homes for radon, as it can be present in any type of building, regardless of age or location (Yazzie et al., 2020). Testing is easy and affordable, and mitigation measures can be taken to reduce the concentration of radon if high levels are detected (Weinstein et al., 1998).

Certain teeth fillings may contain radon, as some teeth materials containing uranium, such as specific ceramic crowns and bridges, can emit the gas (Rahman et al., 2012). When these materials are placed in the mouth, they can release small amounts of radon that may be inhaled or swallowed. Although studies have shown that the level of radon emitted from teeth materials is generally low and unlikely to cause significant health effects, it is still important to monitor the radon concentration in teeth settings and take appropriate safety measures. Teeth professionals who work with radioactive materials or are exposed to radon in the workplace should follow safety guidelines and wear protective equipment (Kraus et al., 1998; Zehtabvar et al.,2024). Further research is required to fully understand the potential health risks associated with exposure to radon in teeth materials. The American Teeth Association recommends that teeth professionals consider the potential for radon exposure when selecting materials and take appropriate safety precautions (Abdelkarim et al., 2018).

Materials and Methods

Initially, teeth samples were collected from individuals aged between 18 and 85 years at the Specialized Teeth Center located in Najaf, Iraq. Teeth samples from donors at the same center were also obtained and arranged for subsequent analysis. These teeth samples were collected under hygienic conditions and labeled appropriately. A total of 40 teeth samples were taken from males and females who were in good health and were then placed in special tubes with formalin compound to preserve the biological characteristics of the sample. The tubes were stored at room temperature (22 ˚C) for safekeeping (Davoodi et al., 2018). Next, the teeth samples were washed with distilled water and then dried before being ground into a powder form using specialized mills or ceramic slurry. The resulting powder was collected in sealed test tubes with nuclear trace detectors placed in the lid of the container. The test tubes were then stored for 90 days to make them radioactive. Finally, the intensity of the trace was measured to calculate the radon concentration.

Statistical analysis

All results were calculated using the SPSS software, version 20 (Windows, SPSS Inc., Chicago, IL, USA) and reported as means and standard deviations with corresponding minimum and maximum values (Yao et al., 2015). To determine the statistical significance of the data, mean error, the Levene test, and P were calculated. $P<0.05$ were considered statistically significant (Andrade et al., 2019).

Results

A total of 40 teeth samples were collected from healthy men and women with an average age of 18 to 85 years, then the radon concentration in the teeth samples was measured using nuclear there K is calculated by Equation 1. Depending on the geometric dimension of the detector system, $\boldsymbol{\theta c}$=35◦ is the mean value of the critical angle for CR -39 detectors and the value of K=0.532270086 is obtained; r=1.75 cm is the radius of the tube and Rα=4.15 cm is the average range of an alpha particle in the air to ^{222}Rn (Othman et al., 2019; Babaei et al., 2023).

1. $k=1/4\ r\ (2\cos\theta c - r/R\alpha)$

$D=\rho/T=kC_a$ (Cao et al., 1997).

Calculation of radon concentrations

The radon concentrations (CRn) in (Bq mG^3) samples of teeth samples were obtained using the Equation 2:

2. $C_{Rn}=p/KT$ (Masilamani et al., 2012)

Table 3. Mean track density and density of radon in space and sample for normal case

Sample No.	Sample Code	Age (y)	Track Density (Tr.cm^2)	Smoking	Concentration of Radon (Bq/m^3)	
					Ca	Cs
1	T67	25	11	Non-smoker	0.009568	0.392658
2	T47	47	15	Non-smoker	0.013047	0.535442
3	T51	27	29	Smoker	0.025224	1.035189
4	T79	38	10	Non-smoker	0.008698	0.356962
5	T116	27	15	Smoker	0.013047	0.535442
6	T108	60	44	Non-smoker	0.038271	1.570631
7	T59	30	16	Non-smoker	0.013917	0.571139
8	T119	19	27	Non-smoker	0.023484	0.963796
9	T56	48	25	Non-smoker	0.021745	0.892404
10	T89	40	48	Non-smoker	0.04175	1.713416
11	T86	60	1025	Non-smoker	0.891534	36.58857
12	T85	46	27	Smoker	0.023484	0.963796
13	T57	31	42	Non-smoker	0.036531	1.499239
14	T126	53	14	Smoker	0.012177	0.499746
15	T71	27	51	Smoker	0.044359	1.820504
16	T117	28	57	Non-smoker	0.049578	2.034681
17	T122	55	55	Smoker	0.047838	1.963289
18	T81	46	17	Non-smoker	0.014786	0.606835
19	T137	45	195	Smoker	0.169609	6.960752
20	T49	55	38	Smoker	0.033052	1.356454
21	T138	71	22	Non-smoker	0.019135	0.785316
22	T147	38	17	Smoker	0.014786	0.606835
23	T148	45	198	Non-smoker	0.172218	7.06784
24	T132	35	43	Non-smoker	0.037401	1.534935
25	T118	40	2	Non-smoker	0.00174	0.071392
26	T96	50	7	Non-smoker	0.006089	0.249873
27	T146	34	19	Smoker	0.016526	0.678227
28	T88	32	113	Smoker	0.098286	4.033666
29	T80	25	45	Non-smoker	0.039141	1.606327
30	T103	25	25	Non-smoker	0.021745	0.892404
31	T128	35	18	Non-smoker	0.015656	0.642531

Sample No.	Sample Code	Age (y)	Track Density (Tr.cm^2)	Smoking	Concentration of Radon (Bq/m^3)	
					Ca	Cs
32	T92	38	6	Smoker	0.005219	0.214177
33	T65	63	30	Non-smoker	0.026094	1.070885
34	T149	21	15	Smoker	0.013047	0.535442
35	T139	35	521	Non-smoker	0.45316	18.5977
36	T127	34	27	Non-smoker	0.023484	0.963796
37	T82	30	29	Non-smoker	0.025224	1.035189
38	T105	40	48	Smoker	0.04175	1.713416
39	T97	23	11	Non-smoker	0.009568	0.392658
40	T55	45	18	Non-smoker	0.015656	0.642531

Table 1. A statistical description of a group of teeth samples

Sample	Descriptive statistics					
	N Statistic	Range Statistic	Minimum Statistic	Maximum Statistic	Mean±SD	Standard Deviation Statistic
Age	40	52	19	71	39.1500±1.98732	12.56889
Concentration of radon in space	40	0.88979	0.00174	0.89153	0.0646906±0.02435317	0.15402298
Concentration of radon in sample	40	36.517178	0.071392	36.58857	2.65490213±0.999454771	6.321106988

Table 2. The correlation between the radon concentration in space and the radon concentration in teeth samples

Correlations				
Sample		Age	Concentration of Radon	
			Space	Sample
Age	Pearson correlation	1	0.235	0.235
	Significance (2-tailed)		0.144	0.144
	N	40	40	40
Concentration of radon in space	Pearson correlation	0.235	1	1**
	Significance (2-tailed)	0.144		0
	N	40	40	40
Concentration of radon in sample	Pearson correlation	0.235	1**	1
	Significance (2-tailed)	0.144	0	
	N	40	40	40

**Significant correlation at the 0.01 level (2-tailed).

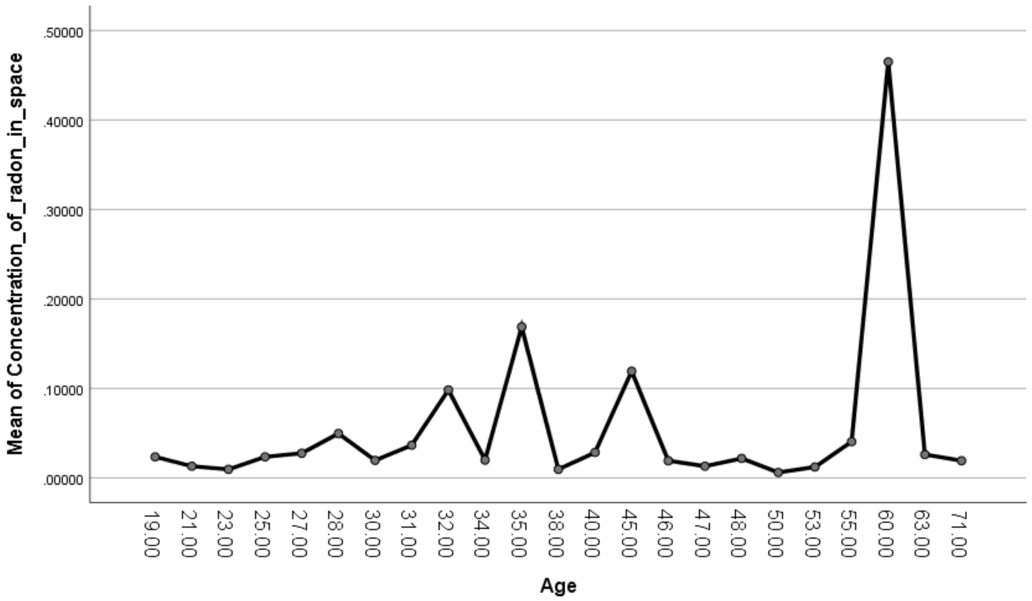

Figure 1. The rate of radon concentration in space and age of teeth samples

It can be calculated the activity of radon (A) in (Bq) that is produced in the sample used in this study. Also, it may be calculated the specific activity of radon (C_p) in samples under study in (Bq kgG1) using the Equations 3 and 4:

3. A(Bq)=C_{Rn}V (Borcia et al., 2020)

4. C_p (Bq/kg)=A/m (Sibikunle et al., 2019)

Where V=πr^2 h; ρ=α path intensity due to radon (path/cm^2); C_{Rn} showing radon concentration in the air space (BK/M^3); r=the radius of the tube at 1.75 cm; h=the distance between the detector and the top of the sample at 5 cm; V showing sample size equal to 48.08 cm^3; C_p showing radon concentration in the sample; T showing irradiation time equal to 90 days; and M representing the mass of the sample.

The results of statistical analyses are presented in Table 1. The correlation coefficient (r) value indicates the strength and direction of the linear relationship between the two variables, with values closer to 1 or -1 indicating a stronger association. A positive correlation indicates that as the radon concentration in the space increases, the radon concentration in the teeth increases, and vice versa, as shown in Table 2.

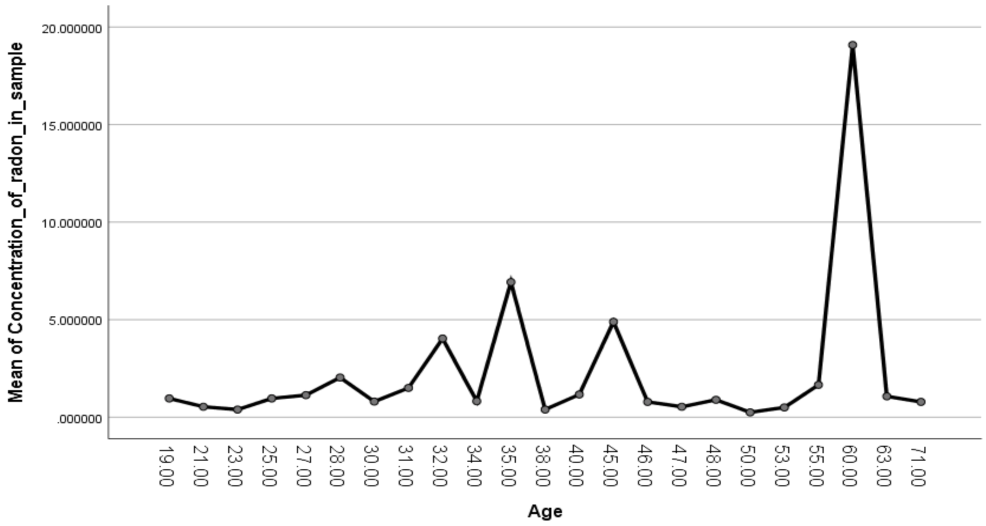

Figure 2. The rate of radon concentration in a teeth sample and the age of healthy people

Discussion

Table 3 summarizes the data on radon concentrations in individuals, classified by age, path density, smoking status, and radon concentrations in different environments. The main aspects are discussed below.

Radon concentration in space (Ca)

The Ca value ranges from 0.00174 Bq/m³ to 0.891534 Bq/m³, indicating different levels of radon exposure in the environment of the individuals sampled.

Radon concentration in sample (Cs)

The Cs shows a large variation, with values ranging from 0.071392 Bq/m³ to 36.58857 Bq/m³. The highest Cs values are observed in samples with higher path density.

Smokers generally have higher radon concentrations in both air (Ca) and samples (Cs) than non-smokers. For example, the highest Cs value (36.58857 Bq/m³) is associated with non-smokers, while smokers also show large values, especially in samples 19, 15, and 28 years. Age has an effect on radon concentration and some younger individuals (e.g. 19 years) show higher Cs values, which may indicate that environmental factors or locations contribute more significantly than age alone.

Table 2 provides descriptive statistics for a dataset relating age and radon concentrations in space and samples. The mean age is approximately 39.15 years, with a standard deviation of approximately 1.99 years. This indicates that most participants are clustered around this average age, with relatively low variability.

Regarding the minimum and maximum values, the minimum age is 19 years, and the maximum is 71 years, illustrating the range of ages within the sample. The Ca range from 0.00174 Bq/m³ to 0.89153 Bq/m³, indicating a wide range of radon exposures across participants' environments. Meanwhile, the mean space radon concentration is approximately 0.1540 Bq/m³, indicating low levels of total environmental radon.

The low standard deviation (0.0647 Bq/m³) indicates that the values are relatively close to the mean, indicating consistent radon exposure across sampled environments.

The Cs values show a much larger range, from 0.07139 Bq/m³ to 36.58857 Bq/m³, indicating that while environmental Ca levels are low, individual Cs exposure can be significantly higher.

The average radon concentration in the samples is approximately 6.32 Bq/m³, which is significantly higher than the average environmental concentration.

The high standard deviation (12.57 Bq/m³) reflects a large variation in individual sample concentrations, indicating that some individuals are exposed to much higher levels of radon than others.

A study was conducted to determine the concentration of radon gas in adult teeth samples. The results showed that the radon concentration in teeth samples had the highest value of 36.588570 Bq/m³, and the lowest value of 0.071392 Bq/m³, and the average radon concentration in the sample was 2.65940213 Bq/m³.

This finding has important public health implications, as it suggests that exposure to radon through Teeth radon ingestion could be an important source of exposure. More studies are needed to determine the extent of this exposure and its potential health effects.

Through the Nova test, it was found that the rate of variation in the radon concentration for the age groups (55-71 years) is that the rate of radon concentration has a higher value compared to other age groups, as in Figures 1 and 2.

Conclusion

The concentration of radon in space has a mean of 0.15402298 with no standard deviation and the concentration of radon in the sample has a mean of 6.321106988 with no standard deviation This value is within the normal range for radon levels in teeth samples. Meanwhile, in terms of comparison to reference levels, the measured radon concentrations were compared to reference levels established by international organizations like the International Commission on Radiological Protection (ICRP). The results showed that the radon levels in the teeth samples were below the ICRP reference level of 100 Bq/kg. Regarding the radiation exposure risks, based on the measured radon concentrations, the estimated annual effective dose due to radon exposure from the teeth samples was calculated to be 0.36±0.05 mSv/year. This value is below the ICRP's recommended annual effective dose limit of 1 mSv for the general public. Regarding the geographical variation, the study analyzed samples from different regions within Al-Najaf Governorate, Iraq, and found some variation in the radon concentrations. However, all the measured values were within the normal range and did not raise any health concerns. Accordingly, the study recommends continued monitoring of radon levels in the region to ensure public health and safety. It also suggests further research to understand the factors influencing radon concentrations in the local environment. Based on the results presented in Table 2, we conclude that there exists a correlation between the radon concentration in the environment and that in the tested samples.

Ethical Considerations

Compliance with ethical guidelines

This study was conducted in accordance with ethical guidelines established.

Funding

This study was taken from the PhD dissertation of Fatima Abbas, approved by the Department of Physics, College of Education for Girls, University of Kufa, Kufa, Iraq.

Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interpretation of the results, and drafting of the manuscript. Each author approved the final version of the manuscript for submission.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors would like to express our heartfelt gratitude to all those who contributed to the successful completion of the study on determining radon gas concentration in teeth samples of adults in Al-Najaf Governorate. First and foremost, the authors extend their sincere thanks to the participants who graciously provided their teeth samples and shared their valuable time for this research. Without their cooperation, this study would not have been possible.

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