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Environmental Radiological Assessment of Radon-222 in Biological Fluids (Blood and Urine) for the Adult Population of Al-Diwaniyah, Iraq Using CR-39 Detectors

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ABSTRACT

This research was conducted to determine radon (Rn-222) concentrations in the blood and urine of 52 adult male and female residents of the area. Using CR-39 in Diwaniyah
Governorate nuclear track detectors, the study revealed that the average radon (Rn-222) concentration in male blood samples was 6.5636 ± 1.0596 Bq/m³, while in urine samples, it was 4.7359 ± 0.8218 Bq/l for female participants, the average radon (Rn-222) concentration in blood was 7.2023 ± 1.1626 Bq/m³, and in urine samples, it was 4.8780 ± 0.8375 Bq/l. These results fall within the permissible limits established by the World Health Organization (WHO).

1. Introduction

Environmental pollution is currently one of the most critical issues threatening human life. The primary driver of this pollution is human activity, specifically the lack of proper environmental planning to mitigate pollutants, which leads to a significant increase in pollution levels beyond natural limits [1]. Among these environmental pollutants are those from natural sources, including radioactive pollutants. These are omnipresent and can be of cosmic origin, such as radiation from the sun resulting from nuclear fusion reactions [2]. Another type of radioactive source is terrestrial. These are found within the Earth's crust—including soil, water, and rocks and consist of terrestrial nuclides represented by natural decay chains, such as the Uranium-238 (U-238) and Uranium-235 (U-235) series. This also includes elements produced by the decay of these radioactive isotopes, such as Radon gas (Rn-222), and other radioactive elements considered among the most harmful pollutants to human health after tobacco smoking [3]. Radiation can be defined as "the emission of energy through a medium in the form of waves or particles" [4]. Radiation is

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classified into two categories: ionizing radiation, which ionizes the medium it passes through, and non-ionizing radiation, which does not. This classification depends on the energy level; if the radiation energy exceeds 10 eV it is considered ionizing. If it is lower, it is non-ionizing, such as radio waves and ultraviolet rays [5,6]. Certain nuclei undergo changes or decays that result in the release of radiation, such as Alpha particles (a), Beta particles (β), or Gamma rays (y). These represent the primary forms of radiation that significantly impact human health [7]. Radon gas (222Rn), found in the Uranium-238 series, is characterized as a chemically inert gas with a half-life of approximately 3.8 days. It is soluble in organic compounds, and its solubility in olive oil at 37°C is 6.25 [8]. Radon is a colorless, tasteless, and odorless gas. It has three naturally occurring isotopes: 1. Radon-222 (Rn-222). 2. Radon-220 (Rn-220), commonly known as Thoron. 3. The third isotope of Radon Actinon- 219 (Rn-219). the third isotope of Radon is Radon-219 (Rn-219), commonly known as Actinon. These isotopes are all radioactive, unstable elements that decay by emitting Alpha particles (α) [9]. Radon-222 (Rn-222) decays by emitting Alpha particles with an energy of approximately 5.49 MeV. This decay process produces what are known as "Radon daughters" (progeny), which include: Polonium-218 (Po-218) Lead-214 (Pb-214) Bismuth-214 (Bi-214) Polonium-214 (Po-214) These progeny are all capable of emitting various types of ionizing radiation, particularly high-energy Alpha particles. The half-lives of these elements are relatively short, ranging from fractions of a second to several minutes [10]. Radon-222 exists naturally in various environments, including water, soil, and certain types of rocks. Its concentrations and levels vary from one location to another; it can diffuse freely in water and air, traveling long distances before decaying [11]. Due to several environmental factors, such as climate fluctuations and industrial proliferation, the concentrations of Radon and other unstable heavy metals are steadily increasing [12]. The alpha particles released during Radon decay can cause significant harm to human health. Because they are heavy and charged, they have a high absorption capacity within the body. Consequently, when they collide with cellular atoms, they cause major disruptions in tissues and organs [13]. Chronic exposure to Radon gas leads to various illnesses, including lung cancer, kidney failure, and respiratory system impairment [14]. Upon inhalation, Alpha particles penetrate cells and soft tissues, causing clear and substantial damage to nucleic acids (DNA). This damage is often permanent and irreversible. The extent of the harm depends on the duration of exposure, the energy of the particles, and the absorbed dose [15,16]. Research focusing on measuring Radon levels across different demographics and regions is of paramount importance for evaluating global Radon concentrations. While many previous studies have calculated Radon concentrations in various groups, most have been limited to a single variable, such as blood or urine. This study seeks to calculate Radon concentrations using two variables simultaneously—blood and urine—to contribute to the global understanding of Radon levels and the extent of its contamination worldwide.

2. Methdology

2.1 Area of study

Al-Diwaniyah Governorate was selected as the focal area for the current study. Located in the south-central part of Iraq, it is bordered by Babylon Governorate to the north and Najaf Al-Ashraf Governorate to the west. Al-Diwaniyah spans an estimated area of 8,153 km² and is home to a population of exceeding 1.5 million people. This demographic and environmental context makes the study of its radiological status an urgent necessity to assess the health risks looming over the population.

2.2 Sample collection

The study involved collecting biological samples, which included 26 blood samples and 26 urine samples from healthy volunteers residing in Al-Diwaniyah Governorate.

Additionally, data regarding each donor's smoking habits were gathered. The samples were selected based on specific criteria and procedures, targeting individuals over the age of 18 to ensure a representative sample of adults of both genders. To achieve a comprehensive radiological survey across the study area, the collection process was geographically distributed to include various and diverse neighborhoods. The blood collection process strictly adhered to the health protocols and mechanisms approved by the Ministry of Health; blood samples were drawn intravenously using sterile syringes and transferred immediately into EDTA tubes to prevent coagulation As shown in figures (1). Meanwhile, Urine samples were preserved in sterile, airtight, cylindrical plastic containers in preparation for laboratory analysis and the estimation of radon concentrations.

2.3 The preparation and measurement samples

After collecting the samples using proper sanitary methods, the blood samples were placed in pieces of glass and dried by keeping them in a closed place at a controlled room temperature for a period ranging from three days to a week to dry naturally. [17]. Once dried to the required degree, they were ground using a manual mill into a fine powder, and then the ground blood was filtered to achieve homogeneity. After that, the samples were weighed at 0.5 grams per blood powder sample, then placed in cylindrical plastic containers with dimensions of 5 cm in height and 3 cm in width. The detector, of type CR-39, known for its high efficiency in detecting emitted alpha particles, was fixed on the lid of the plastic container. Subsequently, the plastic containers were tightly sealed to give them resistance to any external effects, with the detector attached using double-sided adhesive, similarly for urine samples. The urine was placed in plastic containers and the detector was fixed in the same way on top of the containers, and securely closed. As shown in figures (2) The samples were then stored for 90 days to record the effects of alpha particles on these samples. [18]

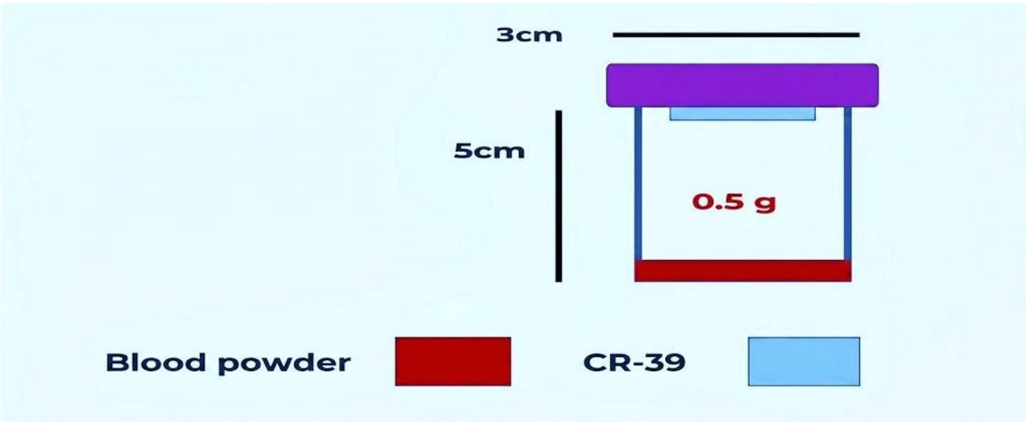

Figure 1. Plastic tubes for measuring radon concentrations in blood using CR-39 detector

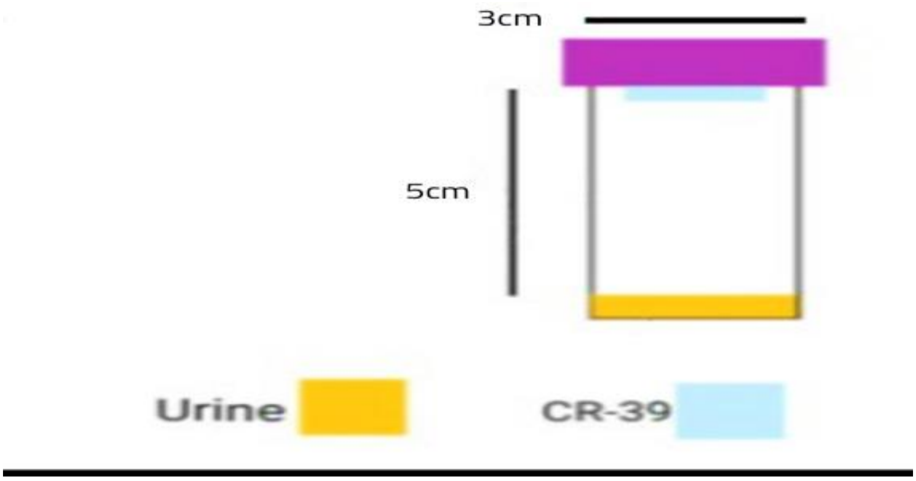

Figure 2. Plastic tubes for measuring radon concentrations in urine using CR-39 detector

2.4 Methodology and Data Analysis

Following the 90-day exposure period, all detectors were collected and transported to the research laboratory. Subsequently, the detectors underwent a chemical etching process using an aqueous solution of sodium hydroxide (NaOH) at a normality of 6.25 N. This process was conducted at a constant temperature of 70°C for a duration of 6 hours [19-21]. The solution acts upon the regions damaged by alpha particles within the detector, revealing the latent nuclear tracks. These tracks were then meticulously examined using an optical microscope at a magnification of 400x [22]. To ensure high precision, the alpha track density was adjusted by subtracting the background radiation track density, thereby enhancing the accuracy of the measured radiation exposure in the samples.

The nuclear track density was calculated using the following equation. [23]:

$\rho = N/A$ …………………. (1)

Where:
ρ: The nuclear track density, measured in units of (Tr/cm^2).
N: The total average of nuclear tracks. (Tr)
A: The area of the field of view. (Cm^2)

The radon gas concentration was then determined using the following formula:

$C_{Rn} = \rho/K.t$ ……………… (2)

Where:
C_{Rn}: The radon concentration. (Bq/m^3)
ρ: The nuclear track density (Tr/cm^2).
t: The exposure duration. (day)
K: The diffusion constant (calibration factor). 0.2917 ± 0.0511 [24.25].

Finally, the statistical error (σ) was calculated using the following equation [26]:

$\sigma = \frac{\sqrt{\Sigma Ni}}{n.A}$ ………………… (3)

Where:
σ: The statistical error coefficient.
$\sum N_1$: The total sum of tracks across all fields of view.
n: The number of fields of view.
A: The area of the field of view

3.**Results and discussion**

3.1 Radon Concentration Analysis in Blood Samples

Radon gas concentrations were analyzed in blood samples from adult males and females, yielding the following results:

Male Participants. Among the male group, the highest radon concentration was recorded in sample B12, measuring 14.6274 ± 2.1061 Bq/m³ (age 25).

Conversely, the lowest concentration was found in sample B5, measuring 1.2192 ± 0.2361 Bq/m³ (age 29). The overall mean concentration for males was 6.5636 ± 1.0596 Bq/m³.

Table 1. Radon gas concentrations in blood samples from males

Code of Sample	**Age (years)**	**Gender**	**Smoking**	**C_{Rn} Bq/m^3**
B1	58	male	NO	6.2471 ± 1.0521
B2	22	male	YES	7.7741 ± 1.2654
B3	19	male	YES	4.1144 ± 0.7311
B4	25	male	YES	2.1331 ± 0.4013
B5	29	male	YES	1.2192 ± 0.2361
B6	30	male	NO	4.4135 ± 0.7783
B7	23	male	YES	3.1993 ± 0.5837
B8	24	male	YES	9.9033 ± 1.5452
B9	26	male	YES	8.3832 ±1.3471
B10	18	male	YES	3.9611 ± 0.7062
B11	27	male	YES	11.2763 ± 1.7161
B12	25	male	YES	14.6274 ± 2.1061
B13	47	male	YES	8.0753 ± 1.3063
Mean ± SD		6.6536 ± 1.0596		
Max		14.6274 ± 2.1061		
Min		1.2192 ± 0.2361		

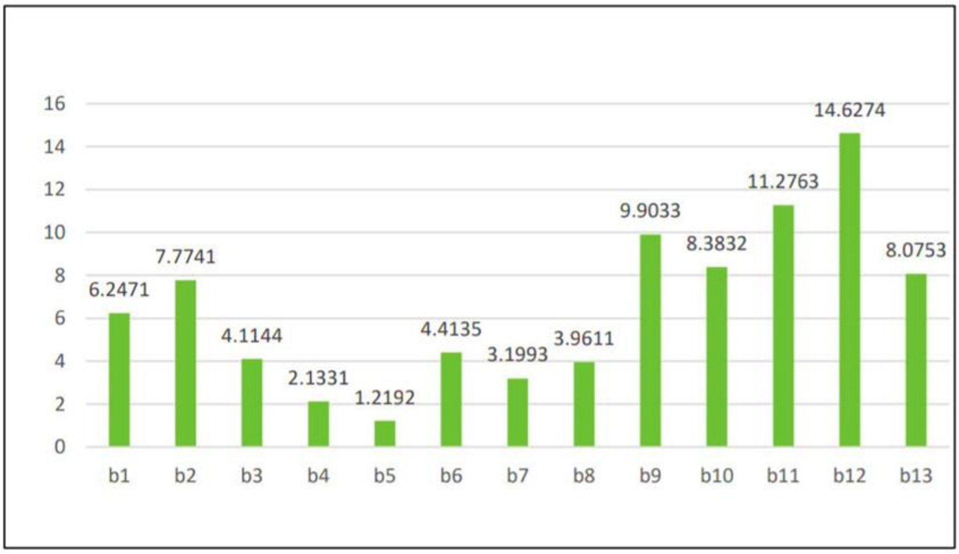

Figure 3. Radon gas concentrations in blood samples from males

Female Participants: For the female group, the highest concentration was observed in sample B1, reaching 11.27512 ± 1.716 Bq/m³ (age 38). The minimum value recorded in the B5 was 0.906 ± 0.122 Bq/m³ (age 35). The calculated mean concentration for females was 7.2023 ± 1.1626 Bq/m³.

Table 2. Radon gas concentrations in blood samples from female

Code of Sample	Age (years)	Gender	Smoking	C_{Rn} Bq/m^3
B1	38	female	NO	11.27512 ± 1.716
B2	60	female	NO	9.29421 ± 1.591
B3	64	female	NO	8.8373 ± 1.4083
B4	27	female	NO	3.9613 ± 0.7061
B5	35	female	NO	0.609 ± 0.122
B6	21	female	NO	7.9233 ± 1.2269
B7	52	female	NO	3.5143 ±0.6324
B8	44	female	NO	10.2084 ± 1.5843
B9	32	female	NO	9.5996 ±1.5062
B10	67	female	NO	5.0282± 0.8721
B11	39	female	NO	8.6841 ±1.3872
B12	34	female	NO	9.5132 ± 1.4065
B13	36	female	NO	5.1812 ± 0.8953
Mean ± SD		7.2023 ± 1.1626		
Max		11.27512 ± 1.716		
Min		0.609 ± 0.122		

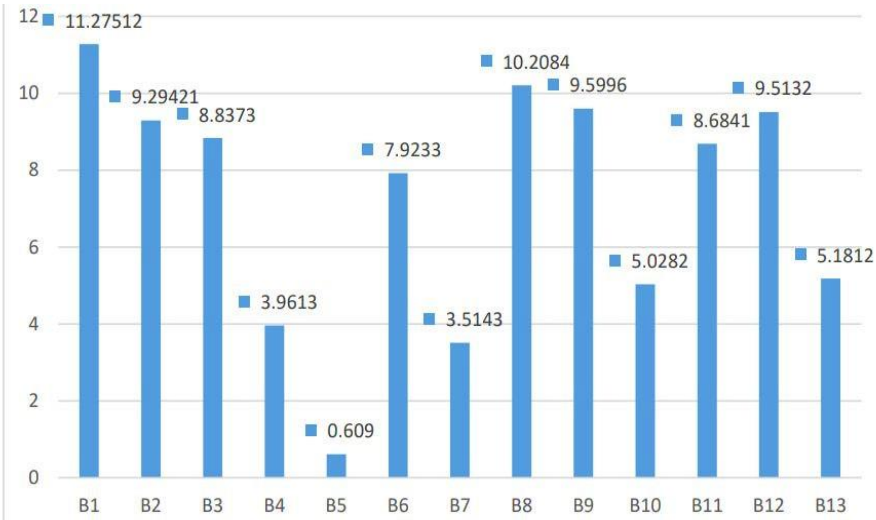

Figure 4. Radon gas concentrations in blood samples from female

3.2 Radon Concentration Analysis in Urine Samples

The analysis of radon gas concentrations in urine samples collected from adult males and females yielded the following data: Male Cohort.In the male group, the maximum radon concentration was recorded in sample U2, measuring 7.3132 ± 1.2024 Bq/L (age 27). The minimum concentration was observed in sample U12, measuring 3.1919 ± 0.5829 Bq/L (age 22). The overall mean concentration for the male participants was calculated at 4.7358 ± 0.8218 Bq/L.

Table 3. Radon gas concentrations in urine samples from males

Code of Sample	Age (years)	Gender	Smoking	C_{Rn} Bq/l
U1	23	male	YES	3.6564 ±0.6571
U2	27	male	YES	7.3132 ±1.2024
U3	58	male	NO	5.7921 ±0.9853
U4	30	male	NO	4.5711 ±0.8028
U5	18	male	YES	3.1995 ±0.5833
U6	24	male	YES	6.5511 ±1.0952
U7	25	male	YES	6.7045 ±1.1171
U8	25	male	YES	5.1871 ±0.8956
U9	29	male	YES	3.6672 ±0.6577
U10	19	male	YES	4.2665 ±0.7544
U11	47	male	YES	4.1148 ±0.7306
U12	22	male	YES	3.1919 ±0.5829
U13	26	male	YES	3.3522 ±0.6191
Mean ± SD		4.7359 ± 0.8218		
Max		7.3132 ±1.2024		
Min		3.1919 ±0.5829		

Figure 5. Radon gas concentrations in urine samples from males

Female Cohort: For the female group, the highest concentration was identified in sample U1, reaching 8.9891 ± 1.4276 Bq/L (age 35). Conversely, the lowest value was found in sample U6, measuring 1.2193 ± 0.2361 Bq/L (age 52). The mean radon concentration for females was determined to be 4.877 ± 0.8375 Bq/L.

Table 4. Radon gas concentrations in urine samples from female

Code of Sample	Age (years)	Gender	Smoking	C_{Rn} Bq/l
U1	35	female	NO	8.9891 ±1.4276
U2	44	female	NO	4.1143 ±0.7302
U3	60	female	NO	4.7238 ±0.8253
U4	32	female	NO	3.5131 ±0.6321
U5	21	female	NO	5.1825 ±0.8953
U6	52	female	NO	1.2193 ±0.2361
U7	27	female	NO	2.4382 ±0.4542
U8	34	female	NO	6.2471 ±1.052
U9	64	female	NO	6.4272 ±1.063
U10	67	female	NO	2.7421 ±0.5061
U11	39	female	NO	7.4663 ±1.2232
U12	36	female	NO	4.7135 ±0.8796
U13	38	female	NO	5.6377 ± 0.6932
Mean ± SD		4.878 ± 0.8375		
Max		8.9891 ±1.4276		
Min		1.2193 ±0.2361		

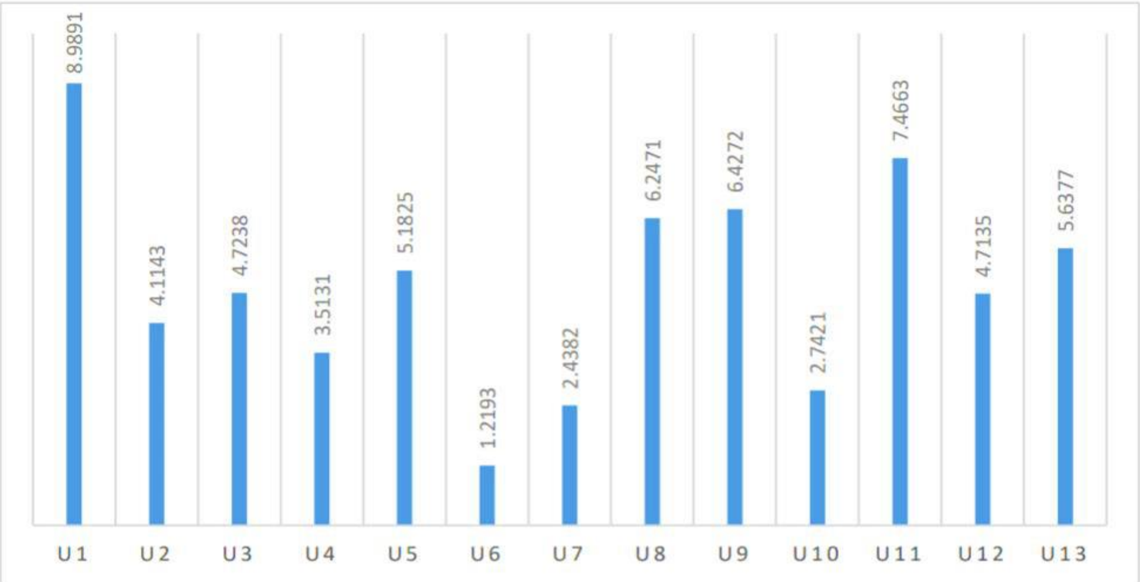

Figure 6. Radon gas concentrations in urine samples from female

4. Conclusions

"Based on the findings of this study, it is concluded that radon gas concentrations in blood and urine samples are all within the permissible limits established by the World Health Organization (WHO), which is 100 Bq/m³. Moreover, the results indicate that radon concentrations in blood samples are significantly higher than those observed in urine."

There was a difference between the radon (Rn-222) levels in the blood and urine of women, with the highest recorded blood level being 11.27512 ± 1.716, while the highest urine level was 8.9891 ± 1.4276. Similarly, the highest blood radon concentration in men was 14.6274 ± 2.1061, and the highest urine concentration was 7.3132 ± 1.2024.

The difference between radon (Rn-222) levels in males and females was significant, with the highest blood concentration in males being 14.6274 ± 2.1061 and the highest urine concentration 7.3132 ± 1.2024. In contrast, the concentrations in females also differed, with the highest blood concentration in females being 11.27512 ± 1.716 and the highest urine concentration in females being 8.9891 ± 1.4276.

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