Measurements of alpha emitters concentration (^{222}Rn, ^{226}Ra and ^{238}U) in blood samples of patients with renal failure of non-smokers in Najaf city, Iraq

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Abstract: The estimation of ^{222}Rn, ^{226}Ra, and ^{238}U concentrations in human blood is very important to assess the radiation exposure. The fission track method is used to detect alpha emitters in the blood of patients with kidney failure in Najaf, Iraq. The study found that uranium concentrations in renal failure blood tests ranged from 1.507 ± 0.24 ppb to 0.104 ± 0.41 ppb in non-smokers, while radon concentrations ranged from 8.763 ± 0.00246 Bq/m^3 to 0.61 ± 0.0606 Bq/m^3, and radium concentrations from 0.353 Bq/m^3 to 0.024 Bq/m^3. In contrast, healthy non-smokers had uranium concentrations between 1.014 ± 0.23 ppb to 0.078 ± 0.36 ppb, radon concentrations between 5.897 ± 0.012 Bq/m^3 to 0.457 ± 0.071 Bq/m^3, and radium concentrations between 0.237 Bq/m^3 to 0.018 Bq/m^3. The study found that individuals with renal failure have higher alpha emitter levels, 1.5 times higher than the healthy group, and these levels increase with age and are higher in women.

Keywords: alpha emitters concentrations; fission track technique; blood samples; renal failure.

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1 Introduction

Environmental radiation is produced by a number of naturally occurring and artificial sources. The primary sources of natural radioactivity that have lasted since the creation of the Earth are nuclides with exceptionally long half-lives, and they come from cosmic rays. Atomic fuel production facilities are the main sources of artificial radiation that harms the environment, military shells with an eternally defended layer that use depleted uranium and spent fuel handling facilities. Likewise, another of the radioactive contamination sources is fleeting nuclides from the creation of radioisotopes for clinical applications. Uranium is a naturally occurring alpha-emanating radionuclide and a poisonous weighty metal, omnipresent in rocks and different other mineral stores (Taylor and Taylor, 1997). The unconstrained change of a core is called radioactivity, and the overabundance energy discharged is a type of radiation. Radionuclides such as radon and uranium enter the human body through the soil, consumption of plants, fish, meat, vegetables, water and air inhalation (IAEA, 2004; Hassan, 2006). Radon is noble gas, has a density of 9.73 kg/m^3 at 0°C (32°F or 273.15 K) at standard atmospheric pressure and atomic number of 86; it is odourless, colourless and tasteless. Radon is the immediate decay product of radium. Its most stable isotope has a half-life of only 3.8 days. The demonstration of change is named 'rot' and the nuclide that changes and transmits radiation is known as a 'radionuclide'. A few weighty cores rot by creating an alpha molecule comprising two protons and two neutrons. Indistinguishable from a core of helium, the alpha molecule is a lot heavier than the beta molecule and conveys two units of positive charge (Al-Hamzawi et al., 2014). Alpha emitters causes a couple of clinical issues running from malignant growth to renal failure, respiratory issues, intrinsic anomalies, skin infections, and other dark obscure sicknesses (Segovia et al., 1986). Hashim et al. (2015) used the CR-39 detector to assess the radon concentration in different brands of tobacco cigarettes that is consumed from Iraqi markets and their study reveals that the elevated radon content of sporulation cigarettes (Graven, Royal, Gitanes, Bon, and Master) presents a serious health danger to individuals, potentially increasing the risk of lung cancer and thus raising the possibility of radon-related fatalities.

It is impossible to precisely examine or monitor how uranium behaves after it enters the essential tissues and dispersion structure of the human body. In this context, models are used to address the augmentation of material surrounding the body. These models can be used to process radiation portions to tissues and predict component maintenance and discharge (WHO, 2001).

The purpose of this study is to use a nuclear track detector (CR-39) to measure the levels of the alpha emitters ^{222}Rn, ^{226}Ra and ^{238}U in blood samples taken from some volunteers. It also aims to investigate the associations between elevated levels of these molecules and renal failure in non-smokers, according to their and gender.

2 Materials and methods

The method used to measure the alpha emitters in blood samples has previously been described (Kadhim et al., 2020; Tawfiq et al., 2015). In this study, 26 blood samples from male and female employees in Najaf City were taken (21 from sick and five from healthy individuals). The employees had never been exposed to ^{238}U in the past. They've completed a thorough study on segment information like age and gender. To determine the concentration of alpha emitters in blood tests, the droplet approach was used. Blood (35 µl) was infused into every reagent utilising a micropipette. Reagent region 1 cm^2 After putting the blood test and subsequent to drying it, one more reagent was put on top of it as displayed in Figure 1. In this procedure, the blood tests were illuminated with warm neutrons from (Am-Be) neutron hotspot for seven days to make latent damage to the finder due to ^{238}U (n,f) reaction. The complete neutrons flux was (3×10^5 n cm^{-2}). The element Am is a heavy element that is an automatic emitter of alpha particles. This element covers another element, Be, which is a light element that reacts with alpha particles according to the following reaction, which is the reaction (αf):

$$ {}^{9}_{4}\text{Be} + {}^{4}_{2}\text{He} \rightarrow {}^{12}_{6}\text{C} + {}^{1}_{0}\, n\, fast + 5.71\,\text{MeV} \tag{1} $$

It will produce fast neutrons that are cooled down by paraffin wax surrounding the radioactive source into thermal neutrons and in turn interact with uranium to produce fission fragments that leave tracks on the detector (Al-Hamzawi, 2015). After the irradiation process, we used a NaOH solution with normalcy (N = 6.25) and a temperature of 60°C for 6 hours to chemically etch the CR-39 detectors. Using an optical microscope at a 400x magnification, the density of the induced fission tracks was measured. On surfaces where uranium was distributed uniformly, the fission track densities were assessed.

Figure 1 Blood sample preparation for analysis of the alpha emitters

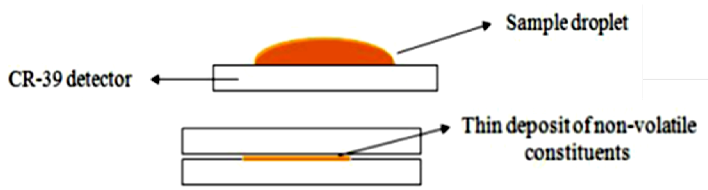


Figure 2 Irradiation of samples and detectors with neutrons (Rostker, 2000)

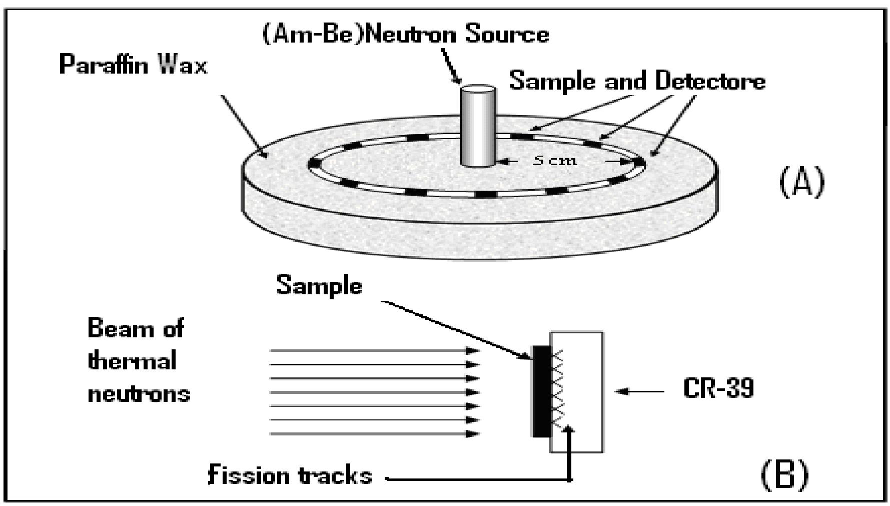


Figure 3 Blood samples are placed above CR-39 nuclear track detector

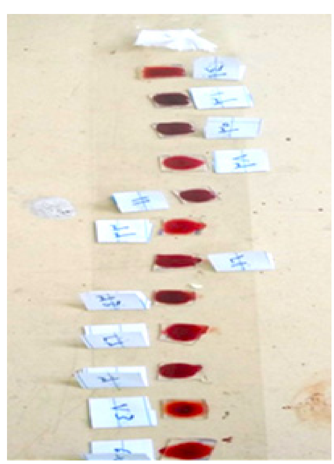


Figure 4 The irradiation source

3 Calculations of alpha emitters concentrations

Alpha emitters (^{222}Rn, ^{226}Ra and ^{238}U) fixation in the blood tests was estimated by correlation between track densities enrolled on the indicator of blood tests and that of the standard samples:

$$C_x = C_s\left(\rho_x/\rho_s\right) \tag{2}$$

$$\rho_x = N_{av}/A \tag{3}$$

where ρ_x and ρ_s the induced fission track density for the standard sample and the unknown sample in (tracks/mm^2), C_x and C_s indicate the amount of alpha emitters in the standard and unknown samples in (ppb), N_{av} number of tracks and A is the area of field view. The following equation should be used to determine the radon levels in human blood samples (Tawfiq et al., 2013; Al-Tememy, 2007):

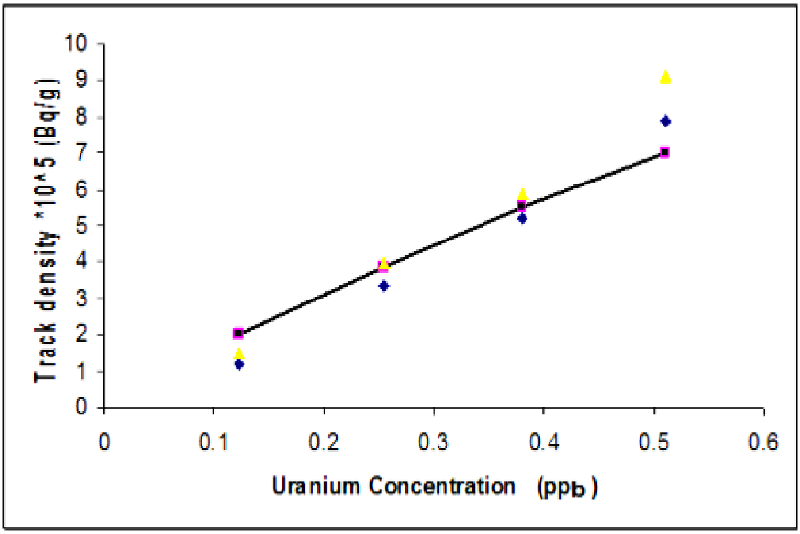
$$C_{Rn} = \rho/k \times T \tag{4}$$

The (k) factor (the detector calibration factor) can be estimated using the following equation (Al-Nafiey et al., 2012):

$$k = 0.25r\left(2\cos\theta_c - \frac{r}{r_a}\right) \tag{5}$$

where r refers to radius of the tube (0.75cm), θ_c is used to describe the detector's critical angle (10–30°) (Salih, 2014); and r_a refers to the alpha particle range (4.15 cm) in the air (Salih, 2014). The concentrations were calculated using a detector calibration factor of 0.212 tr./cm^2.d per Bqm^3.

Figure 5 The relationship between track density and uranium content in standard samples is expressed in (ppb) (Al-Tememy, 2007)



4 Results and discussion

In this study, 42 blood samples were collected from Kidney Center in Sadr Medical City in Najaf, 21 samples for patients with renal failure and 21 samples for reference healthy volunteers, all volunteers are non-smokers. The calculations of alpha-emitters (^{222}Rn, ^{226}Ra and ^{238}U) concentration in blood samples were obtained using CR-39 solid state nuclear track detectors. The irradiation method was used by a radioactive source (Am-Be) in the College of Education for Pure Sciences Ibn Al-Haytham at the University of Baghdad.

For the group of renal failure patients, the results were as follows: the highest concentration of ^{238}U for renal failure patient was (1.507 ± 0.24 ppb) in the blood samples, and the lowest concentration of ^{238}U was (0.104 ± 0.41 ppb), and the average concentration of ^{238}U was (0.599±0.34 ppb) in the blood samples, and the highest concentration of ^{222}Rn for renal failure patient was (8.763 ± 0.0246 Bq/m^3) in the blood samples, and the lowest concentration of ^{222}Rn was (0. 61 ± 0.0606 Bq/m^3), and the average concentration of ^{222}Rn was (3.486 ± 0.027 Bq/m^3) in the blood samples, and the highest concentration of ^{226}Ra for renal failure patient was (0.353 Bq/m^3) in the blood samples, and the lowest concentration of ^{226}Ra was (0.024 Bq/m^3), and the average concentration of ^{226}Ra was (0.140 Bq/m^3) in the blood samples. Blood samples from a patient from Al-Ansar district had the highest amount of alpha emitters, and the lowest concentration of alpha emitters for a patient from Al-Nida district. All these data for patients with renal failure are summarised in Table 1.

For the group healthy volunteers, the results were as follows: the highest concentration of ^{238}U for renal failure patient was (1.014 ± 0.23 ppb) in the blood samples, and the lowest concentration of ^{238}U was (0.078 ± 0.36 ppb), and the average concentration of ^{238}U was (0.399 ± 0.164 ppb) in the blood samples, and the highest concentration of ^{222}Rn for renal failure patient was (5.897 ± 0.012 Bq/m^3) in the blood samples, and the lowest concentration of ^{222}Rn was (0.457 ± 0.071 Bq/m^3), and the average concentration of ^{222}Rn was (2.318 ± 0.0391 Bq/m^3) in the blood samples, and the highest concentration of ^{226}Ra for renal failure patient was (0.237 Bq/m^3) in the blood samples, and the lowest concentration of ^{226}Ra was (0.018 Bq/m^3), and the average concentration of ^{226}Ra was (0.0935 Bq/m^3) in the blood samples. Blood samples from a patient from Al-Ansar district had the highest amount of alpha emitters it was one of the volunteers from Al-Ansar district, and the lowest concentration of alpha emitters it was one of the volunteers from Al-Salam district.

All these data for patients with renal failure are summarised in Table 1. Radon concentration in blood samples of males in healthy group was (2.152 ± 0.033 Bq/m^3) while radon concentration in blood samples of females in healthy group was (2.485 ± 0.025 Bq/m^3) and radon concentration in blood samples of males in patients group was (3.082 ± 0.042 Bq/m^3) while radon concentration in blood samples of females in patients group was (3.891 ± 0.018 Bq/m^3), and males in the healthy group had blood samples with uranium concentrations that was (0.370 ± 0.31 ppb) while uranium concentration in blood samples of females in healthy group was (0.428 ± 0.23 ppb) and uranium concentration in blood samples of males in patients group was (0.505 ± 0.24 ppb) while uranium concentration in blood samples of females in patients group was (0.693 ± 0.32 ppb), and radium concentration in blood samples of males in healthy group was (0.086 Bq/m^3) while radium concentration in blood samples of females in healthy group was (0.101 Bq/m^3) and radium concentration in blood samples of males in patients group was (0.118 Bq/m^3) while radium concentration in blood samples of females in patients group was (0.162 Bq/m^3) as in Figures 6, 7 and 8. When compared to the findings of prior research that included all categories of smokers and non-smokers, it should be highlighted that there is a drop in the concentrations of alpha emitters ^{222}Rn, ^{226}Ra and ^{238}U among non-smokers. The obtained results were compared and treated statistically using a program (spss, version 22) to obtain the importance of the probability factor (P-value) for studied results (Tables 6 and 7). When ($P < 0.05$) the difference between the results is significant, and when be ($P < 0.001$), it is highly significant. Considering that the P value is ($P > 0.05$), it is not noteworthy.

The purpose for such outcomes can be credited to the way that southern Iraq was the focal point of military operations during the Gulf Wars I and II, and the discarded weapons are as yet lying around here. This demonstrates that individuals living in southern Iraq are presented with uranium levels in blood assessed by the (ICRP) to be 1.15 ppb. The outcomes acquired for healthy individuals were inside the universally average cutoff points when contrasted and the consequences of healthy people convergences of alpha emitters. The results showed that the concentration of alpha emitters in the blood increases in patients with renal failure, which is 1.5 times more than the concentrations in the healthy group as Figures 6, 7 and 8. The results also showed an increase in the concentrations of alpha emitters in females because the volume of blood in females is less than the volume of blood in males, where the volume of blood in females is (4–5 litres), while the volume of blood in males is (5–6 litres) as shown in Figures 9, 10 and 11.

The results showed that the concentration of alpha emitters in women is 1.142 times higher than in men. As seen by the data, the outcomes also demonstrated that alpha emitter concentrations rose with age (Figures 12, 13, 14, 15). The purpose for such outcomes can be credited to the way that southern Iraq was the focal point of military operations during the Gulf Wars I and II, and the discarded weapons are as yet lying around here. This demonstrates that exposure of individuals living in southern Iraq were greater than those in other parts of the country. The centralisation of uranium concentration in blood by the (ICRP) is assessed to be 1.15 ppb. The outcomes acquired for healthy individuals were inside the universally average cutoff points when contrasted and the consequences of healthy people convergences of alpha emitters.

Table 1 Range and average of alpha emitters concentration (^{222}Rn, ^{226}Ra and ^{238}U) in blood samples renal failure patients of non-smokers

Sample code	*Gender*	*Age*	*Track density (tracks/mm^2)*	*Radon concentration (Bq/m^3)*	*Uranium concentration ppb*	*Radium concentration (Bq/m^3)*
S1	male	77	326.19 ± 0.0167	8.763 ± 0.0246	1.507 ± 0.24	0.353
S2	female	38	165.132 ± 0.0296	4.36± 0.0398	0.749 ± 0.28	0.175
S3	male	32	137.727 ± 0.0491	3.71 ± 0.0216	0.638 ± 0.42	0.149
S4	female	33	143.245 ± 0.0318	3.85 ± 0.0319	0.662 ± 0.13	0.155
S5	male	17	30.737 ± 0.0162	1.01 ± 0.0136	0.173 ± 0.37	0.040
S6	female	35	148.8 ± 0.0373	4.00 ± 0.0193	0.688 ± 0.27	0.161
S7	male	29	123.58 ± 0.0610	3.40 ± 0.0240	0.584 ± 0.32	0.137
S8	male	33	141.245 ± 0.0398	3.85 ± 0.0125	0.662 ± 0.28	0.155
S9	male	15	25.257 ± 0.0107	0.61 ± 0.0606	0.104 ± 0.41	0.024
S10	female	37	166.25 ± 0.0620	4.440 ± 0.0327	0.763 ± 0.38	0.179
S11	female	76	328.005 ± 0.0198	8.65 ± 0.0302	1.487 ± 0.31	0.348
S12	female	20	58.439 ± 0.0290	1.47 ± 0.0346	0.252 ± 0.31	0.059
S13	male	32	139.098 ± 0.0736	3.54 ± 0.0173	0.608 ± 0.47	0.142
S14	male	20	45.292 ± 0.0288	1.217 ± 0.0222	0.209 ± 0.33	0.046
S15	male	40	169.613 ± 0.0109	4.561 ± 0.0346	0.784 ± 0.25	0.183
S16	male	19	45.033 ± 0.0496	1.209 ± 0.0136	0.209 ± 0.18	0.048
S17	female	23	67.401 ± 0.0468	1.81 ± 0.0277	0.318 ± 0.48	0.072
S18	male	18	32.737 ± 0.0498	0.87 ± 0.0264	0.152 ± 0.36	0.035
S19	male	36	157.318 ± 0.0700	4.231 ±0.0230	0.731 ± 0.28	0.170
S20	female	34	141.874 ± 0.0309	3.814 ± 0.0248	0.659 ± 0.51	0.153
S21	female	32	143.06 ± 0.0610	3.844 ± 0.0357	0.664 ± 0.38	0.155
Mean ± SD				**3.486 ± 0.027**	**0.599 ± 0.34**	**0.140**

Table 2 Alpha emitters concentration (ppb) range and average in blood samples group of healthy non-smokers

Sample code	*Gender*	*Age*	*Track density (tracks/mm²)*	*Radon concentration (Bq/m³)*	*Uranium concentration ppb*	*Radium concentration (Bq/m³)*
S1	female	54	206.45 ± 0.013	5.86 ± 0.023	1.007 ± 0.27	0.223
S2	male	28	104.556 ± 0.018	2.97 ± 0.027	0.510 ± 0.17	0.119
S3	female	24	87.215 ± 0.038	2.477 ± 0.0216	0.426 ± 0.18	0.099
S4	male	24	90.696 ± 0.020	2.576 ± 0.052	0.443 ± 0.36	0.103
S5	female	15	19.493 ± 0.071	0.553 ± 0.012	0.095 ± 0.26	0.022
S6	male	25	94.177 ± 0.058	2.676 ± 0.072	0.460 ± 0.39	0.107
S7	female	21	78.215 ± 0.083	2.224 ± 0.037	0.382 ± 0.41	0.089
S8	female	55	207.594 ± 0.0198	5.897 ± 0.012	1.014 ± 0.23	0.237
S9	female	12	16.012 ± 0.0107	0.457 ± 0.071	0.078 ± 0.36	0.018
S10	male	28	105.253 ± 0.062	2.99 ± 0.034	0.514 ± 0. 27	0.120
S11	male	23	89.43 ± 0.041	2.54 ± 0.051	0.436 ± 0. 25	0.102
S12	male	17	37.025 ± 0.038	1. 051 ± 0.039	0.18 ± 0. 34	0.042
S13	female	23	88.037 ± 0.063	2.502 ± 0.038	0.431 ± 0.36	0.100
S14	female	16	28.67 ± 0.085	0.815 ± 0.016	0.14 ± 0.45	0.032
S15	female	29	107.405 ± 0.011	3.051 ± 0.049	0.524 ± 0.21	0.123
S16	female	22	90.569 ± 0.072	2.573 ± 0.072	0.442 ± 0. 57	0.103
S17	male	18	42.721 ± 0.051	1.213 ± 0.035	0.208 ± 0.13	0.048
S18	female	14	24.165 ± 0.079	0.687 ± 0.069	0.118 ± 0. 34	0.027
S19	female	27	99.620 ± 0.087	2.83 ± 0.034	0.486 ± 0. 30	0.114
S20	male	25	89.810 ± 0.063	2.551 ± 0.023	0.438 ± 0. 24	0.102
S21	male	18	28.544 ± 0.038	0.811 ± 0.032	0.139 ± 0.27	0.032
Mean ± SD				**2.318 ± 0.0391**	**0.399 ± 0.164**	**0.0935**

Table 3 Statistical description of radon concentrations (Bq/m³) in blood samples for the two groups of patients and healthy

Statistical values	*Patients group*	*Healthy group*
No. of subjects	21	21
Max.	8.763 ± 0.0246	5.897 ± 0.012
Min.	0. 61 ± 0.0606	0.457 ± 0.071
Mean ± Std. Error	**3.486 ± 0.027**	**2.318 ± 0.0391**

Figure 6 Average radon concentrations in the blood samples of the two study groups

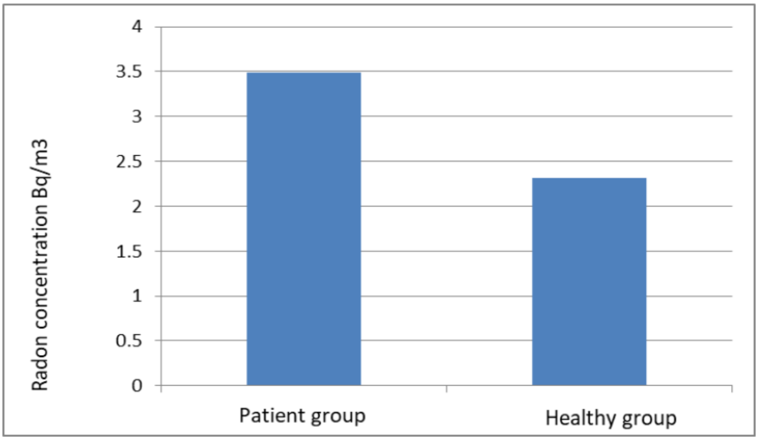


Table 4 Statistical analysis of uranium concentrations (ppb) in blood samples from sick and healthy people

Statistical values	*Patients group*	*Healthy group*
No. of subjects	21	21
Maximum	1.507 ± 0.24	1.014 ± 0.23
Minimum	0.104 ± 0.41	0.078 ± 0.36
Mean ± Std. Error	0.599 ± 0.34	0.399 ± 0.164

Figure 7 Average uranium concentrations in the blood samples of the two study groups

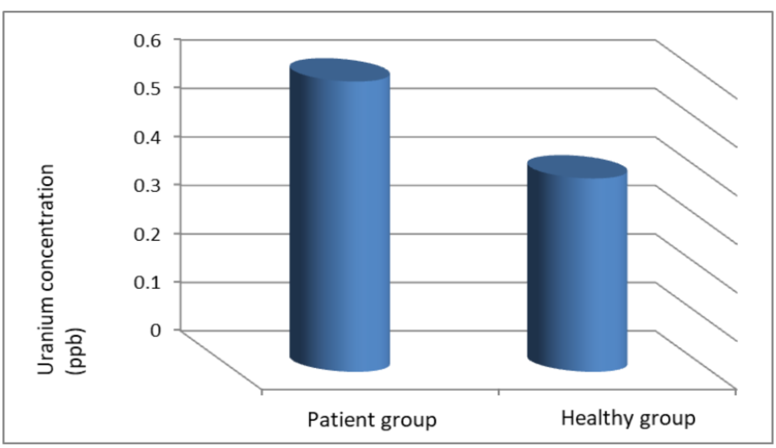


Table 5 Statistical description of radium concentrations (Bq/m^3) in blood samples for the two groups of patients and healthy

Statistical values	*Patients group*	*Healthy group*
No. of subjects	21	21
Maximum	0.353	0.237
Minimum	0.024	0.018
Mean ± Std. Error	0.140	0.0935

Figure 8 Average radium concentrations in the blood samples of the two study groups

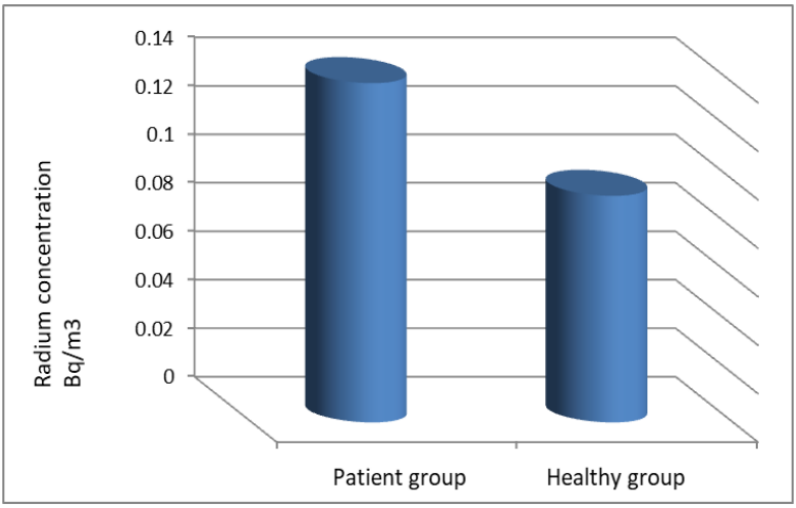


Table 6 Radon concentration (Bq/m^3) as a function of gender healthy and patients

Group	*Gender*	*No. of samples*	*Mean ± SD*	*P-value*
Healthy	Males	9	2.152 ± 0.033	$P < 0.05$
	Females	12	2.485 ± 0.025	
Patients	Males	12	3.082 ± 0.042	$P < 0.05$
	Females	9	3.891± 0.018	

Figure 9 Average radon concentrations in blood samples of the two study groups as a function of gender (see online version for colours)

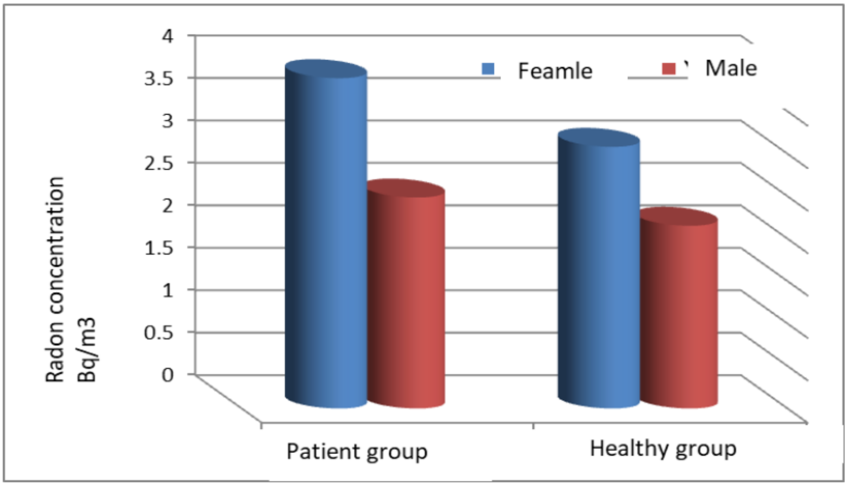


Table 7 Uranium concentration (ppb) as a function of gender healthy and patients

Group	*Gender*	*No. of samples*	*Mean ± SD*	*P-value*
Healthy	Males	9	0.370 ± 0.31	$P < 0.05$
	Females	12	0.428 ± 0.23	
Patients	Males	12	0.505 ± 0.24	$P < 0.05$
	Females	9	0.693± 0.32	

Figure 10 Average uranium concentrations in blood samples of the two study groups as a function of gender (see online version for colours)

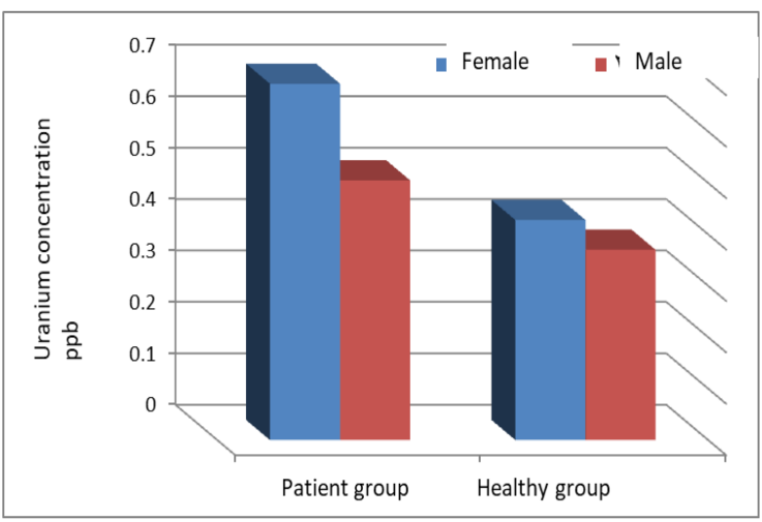


Table 8 Radium concentration (Bq/m^3) as a function of gender healthy and patients

Group	*Gender*	*No. of samples*	*Mean*
Healthy	Males	9	0.086
	Females	12	0.101
Patients	Males	12	0.118
	Females	9	0.162

Figure 11 Average radium concentrations in blood samples of the two study groups as a function of gender (see online version for colours)

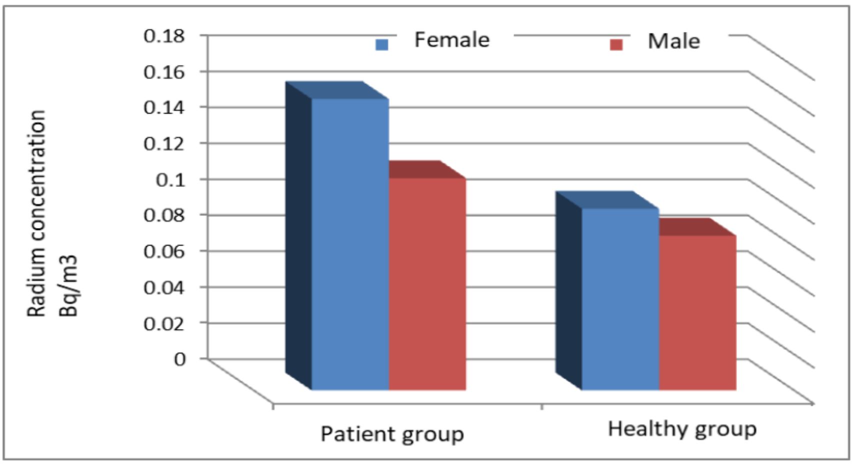


Table 9 Radon, uranium, radium concentrations in blood samples of the two study groups as a function of age

Classification	*Age*	*Male*	*Female*	*Total*	*Radon concentration (Bq/m^3)*	*Uranium concentration ppb*	*Radium concentration (Bq/m^3)*
Patients group	15–20	5	1	6	1.064 ± 0.034	0.183 ± 0.28	0.043
	21–40	6	7	13	3.807 ± 0.028	0.656 ± 0.36	0.153
	Above 41	1	1	2	8.707 ± 0.021	1.501 ± 0.28	0.351
Healthy group	12–20	3	4	7	0.798 ± 0.023	0.137 ± 0.38	0.032
	21–30	6	6	12	2.66 ± 0.031	0.459 ± 0.23	0.107
	Above 50	–	2	2	5.878 ± 0.020	1.013 ± 0.18	0.237

Figure 12 Radon concentrations in blood samples from patients as a function of age

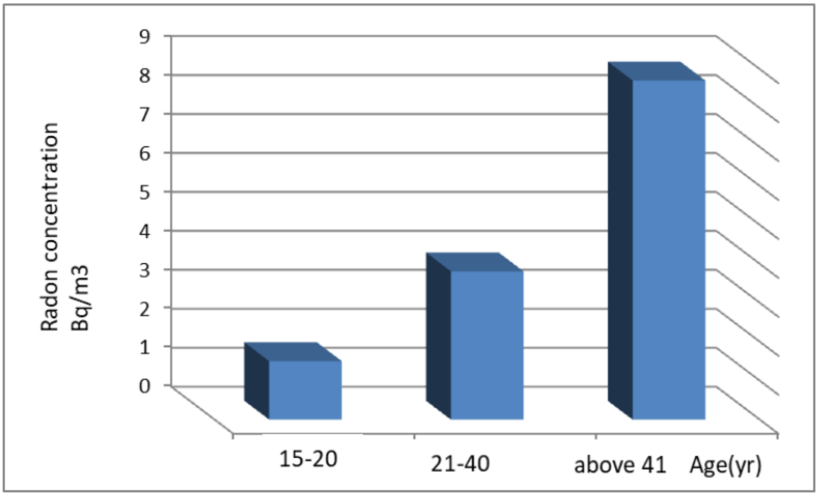


Figure 13 Uranium concentrations in blood samples of patients as a function of age

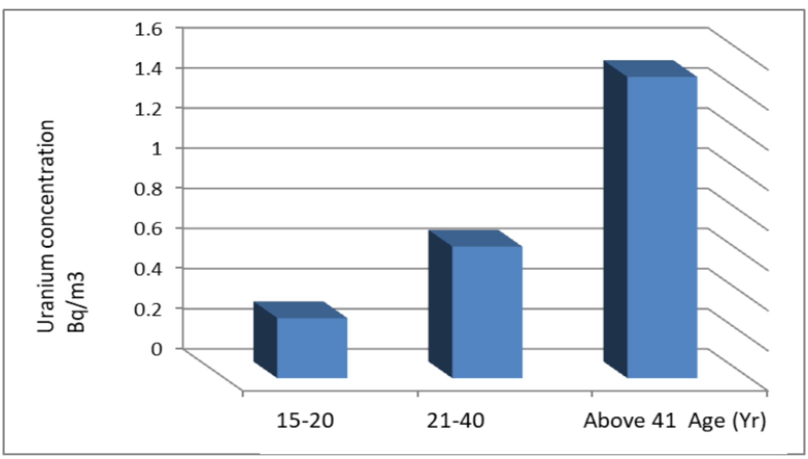


Figure 14 Radium concentrations in blood samples from patients as a function of age

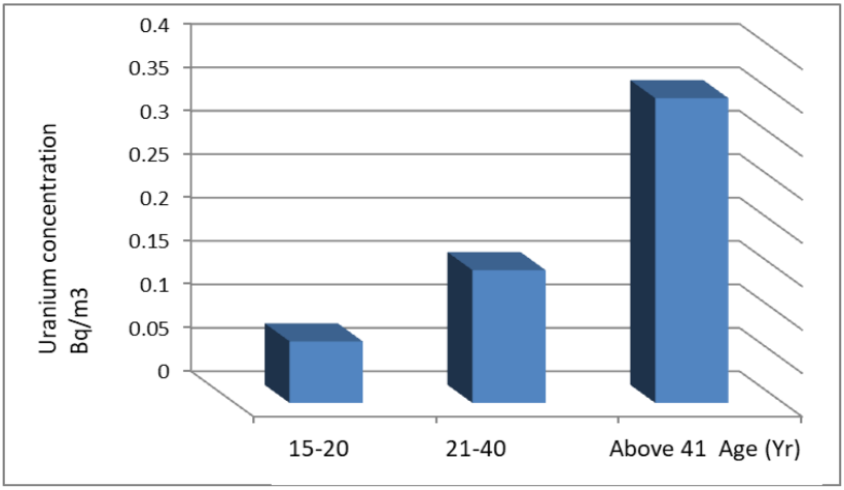
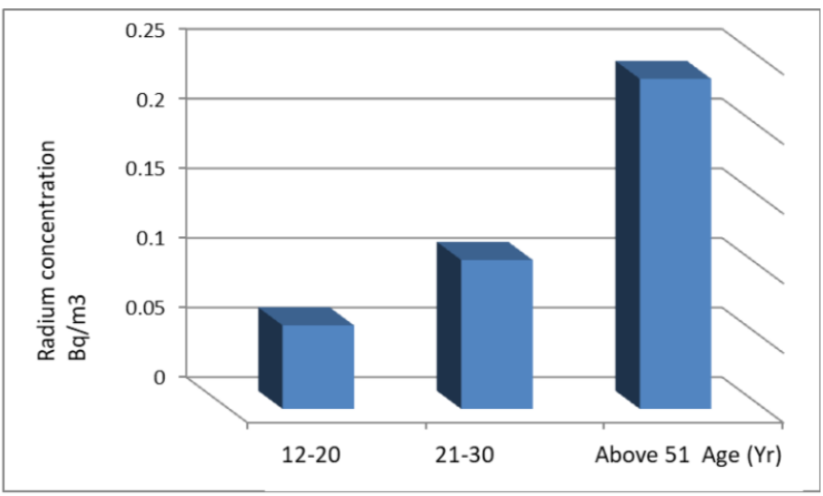


Figure 15 Radium concentrations in healthy blood samples as a function of age



5 Compared with the results of other studies

In this study, radon concentrations in blood samples for both groups healthy and patients ranged from (0.457 ± 0.071 Bq/m^3) to (8.763 ± 0.0246 Bq/m^3), and radon concentrations ranged from (0.078 ± 0.36 ppb) to (1.507 ± 0.24 ppb). Other studies have varied Radon concentrations in blood samples in different regions, as shown in Tables 10 and 11.

Table 10 A comparison of uranium concentrations (ppb) in blood samples in this study with the results of other studies

No.	*Country*	*Uranium concentration*		*References*
1	India	Max.	0.74	Das et al., 1986
		Min.	0.33	
2	Mexico	Max.	1.4	Romero et al., 1984
		Min.	0.4	
3	Denmark	Max.	8.7	Koul and Chadderton, 1980
		Min.	0.35	
4	Iraq	Max.	1.9	Tawfiq et al., 2013
		Min.	0.26	
5	Present study	Max.	1.507 ± 0.24	Present work
		Min.	0.078 ± 0.36	

Table 11 Comparison of radon concentrations (Bq/m^3) in blood samples in this study with the results of other studies

Country	*Radon concentration (Bq/m^3)*	*References*
Malayasi	734.50	Salih et al., 2016
Iraq (Najaf)	8.62-55.37	Abdulwahid et al., 2020
Iraq (Karbala)	64.3	Mohsen et al., 2019
Iraq	0.457 ± 0.071 – 8.763 ± 0.0246	Present work

6 Conclusions

In our investigation, we noted the concentration of alpha emitters in blood samples from patients suffering from renal failure was 1.5 times higher than that of the healthy group. This suggests that ageing has an observable influence on alpha levels in blood. With age, the emphasis increases. Females had greater average alpha emitter concentrations than males did, for both sick and healthy persons. The findings indicated that non-smokers had lower alpha emitter concentrations, in contrast to prior research on smokers. The fixation of alpha emitters in the blood of healthy individuals is as near to the ICRP organisation as feasible, according to the results (1.15 ppb).

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