Determination of Alpha Particles Levels in Blood Samples of Cancer Patients at Karbala Governorate, Iraq

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A R T I C L E I N F O	A B S T R A C T
	Introduction: Alpha particle emitters are very damaging and harmful when entering into the human body ,if ingested or inhaled , swallowed or absorbed into the lungs or bloodstream . Uranium (^{238}U), Radium (^{226}Ra) and Radon (^{222}Rn) are typical alpha-particle emitters. ***Material and Methods:*** we measured the level of alpha particles emitted from ^{222}Rn, ^{226}Ra, and ^{238}U in blood samples of 10 cancer patients diagnosed using solid-state nuclear track detector. The samples were collected from hospitals located in Karbala Governorate of Iraq. This study was carried out between October and December 2017. Alpha particles concentrations of the collected blood samples were estimated in patient and control groups. ***Results:*** The mean concentrations of radon, radium, and uranium concentration were 64.3±25.92 Bq/m^3, 3.1±1.24 Bq/kg and 1.4±0.58 ppm, respectively. Also, the results showed that radon concentrations, activity concentrations of radon, radium concentrations, and uranium concentrations were significantly higher in the patient group compared to the controls (P<0.05). ***Conclusion:*** It was found that radon concentrations in all the studied blood samples were within the allowed limit according to International Commission on Radiological Protection and International Atomic Energy Agency (200 Bq/m^3), except for sample C4(male, type of cancer is colon) that had a value of 265.15±18.94 Bq/m^3.

Introduction

There are some amounts of radionuclides inside human body. These either originate from continuous exposure to natural radiation (i.e., cosmic ray, terrestrial sources, and radon) and man-made sources of radiation, or they naturally exist from birth inside the body such as potassium-40 (^{40}K), carbon-14 (^{14}C), and lead-210 (^{210}Pb) [1]. It should be noted that radionuclides like uranium (natural/depleted), thorium, and other different isotopes enter human body through three main pathways. The first one is inhalation that is estimated to be the most common way of radioisotope intake. The second is ingestion, which includes drinking water, eating food, or smoking cigarettes. The third is dermal contact with radionuclides, which might enter the circulatory system via open wounds [2].

It has been established that the average amount of uranium-238 that can be entered into the body via nutrition is 5 Bq, and its specific concentration has been estimated to be around bones (0.15 Bq/Kg) and soft tissues (5×10^{-3} Bq/Kg). When considering the

level of thorium-232, which is almost concentrated in the bones and can increase with age, activity concentration is around 4×10^{-2} Bq/kg in bones and 3×10^{-4} Bq/kg in soft tissues [3]. Additionally, the concentration of radium-226 in the soft tissues is around 2.7 µBq. Polonium-210 has drawn considerable attention due to its presence in tobacco products at a concentration of around 15 µBq. It is also present in the species that are usually taken by marine biologists [4].

It should be noted that the human body is initially exposed to the natural radiation originated from the sun, cosmic ray, and the naturally occurring radioactive elements already existing in the earth's crust [5], which are developed throughout the formation of the solar system and via the interactions of cosmic rays with molecules in the atmosphere [6]. Space cosmic rays consist of high-energy photons, electrons, gamma rays, and X-radiations. The radon exhaled from the ground is generally originated from the decay of naturally existing radium, which is

estimated to be the main source of radiation exposure [7]. The radioactive elements primarily discovered in the earth's crust are uranium, thorium, and potassium. The latter elements emit alpha, beta, and gamma radiations.

Internal radiation originates from those radioactive materials that naturally exist inside the human body. Nevertheless, potassium and carbon are the major isotopes that cause the main exposure to internal radiation. In this regard, potassium is considered an important mineral for life, whereas potassium-40, which constitutes about 0.01% of all potassium, is almost naturally radioactive. Carbon accounts for around 23% of human body weight.

Cosmic radiation contributes to the creation of radioactive carbon-14, which constitutes a small proportion of all carbon. In this regard, potassium and carbon enter the body via the food chain [8]. Internal radioactive contamination occurs when radioactive substances invade the body. Body parts like skin, mouth, and nose can be considered as the most obvious routes of internal contamination. In addition, radioactive substances can enter the body via the same routes as any other substance [9, 10]. The biological effect of radiation on living cells can have three consequences, including repairable injury or cell damage, which results in no residual damage, cell death (this case normally happens in millions of cells inside the body every day), and then replacement of these cells through normal biological mechanisms.

Cells that incorrectly repair themselves can result in certain biophysical alterations [11, 12]. In this context, the biological effects of radiation depend on the period between irradiation and appearance, meaning that the short-term effects result from acute dose exposure and long-term effects follow chronic dose exposure [13]. This study aimed to investigate the alpha particles (i.e., radon-222, radium-226, and Uranium-238) concentrations in blood samples of patients suffering from cancer at Karbala Governorate using the LR-115 type II SSNTD (solid state nuclear track) technique.

Materials and Methods

The study was conducted on 10 randomly selected cancer patients (i.e., 5 males and 5 females), whose age ranged between 19 and 80 years old, as the case group, and two patients with no cancer as the control group. Patient information obtained using a questionnaire comprising name, gender, age, type of cancer, region, and other data is illustrated in Table 1. It should be noted that all the patients had different kinds of cancer and had not received radiotherapy. The samples were selected from the cancer hospital in Karbala Governorate, Iraq.

Three milliliters of venous blood was drawn using a disposable needle and plastic syringe from patient and control subjects. Blood was left at room temperature for 10 min for clotting, centrifuged at 6000 rpm for 10 min, and then the serum was separated and transported into new disposable test tubes (Figure 1). The tubes were labeled with the corresponding patient numbers. After that, the blood samples were kept in an icebox (4°C) and then transferred to a lab for refrigeration until the date of analysis starts. Each sample was given a specific code in order to distinguish them from each other.

Figure1. Preparation of blood samples

Table1. Samples under study

No.	Sample code	Gender	Age/Year	Type of cancer
1	C1	Male	19	All(Acute lymphoblastic leukemia)
2	C2	Male	24	Colorectal
3	C3	Female	24	Cervical
4	C4	Male	29	Colon
5	C5	Female	39	All(Acute lymphoblastic leukemia)
6	C6	Female	50	Breast
7	C7	Male	57	Leukemia
8	C8	Female	60	All(Acute lymphoblastic leukemia)
9	C9	Female	75	Breast
10	C10	Male	80	Lung

In this technique, the same volume of blood was placed in an emanation chamber (BD Vacutainer, china), which was then closed for a period of four weeks in order to reach equilibrium between radium and radon. ALR-115 type II detector (made by the Track Analysis Systems Ltd., Bristol, UK) with a thickness of 12 μm was placed in blood samples for measuring alpha particles. Specifically, one-track detector was placed in a container. These detectors were fixed at the top end of a plastic cup whose diameter was 1.5 cm and its length was 6 cm (Figure 2).
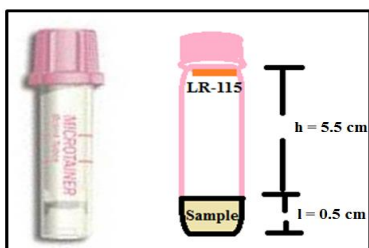

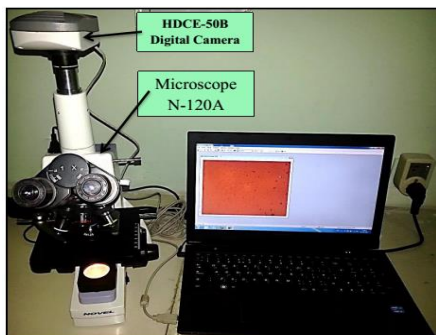**Figure 2.** Diagram of container for measuring alpha concentrations

Figure 3. The optical microscope used in this study

The LR-115 type II detector was cut into an area of 1×1 cm² and placed in the upper part of the containers. A piece of the LR–115 type II detector was placed at the bottom of each cylinder cover, with samples at the bottom of cylinder, and then sealed for exposure for 32 days in a refrigerator.

At the end of the exposure time, LR-115 type II detector was etched with sodium hydroxide (NaOH) solution at 60°C for 1.5 hours. Solution normality was 2.5 in the water bath [14]. The detectors were then washed using distilled water. Track density as detected by the LR-115 type II detector (track/cm²) was computed using an optical microscope (NOVEL, China) with a magnification of 10 × 40 (Figure 3). The correction for background was conducted by subtracting background from the recorded alpha track density.

Calculation

The concentration of ²²²Rn in the air gap of the tube (C_{Rn}^a) was calculated using the following formula [15]:

$$C_{Rn}^a \left(\frac{Bq}{m^3} \right) = \frac{\rho}{K\,t} \tag{1}$$

Where ρ represents the track density of the irradiated detector (Tr/cm²), t denotes exposure time (e.g., 62 d), and K refers to the calibration factor (or sensitivity factor). This factor (K) can be determined using the following equation [16]:

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

Where r represents the radius of the tube (r= 0.75cm), θc is the critical angle of the LR-115 type II detector (θc = 40°) [16], and r_a refers to the range of alpha particle in the air (r_a=4.15 cm) [17]. Consequently, the calibration factor was considered 0.022 Tr./cm².d per Bq/m³ [14].

Radon concentration within the sample (C_{Rn}^s) can be calculated using the following equation [18]:

$$C_{Rn}^s \left(\frac{Bq}{m^3} \right) = \frac{C_{Rn}^a \lambda_{Rn}\, h\, t}{l} \tag{3}$$

Where λ_{Rn} represents the ²²²Rn decay constant (0.1814 d⁻¹), h denotes the distance between the sample surface and the detector, t shows the irradiation duration (i.e., 62 d), and l represents the thickness of the sample layer in the test tube. The concentration of radon inside the sample ($C_{Rn}^{s,ac}$) was determined using the equation below:

$$C_{Rn}^{s,ac} \left(\frac{Bq}{kg} \right) = \frac{C_{Rn}^s\, l\, A^s}{M^s} \tag{4}$$

Where A^s represents the surface area of the sample and M^s refers to sample mass.

Radium concentration (²²⁶Ra) within the sample ($C_{Ra}^{s,ac}$) was determined using the following equation [19]:

$$C_{Ra}^{s,ac} \left(\frac{Bq}{kg} \right) = \frac{C_{Rn}^a\, h\, A^s}{M^s} \tag{5}$$

Radon activity in the sample (A_{Rn}^s) was determined using the following formulas:

$$A_{Rn}^s (Bq) = C_{Rn}^s\, V^s \tag{6}$$
$$V^s = \pi\, l\, r^2 \tag{7}$$

Where V^s is the sample volume in m³.

The number of uranium atoms (²³⁸U) of the sample (N_U^s) at secular equilibrium can be obtained according to Podgorsak [20]:

$$N_U^s = \frac{A_{Rn}^s}{\lambda_U} \tag{8}$$

Where λ_U is the uranium decay constant (4.9 × 10⁻¹⁸/s). Hence, uranium weight (g) in the sample (M_U^s) can be estimated as follows [21]:

$$M_U^s = \frac{N_U^s\, A_U}{N_A} \tag{9}$$

Where A_U is the mass number of ²³⁸U, and N_A is Avogadro's number. Thus, the concentration of uranium (C_U^s) in ppm can be calculated as:

$$C_U^s (ppm) = \frac{M_U^s}{M^s} \tag{10}$$

Statistical Analysis

The statistical analysis of the results were obtained by using ANOVA program (The software that used in present study is SPSS20) and Independent test, comparisons between the results were carried out by their mean

Results

The concentration and activity concentrations of radon, radium concentrations, and uranium concentrations were determined in the blood samples using the LR-115 type II detector for different types of cancer (Table 1). The results indicated that the highest value of radon concentration in blood samples was found in C6 at 265.15±18.94 Bq/m³, while the lowest value belonged to sample C1 at 4.73±0.95 Bq/m³, when compared to the control groups (i.e., 2.84±0.47 Bq/m³ and 3.79±0.53 Bq/m³).

Activity concentrations of radon in unit of Bq/kg ranged from 1.32±0.26 Bq/kg in C1 samples to 74±5.29 Bq/kg in C6 samples, while the control group's levels were at 0.79±0.13 Bq/kg and 1.06±0.15 Bq/kg, respectively. The results of radium concentrations in Bq/kg ranged from 0.23±0.05 mBq/kg in C1 samples to

12.75±0.91 mBq/kg in C6 sample, while the control group's levels were 0.14±0.02 mBq/kg and 0.18±0.03 mBq/kg, respectively. On the other hand, uranium concentrations of the case group were within the limit of 0.11±0.02 ppm to 5.97±0.43 ppm, while the control group values ranged from 0.06±0.01 ppm and 0.09±0.01 ppm (Table 2).

Figure 4 demonstrates a statistically significant increase ($P \leq 0.05$) in the average of radon concentration, activity concentration of radon, radium concentration, and uranium concentration in the case group compared to the controls.

Figure 5 reveals a clear significant difference in alpha particles levels when comparing male and female patients, which is clearly decreased in male patients compared to female ones. The latter argument is statistically supported by P-value ($P < 0.05$).

Table 2. Radon, radium, and uranium concentrations

No.	Sample code	Alpha particles levels							
		Radon-222				Radium-226		Uranium-238	
		C_{Rn}^{a} (Bq/m³)	±Error	$C_{Rn}^{s\,ac}$ (Bq/kg)	±Error	C_{Ra} (mBq/kg)	±Error	CU (ppm)	±Error
1	C1	4.73	0.95	1.32	0.26	0.23	0.05	0.11	0.02
2	C2	61.55	8.52	17.18	2.38	2.96	0.41	1.39	0.19
3	C3	23.67	3.79	6.61	1.06	1.14	0.18	0.53	0.09
4	C4	66.29	9.47	18.50	2.64	3.19	0.46	1.49	0.21
5	C5	142.05	14.20	39.65	3.96	6.83	0.68	3.20	0.32
6	C6	265.15	18.94	74.00	5.29	12.75	0.91	5.97	0.43
7	C7	47.35	7.58	13.22	2.11	2.28	0.36	1.07	0.17
8	C8	16.57	0.28	4.63	0.08	0.80	0.01	0.37	0.01
9	C9	6.63	1.89	1.85	0.53	0.32	0.09	0.15	0.04
10	C10	9.47	3.31	2.64	0.93	0.46	0.16	0.21	0.07
	Average±SD	64.3±25.92		18.0±7.23		3.1±1.24		1.4±0.58	
11	Control 1	2.84	0.47	0.79	0.13	0.14	0.02	0.06	0.01
12	Control 2	3.79	0.53	1.06	0.15	0.18	0.03	0.09	0.01
	Avearge±SD	3.3±0.47		0.9±0.13		0.16±0.02		0.1±0.01	
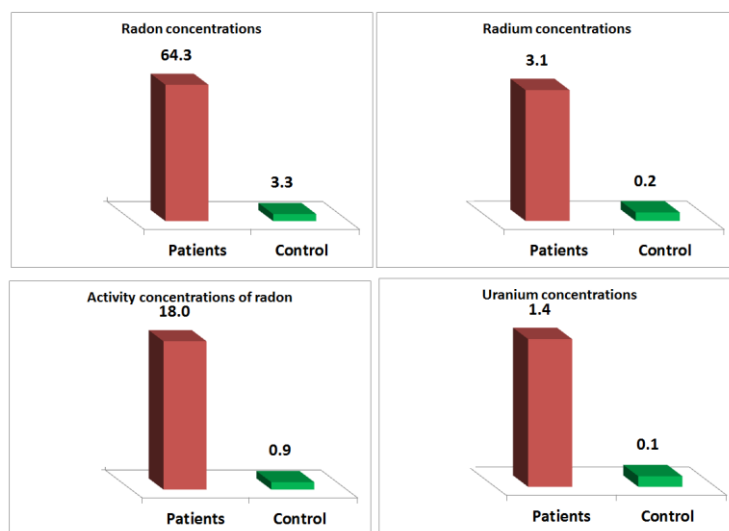
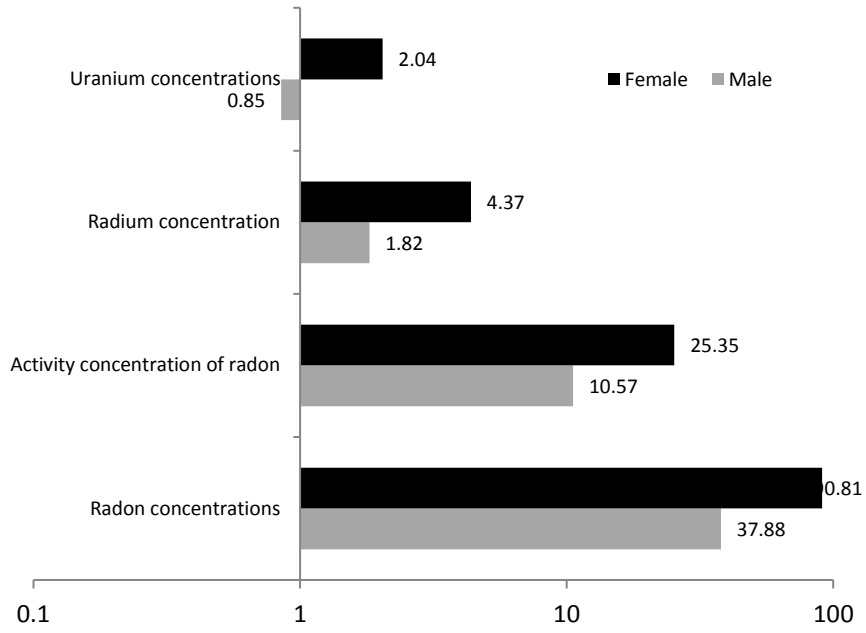**Figure 4.** Comparison of the results between the patient and control groups

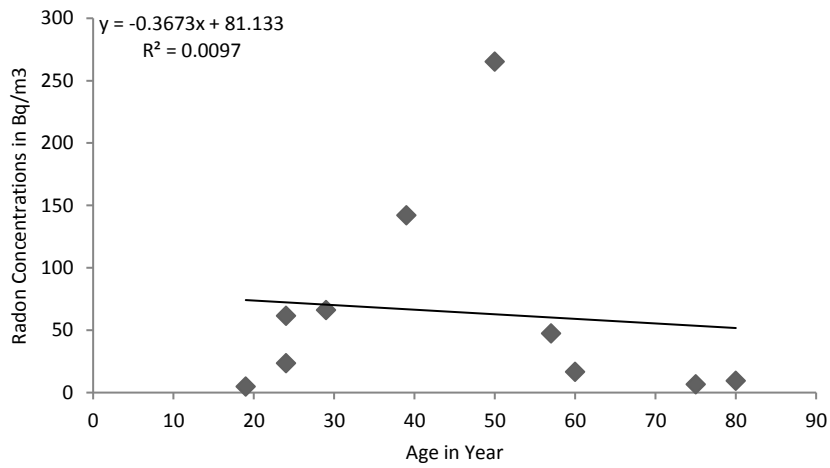**Figure 5.** Alpha particles in male and female patients

Figure 6. Correlation between radon concentration and age

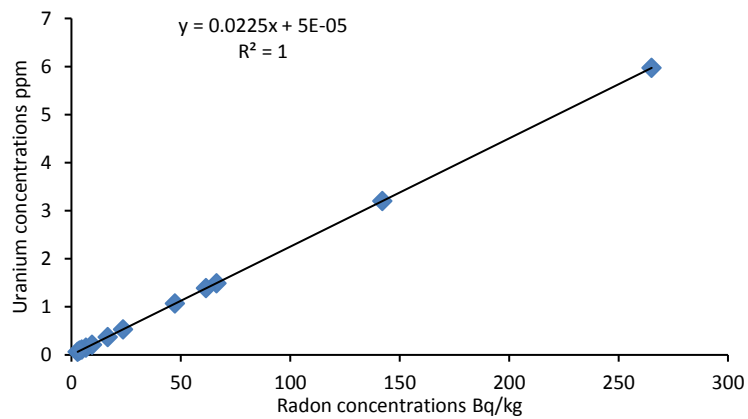**Figure 7.** Correlation between radon and uranium concentrations in samples during the study Period

Figure 6 displays no significant difference (P>0.05) in terms of radon concentration among patients of different ages.

Figure 7 shows the correlation between radon and uranium concentrations in all the blood samples

Discussion

In general, our data demonstrated that the level of radon for all the samples was lower than the acceptable ICRP (International Commission on Radiological Protection) and IAEA (International Atomic Energy Agency) limits (200 Bq/m3) [22, 23], with the exception of sample C6. The present study showed a positive correlation (significant at P<0.05) between radon and uranium concentrations in all the blood samples. As well as, it is notes no significant difference (P>0.05) in terms of radon concentration among patients of different ages. When comparing all the obtained results from blood samples (the control and cancer groups), alpha emission rate in the samples of the blood with cancer group was higher than that of the control group. The reason behind this finding may be due to the samples which were taken from people how were suffering from cancer may be affected by internal irradiation more than those in control group [24]. In case of gender factor, the results in blood samples found that the mean of alpha emission rate in female was higher than men, the reason for this may be attributed to relatively the long period of staying at home for female when compared with that of male ones. In this regards, it is well known the level of radon gas at home is high due to the level of ventilation therefore people who are staying at home for long time is expected to have high radiation exposure [25]. Generally the results obtained in the present study showed that the correlation level between the age factor and mean of alpha emission rate of blood was no clear, the reason for this may attributed to the randomly choosing the blood samples for patients, so it is highly recommended that further studies could be conducted in future in this regards. Also, the results showed that the uranium concentration in the blood is below the allowed limit reported by ICRP (0.115 ppm) [26]. Thus, by comparing the results of this study with those of other studies that have measured, we found that the uranium concentration in human blood as detected by the CR-39 nuclear track detector in Baghdad ranged from 0.22-0.073 ppm [26]. In addition, the results showed that the concentration of uranium in the blood sample under study was lower than those reported in other regions [27, 28], where the results showed that the concentrations of uranium in the blood samples were below the allowed limit.

Conclusion

According to the results of the current study, one can deduce that the radon concentration is less than the acceptable ICRP and IAEA limits, except samples C6. The uranium concentrations in all samples were below the allowed limit of ICRP and values of other studies. The study revealed a significant increase in alpha particles emissions in patients compared to controls. A highly significant decrease in male patients was observed as compared to females. Finally, the results of the present study showed a good correlation between radon and uranium concentrations.

Acknowledgment

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