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Research Article

Uranium, Polonium-218, and Polonium-214 Concentrations in Serum Samples of Cancer Patients at Al-Najaf Governorate

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Abstract: This research examines the concentrations of uranium (U_C), polonium of POW (^{218}Po and ^{214}Po on the wall of the irradiation container), and polonium of POS (^{218}Po and ^{214}Po on the surface of the irradiation container) in serum samples of male and female cancer patients and human health in the Al-Najaf Governorate of Iraq. U_C, ^{218}Po, and ^{214}Po were determined using a track detector technique with a CR-39 detector. The mean values of U_C for male and female cancer patients were 0.110 ± 0.024 ppb and 0.099 ± 0.013 ppb, respectively. The POW's average values for male and female cancer patients were 3.885 ± 2.132 Bqm^{-3} and 2.958 ± 1.146 Bqm^{-3}, respectively while the mean values of POS for male and female cancer patients were 0.702 ± 0.386 Bqm^{-3} and 0.535 ± 0.207 Bqm^{-3}, respectively. The results show that the mean concentrations of U_C, ^{218}Po, and ^{214}Po are significantly higher ($p < 0.001$) in male and female cancer patient groups compared with the healthy group. Also, the mean values of U_C, ^{218}Po, and ^{214}Po concentrations do not correlate with variables for male and female patient groups. Therefore, the concentrations of U_C, ^{218}Po, and ^{214}Po in cancer patients and healthy groups in the present study were not significant in terms of gender. According to the ICRP and WHO report, the concentrations of uranium and polonium in all samples of the current study were within the accepted limits (uranium = 0.810 ppb) and (polonium = 550 Bqm^{-3}), So the serum samples of male and female cancer patients and healthy in the Al-Najaf Governorate of Iraq were not contaminated with uranium.

Keywords: Uranium, Polonium, Blood Serum Radioactivity, Cancer, Irradiation Container, NTDs, Iraq.

1. INTRODUCTION

Essentially, people are exposed to two different types of radiation sources: natural and man-made. While the first source includes terrestrial endogenous radiation, the second source is manmade. In the two situations indicated above, radionuclides are essential for the emission of alpha or beta particles. Through eating or inhalation, these tiny particles may enter the human body [1]. Many radionuclides undergo decay by the emission of alpha (α) particles. The radiological characteristics of these radionuclides must be accurately assessed, particularly regarding their impact on human health [2]. Their existence in human bones, blood, and other tissues induces several health difficulties, including cancer, renal failure, dermatological conditions, a rise in chromosomal abnormalities in live cells, and congenital anomalies [3, 4]. Uranium is a dense, silver-hued radioactive element that is widely found in the Earth's crust and has both radioactive and poisonous properties. It is an element that is known to occur naturally. It includes three isotopes (^{238}U, ^{235}U, and ^{234}U). The latter isotopes, mostly, emit alpha particles, along with some emissions of beta and gamma rays [5]. The daily intake of uranium by the human body comes from water, air, and food, with the latter being the predominant source [6]. Uranium is very hazardous, capable of being ingested and absorbed by the gastrointestinal tract, thereafter entering the circulation upon entering the human body. The radioactive together with the corresponding toxicological properties of uranium and its radioactive isotopes make them a major source of pollution, presenting a risk to both human health and the environment too [7]. The

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World Health Organization (WHO) stipulates that the permissible intake (daily basis) of uranium is around 0.6 µg/kg of body mass. Healthy individuals generally excrete quantity of uranium, on daily basis, in their urine between 0.01 µg and 0.4 µg, depending on their dietary intake [8, 9]. Uranium trace analysis in blood samples is expected to supply with a reliable estimation of the concentration of heavy metals in specific tissues of the body [10]. Uranium accumulation in bones and other organs is later discharged into the blood circulation, resulting in many health issues, including cancer, renal failure, respiratory ailments, congenital anomalies, dermatological conditions, and other unidentified illnesses [7]. Radon is released during the radioactive decay process of uranium-238. Radium-226, its progenitor radionuclide, generates alpha particles that energize it. Upon disintegration into its daughter isotopes, ^{218}Po and ^{214}Po, it emits alpha particles [11, 12]. The distribution of radon varies by geography. Two alpha-emitting decay products, namely ^{218}Po and ^{214}Po, provide the bulk of the radiogenic dosage and have been recognized as the principal cause of radon-induced cancer [13]. Upon inhalation, radon gas infiltrates the lungs and then disseminates throughout the body via the bloodstream, which transports it to other organs. Epidemiological studies are often affected by lifestyle and demographic characteristics; however, in vitro studies have the advantage of removing confounding factors like as smoking and exposure to known or suspected carcinogens [14]. Recently, experts have increasingly revealed that some environmental toxins may play a crucial role in contributing, at least in some instances, to the underlying causes of cancer in both sexes. Given the prevalence of cancer, it is essential to comprehend the risk factors associated with it in human life [15]. Thus, the purpose of this research is to use solid-state nuclear track detectors (CR-39) to assess the levels of alpha emitters such as uranium, ^{218}Po and ^{214}Po in the blood serum of cancer patients in the Governorate of Al-Najaf in the republic of Iraq.

2. MATERIALS AND METHODS

2.1. Sample Collection

The current study was performed on serum samples of male and female cancer patients and healthy humans in the Governorate of Al-Najaf in the republic of Iraq. In 2024, Table 1 provides detailed demographic and clinical information about cancer patients, including their gender, sample code, type of cancer, age, and Body Mass Index (BMI) which can assist in statistical or medical analysis within the present study. The patients' ages range from 20 to 82 years, while BMI values range from 18 to 44. Cancer types vary across the Table, including lung cancer, prostate cancer, breast cancer, leukemia, kidney cancer, skin cancer, and more. There are 15 male and 15 female participants, providing a balanced gender distribution among the patients.

2.2. Sample Preparation

For this study, we obtained blood serum samples from 30 cancer patients aged 20 to 82. Each participant received a unique code, and samples were produced to quantify uranium concentrations, ^{218}Po, and ^{214}Po. Study subjects were mandated to attend the laboratory in which blood samples from the antecubital vein were collected. A professional phlebotomist performed venipuncture at a pathological laboratory in the Governorate of Najaf, collecting and storing 5-6 ml of blood in gel tubes. The latter blood samples were then left to coagulate for 5-10 minutes to enable serum separation during the centrifugation. The apparatus was set to function at a rotating velocity of four thousand revolutions every minute for 3-5 minutes, throughout this period the blood was clearly separated from the studied serum. Every sample was given a unique identification number to indicate for the participant's name. Thereafter, the collected samples of people sera were kept into clean, sterile Eppendorf tubes, each containing one ml, and then to be kept at a specific freezer in preparation for the measuring process [16, 17].

2.3. Irradiation Method

The present study used the Long-term irradiation method [18, 19]. Following the collection and preparation of the samples, 1 ml of blood serum was transferred into sterile plastic tubes. The tubes measured 10 ml in volume, 9.5 cm in length, and 1.5 cm in diameter. The tubes had two detectors (CR-39), each measuring 1 mm in thickness and 1 × 1 cm² in area (from Track Analysis Systems Ltd, UK). The first detector was positioned at the base of the sample to measure uranium concentrations, while the subsequent detector was situated at the top to assess Polonium on

Table 1. Information on cancer patients in the present study.

No.	Gender	Sample code	Type of cancer	Age	BMI
1	Male	*MC1	Lung	52	28
2		MC2		64	25.1
3		MC3		73	27
4		MC4		50	19.1
5		MC5		54	28.7
6		MC6		49	18.8
7		MC7	Prostate	69	34
8		MC8		73	23.8
9		MC9	Leukemia	65	25.3
10		MC10	Throat	74	21
11		MC11	Kidney	65	28.4
12		MC12	Testis	20	27.2
13		MC13	bone	30	29.3
14		MC14	Stomach	42	29.3
15		MC15	Breast	74	28
16	Female	**FC1	Breast	63	23.6
17		FC2		58	31.2
18		FC3		50	31.5
19		FC4		55	32.5
20		FC5		43	32
21		FC6		52	39
22		FC7		42	21.5
23		FC8		33	31
24		FC9	Leukemia	64	30.7
25		FC10		73	18
26		FC11	Skin	20	32
27		FC12		68	44
28		FC13	Larynx	58	26.6
29		FC14	Salivary gland	82	27.2
30		FC15	Lung	56	21

*MC = male cancer, **FC = female cancer

the wall (POW) of the irradiation container and Polonium on the surface (POS) of the irradiation container. The tubes were retained at the Nuclear and Environmental Laboratory at the Faculty of Science/ University of Kufa for a minimum of 90 days. After a three-month exposure period, detectors of CR-39 were taken from containers (plastic) and chemically etched under NaOH (6.25 N) in a bath of water (HH-420, Germany) at 98°C temperature for one hour. The latter detectors were next cleaned utilizing distilled water. Using a 400x optical microscope (Novel, China), the track count was determined by equipped with a digital eyepiece and a specified field of view [20].

2.4. Uranium and Polonium Concentration Assessment

The calibration curve was used in blood serum samples of the present study, which can determine the uranium concentrations (U_C) according to track density per unit time (ρ) in a unit (Track/cm^2.hour), as from the following equation [21]:

$$U_c\ (ppb) = \frac{(\rho + 12.5)}{18.6} \qquad (1)$$

The concentrations of ^{218}Po and ^{214}Po (POW and POS), deposited on the wall and face of the irradiation chamber, were identified using the below equations [22, 23]:

$$D_{P218} = D_{P214} = \frac{C}{4} r \left(\frac{r}{r+h}\right) cos\theta_C \qquad (2)$$

$$D_{P218} = D_{P214} = \frac{C}{4} r \left(\frac{r}{r+h}\right)\left(cos\theta_C \frac{r}{R_\alpha}\right) \qquad (3)$$

where, C refers to the radon concentration, h denotes the distance extended from the sample surface to the detector, r represents the exposure tube radius, that is 0.75 cm, R_α signifies the average range of alpha particle in the air for radon-222, measured at 4.15 cm, and θ_C indicates the mean critical angle for CR-39 detectors, recorded at 15° [23, 24].

3. STATISTICAL ANALYSIS

IBM SPSS Statistics program was employed for the conduction of statistical analysis of the data, particularly (version 27 for the Windows) operating system. The Mann-Whitney test compared mean uranium, POW, and POS concentrations (means ± S.D) in cancer Patients and healthy males and females. This non-parametric test compares two independent groups when the data are not normally distributed. It is used to determine whether the two groups have statistically significant differences.

4. RESULTS AND DISCUSSION

Table 2 demonstrates the results of uranium U_C, POW, and POS concentrations in blood serum samples from cancer patients, male and female, respectively. The values of U_C in male patients ranged from 0.082 ppb to 0.171 ppb while the values of U_C in female patients ranged from 0.084 ppb to 0.126 ppb, respectively. The values of POW in male patients ranged from 1.41 Bqm^{-3} to 9.06 Bqm^{-3} while the values of POW in female patients ranged from 1.60 Bqm^{-3} to 5.24 Bqm^{-3}, respectively. The values of POS in male patients ranged from 0.25 Bqm^{-3} to 1.64 Bqm^{-3}. While the values of POS in female patients ranged from 0.29 Bqm^{-3} to 0.95 Bqm^{-3}, respectively.

Table 2. Results of uranium concentrations in cancer patient groups in the present study.

No.	Gender	Sample code	U_C ppb	POW Bqm^{-3}	POS Bqm^{-3}
1	Male	MC1	0.088	1.92	0.35
2		MC2	0.107	3.54	0.64
3		MC3	0.082	1.46	0.26
4		MC4	0.091	2.15	0.39
5		MC5	0.088	1.92	0.35
6		MC6	0.097	2.71	0.49
7		MC7	0.144	6.72	1.22
8		MC8	0.123	4.98	0.90
9		MC9	0.171	9.06	1.64
10		MC10	0.127	5.28	0.95
11		MC11	0.082	1.41	0.25
12		MC12	0.106	3.51	0.63
13		MC13	0.117	4.39	0.79
14		MC14	0.120	4.66	0.84
15		MC15	0.119	4.57	0.83
16	Female	FC1	0.126	5.24	0.95
17		FC2	0.084	1.60	0.29
18		FC3	0.087	1.82	0.33
19		FC4	0.089	1.99	0.36
20		FC5	0.117	4.42	0.80
21		FC6	0.117	4.43	0.80
22		FC7	0.099	2.91	0.53
23		FC8	0.114	4.22	0.76
24		FC9	0.087	1.84	0.33
25		FC10	0.103	3.26	0.59
26		FC11	0.104	3.35	0.61
27		FC12	0.091	2.22	0.40
28		FC13	0.091	2.16	0.39
29		FC14	0.093	2.33	0.42
30		FC15	0.095	2.58	0.47

Table 3 shows the results of U_C, POW, and POS concentrations in blood serum samples from healthy males and females, respectively. The values of U_C in healthy males ranged from 0.073 ppb to 0.082 ppb while, the values of UC in healthy females ranged from 0.073 ppb to 0.074 ppb, respectively. The values of POW in healthy males ranged from 0.68 Bqm^{-3} to 1.44 Bqm^{-3} while the values of POW in healthy females ranged from 0.66 Bqm^{-3} to 0.74

Bqm^{-3}, respectively. The values of POS in healthy males ranged from 0.12 Bqm^{-3} to 0.26 Bqm^{-3} while the values of POS in healthy females ranged from 0.12 Bqm^{-3} to 0.13 Bqm^{-3}, respectively.

All criteria in blood serum samples are compared between patient and healthy groups using the Mann-Whitney Test. With a p-value less than 0.01. Table 4 and Table 5 clearly illustrate the extremely significant variations between the sick and healthy groups for U_C, POW, and POS. The results indicated that men exhibited the greatest amounts of uranium, ^{218}Po, and ^{214}Po, whilst females had the lowest values. The mean concentrations of uranium, ^{218}Po, and ^{214}Po in cancer patient samples from the Al-Najaf governorate were greater than those in healthy individuals, for both men and females, as seen in Table 4 and Table 5, respectively.

Table 3. Results of uranium concentrations in healthy groups in the present study.

No.	Gender	Sample code	U_C ppb	POW Bqm^{-3}	POS Bqm^{-3}
1	Male	*MH1	0.080	1.26	0.23
2		MH2	0.082	1.44	0.26
3		MH3	0.079	1.20	0.22
4		MH4	0.080	1.26	0.23
5		MH5	0.073	0.68	0.12
6	Female	**FH1	0.074	0.73	0.13
7		FH2	0.073	0.69	0.12
8		FH3	0.073	0.69	0.12
9		FH4	0.074	0.74	0.13
10		FH5	0.073	0.66	0.12

*MH = male healthy, **FH = female healthy

Table 4. Results of uranium, POW and POS concentrations in patient and healthy groups in males.

Radioactivity	Groups	N	Mean ± SD	P value
U_C ppb	patient	15	0.110±0.024	0.001
	healthy	5	0.078±0.003	HS
POW Bqm^{-3}	patient	15	3.885±2.132	0.001
	healthy	5	1.168±0.287	HS
POS Bqm^{-3}	patient	15	0.702±0.386	0.002
	healthy	5	0.212±0.053	HS

Table 5. Results of uranium, POW and POS concentrations in patient and healthy groups in females.

Radioactivity	Groups	N	Mean ± SD	P value
U_C ppb	patient	15	0.099±0.013	0.001
	healthy	5	0.073±0.001	HS
POW Bqm^{-3}	patient	15	2.958±1.146	0.001
	healthy	5	0.702±0.032	HS
POS Bqm^{-3}	patient	15	0.535±0.207	0.001
	healthy	5	0.124±0.005	HS

Figure 1 shows three box plots representing the concentrations of U_C ppb, ^{218}Po (POW), and ^{214}Po (POS) in a group of male patients. The median value of U_C is around 0.10, indicating that most values are concentrated near this point. An outlier above 0.18, located beyond the upper whisker, suggests a case with a high concentration. The IQR

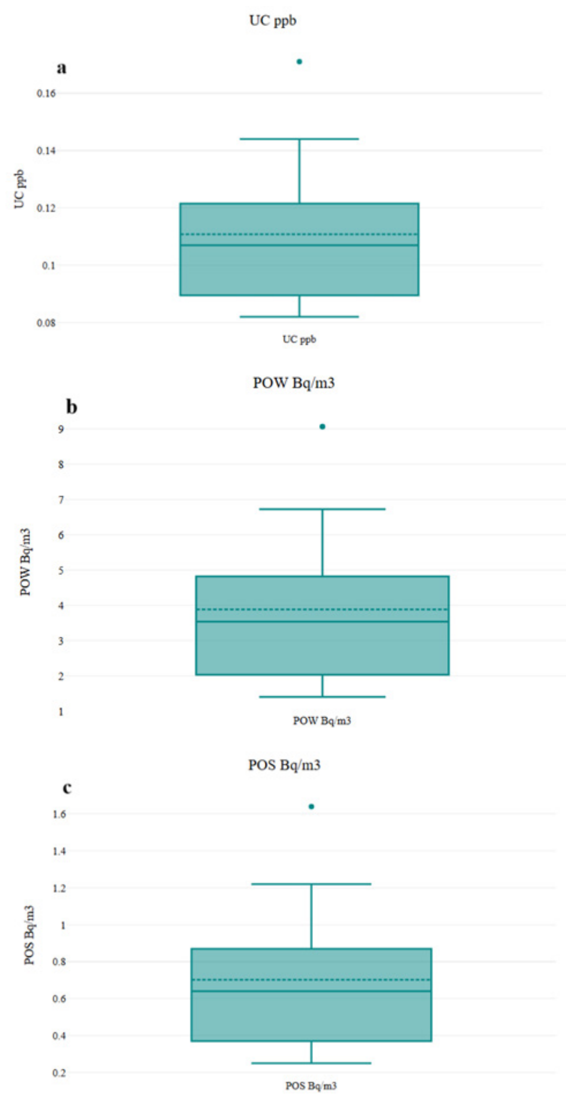

Fig. 1. Box plot of (a) uranium, (b) POW, and (c) POS concentrations in patient groups for male.

shows moderate dispersion, reflecting a relatively stable distribution of concentrations. The median (POW) here is slightly above 4, indicating higher concentrations compared to Uranium. Outliers above 9 indicate some cases with higher-than-usual concentrations. The box shows relatively wide dispersion, suggesting variability in ^{218}Po levels among patients. The median of POS is around 0.8, reflecting lower concentrations compared to ^{218}Po. There are also outliers in sample MC9. Moderate dispersion in the IQR reflects relatively uniform data.

Figure 2 shows three box plots representing the concentrations of U_C**,** POW, and POS in a group of female patients. The median concentration is approximately 0.10, indicating that most values are concentrated around this point. There are no significant outliers, and the upper whisker extends just above 0.12. The IQR shows moderate dispersion, reflecting a stable concentration distribution. The median of POW concentration is around 3, indicating higher levels compared to Uranium. No outliers are present, and the whiskers show moderate spread, with values reaching up to about 5. The relatively wide IQR suggests variability in ^{218}Po concentrations among female patients. The median of POS concentration is near 0.6, indicating lower levels compared to ^{218}Po but slightly higher than Uranium. No outliers are present, and the whiskers extend from approximately 0.2 to 1.0. Moderate dispersion within the IQR suggests a consistent distribution of ^{214}Po concentrations.

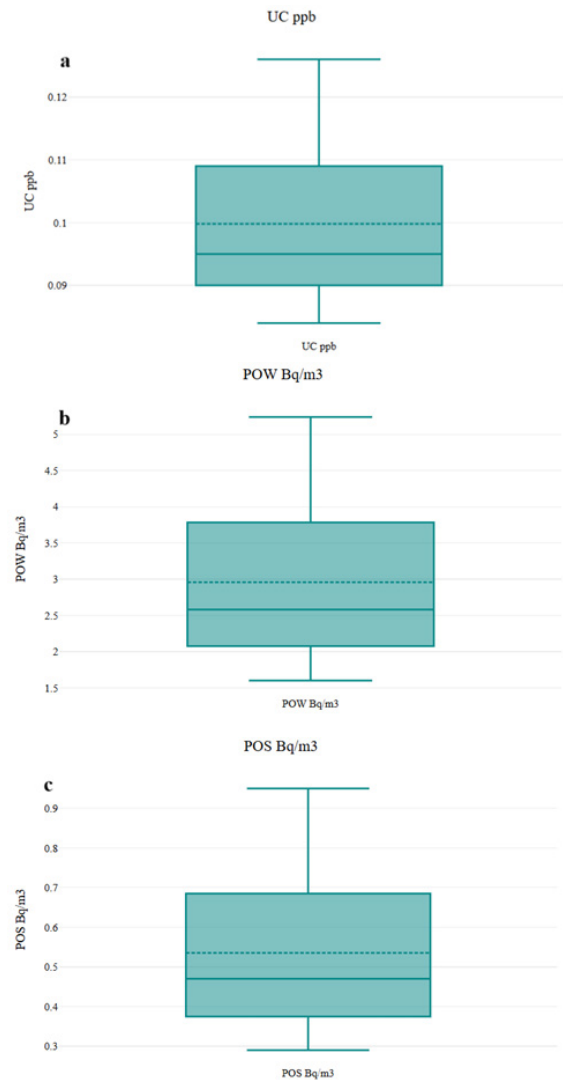

Fig. 2. Box plot of (a) uranium, (b) POW and (c) POS concentrations in patient groups for females.

Uranium is found in trace levels in soil, water, rocks, and living things. Everybody possesses trace amounts of natural uranium. Uranium's inherent radioactivity is low, resulting in little radiotoxicity. However, having considered it is a heavy metal, it has chemical toxicity (lead), which is more serious than its radiotoxicity. Lethal doses of uranium vary from several grams, while the standard body of male (adult) content is around tens of milligrams [8, 25]. Uranium and polonium levels in blood serum samples from male and female patients and healthy people were measured. Both men and women in the ill group had higher mean uranium and polonium levels than healthy people. The Mann-Whitney Test showed a significant difference in uranium levels between the ill and healthy groups ($P<0.01$). The ill have higher uranium and polonium levels than non-patients. The afflicted group had 61% more uranium in their blood below and the internationally healthy group. The findings showed that both sick and healthy persons had blood serum uranium concentrations below the ICRP (International Commission on Radiological Protection) limit of 0.801 ppb [26, 27]. Additionally, none of the samples in this investigation had polonium values above the 550 Bqm^{-3} WHO (World Health Organization) recommended safe level [28]. The findings of this research demonstrate that the amounts of radon progeny (POW and POS) in blood serum samples varied across all men and females, regardless of health status. The prolonged indoor confinement of most women presumably resulted in increased radiation exposure; however, the variation may also stem from the nature of the samples and the nuclear composition inside them.

Table 6. Pearson correlation between variables for female and male patients.

Pearson correlation		U_C		POW		POS	
		M	**F**	**M**	**F**	**M**	**F**
U_C	M	1	-0.3	1**	-0.2	1**	-0.3
	F	-0.3	1	-0.3	1**	-0.2	1**
POW	M	1**	-0.3	1	-0.2	1**	-0.2
	F	-0.2	1**	-0.2	1	-0.2	1**
POS	M	1**	-0.2	1**	-0.2	1	-0.2
	F	-0.3	1**	-0.2	1**	-0.2	1

** Correlation is significant at the 0.01 level (2-tailed).

The study findings indicate that the blood may be devoid of environmental contaminants, and the levels of radon progeny (POW and POS) are much below international safety standards. The findings indicated that radon levels fluctuate based on the kind of cancer, individual patient, and geographical region, attributable to the body's allergic response to radiation [11]. All findings were markedly elevated for male patients compared to female individuals. Radiation induces an allergic reaction in women, perhaps explaining the lower radon levels seen in this demographic; women who spend prolonged durations at home are more susceptible to elevated radiation exposure. Individuals who spend greater durations inside have decreased ventilation rates compared to individuals who spend less time in their residences. Numerous research has been made using CR-39 NTD (Nuclear Track Detectors) to ascertain the quantity of uranium/radon progenies and alpha emitters in biological materials, facilitating a deeper comprehension of radon and its ephemeral offspring. Splatter investigations have been made using CR-39 NTDs, to assess the content of uranium (U_C), radon progenies (POW and POS), and alpha emitters in biological samples, facilitating a deeper comprehension of radon and its ephemeral offspring [29-32].

Table 6 displays Pearson correlation coefficients between Uranium, ^{218}Po (POW), and ^{214}Po (POS) concentrations for both male and female patient groups.

Uranium and ^{218}Po (POW):
For males, there is a very strong positive correlation ($r = 1.000$, $p<0.01$), suggesting that as Uranium levels increase, ^{218}Po levels also increase consistently.

For females, the correlation is weak and not statistically significant ($r = -0.302$, $p>0.05$).

Uranium and ^{214}Po (POS):
In males, there is a strong positive correlation ($r = 1.000$, $p < 0.01$). or females, the correlation is weak ($r = -0.301$) and not significant.

^{218}Po (POW) and ^{214}Po (POS):
In both males and females, there is a significant positive correlation (males: $r = 1.000$, females: $r = 1.000$, $p<0.01$), indicating a consistent relationship between these two isotopes across genders.

Lastly, strong correlations between Uranium, ^{218}Po, and ^{214}Po are observed in male patients, indicating similar concentration patterns. In contrast, correlations are weaker and less significant among females, suggesting different distribution or metabolic patterns.

5. CONCLUSIONS

This research aimed to investigate uranium and polonium concentrations in serum samples from cancer patients and healthy individuals. The results revealed that the mean uranium and polonium levels in patient samples were higher than those in healthy samples. Additionally, male participants exhibited greater mean uranium and polonium concentrations compared to females. However, the concentrations of studied uranium in all examined samples were generally low, remaining below the global average levels reported by the International Commission on Radiological Protection (ICRP). Similarly, polonium concentrations in all samples were below the limits recommended by the World Health Organization (WHO). Therefore, the uranium and polonium (POW and POS) concentrations in blood serum samples from patients and healthy males and females in Al-Najaf Governorate, Iraq, were determined to be within safe limits.

6. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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