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Comparison the Level of Radon Gas Concentration and Its Progenies (^{218}Po, ^{214}Po) for Ovary Tumors (Benign and Malignant) among Female in Najaf, Iraq

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Abstract

Many studies have discovered a direct correlation between cancerous diseases and radiation exposure. The radionuclides such as radon and its progeny which emit alpha particles are highly toxic because they release a large amount of energy in a short distance within living tissue when they enter the body through ingestion or inhalation and absorption through the skin. The object of this study is to determine and compare the concentrations of radon and its progeny in the fresh blood of 60 female patients of different ages suffering from benign ovarian (BO) tumors (N = 30) and malignant ovarian (MO) tumors (N = 30) in Najaf Governorate, Iraq, by using CR-39 detector. The results indicated that the maximum values of concentration of radon (^{222}Rn), and polonium (PO_W, PO_F) in Bq/m³ were 20.138, 0.0582, 0.0266 and the minimum values were 7.638, 0.0220, 0.0101 with the mean value of 12.152, 0.0354, 0.0160 in BO group , while MO group where the maximum value were 142.361, 0.411, 0.188, the minimum value were 6.25, 0.018,0.008 with the mean value were 42.731,0.123, 0.056, respectively. Finally, the radon concentrations and its progeny in all samples were below the permitted limit of ICRP. The concentration measurement of radon and its short-lived progeny is critical in providing basic and important information for related research taking radon and its progeny as radioactive tracers.

Keywords: Radionuclides, Fresh blood; Ovarian tumors; Carcinogenicity; CR-39 detector.

1. Introduction

Every person on Earth is exposed to natural radiation, radon gas is considered the primary source of radiation. Radon (Rn-222) is an odorless, colorless, naturally occurring, radioactive noble gas (Peramune *et al.,* 2023). It is produced by various decay chains of uranium-238 and radium-226 and has no stable isotopes. Radon gas is released from the rocks and ground and enters buildings. There, radon accumulates indoors. Here, alpha particles are introduced to the human organism via food, water, or inhaled air via the digestive or respiratory systems. Radon decays with a half-life of 3.8 days to a short-lived (~30 min or less) series of progeny that have been referred to as radon daughters. Alpha radiation is emitted from Short-lived radon decay products (polonium; ^{210}Po, bismuth; ^{210}Bi, and lead; ^{210}Pb) that can interact with atoms to excite and ionize them and hence may damage human tissue (Catherine, 2023). Ovarian cancer is the deadliest cancer of the female reproductive organs and ranks third internationally. According to GLOBOCAN, Estimated New Cases of 19,710 and 13,270 deaths in 2023 (Yang *et al.,* 2023). By 2040, according to the GLOBOCAN prediction, the number of new cases and fatalities from ovarian cancer will grow by 96% and 100%, respectively (Ye *et al.,* 2024). A Solid-State Nuclear Track Detectors (SSNTDs) also known as etched track detectors are insulating solid materials with specific resistivity 10^6 – 10^{20} Ohm. cm that are used widely in several technical applications for the detection of the heavy ion, α- particle, proton, and fission fragments. The damaged area is called the latent path or path of radiation damage. Solid state nuclear track detector (CR-39) is an amorphous polymer, that consists of short polyallyle chains joined by links containing carbonate and die ethylene glycol groups (C_{12} H_{18} O_7) with a density of 1.30 g/cm^3 and molecular weight of 274 a.m.u. (Salvadori, 2021). The detector (CR-39) has a high efficiency in recording and detection track of alpha-particles and measurement and also for neutron dosimetry and it has some specifications such as being Optically transparent, very sensitive to radiation, highly isotropic and homogeneous, not sensitive to high doses of X-rays, and gamma-rays, having a non-solvent chemical etchant, inexpensive, ease of use as the track. detectors register alpha particles from radon and progeny (Stabilini, 2021). To determine risk factors like alpha energy concentration and exposure to radon progeny, as well as to conclude the potentially dangerous effects of radioactivity on the incidence of gynecological tumors, this study will use the CR-39 solid-state nuclear track technique to measure the concentration levels of radon and its progenies in the blood of female with ovarian tumors (benign and malignant) in the Najaf governorate. Determining the levels of radon and its derivatives in ovarian tumors is of significant importance for understanding their potential role in the development and progression of ovarian cancer. Radon can decay into harmful radioactive particles known as radon progeny, which may become lodged in tissues, and impact various body organs, including the ovaries. Research suggests that long-term exposure to radon and its derivatives could contribute to cellular damage and DNA mutations, potentially increasing the risk of tumorigenesis. By measuring the concentration of radon and its decay products in ovarian tumor tissues, researchers can gain valuable insights into the environmental and biological factors that influence cancer development. This can help identify high-risk individuals, improve early detection methods, and possibly open avenues for targeted interventions or radiation-based therapies for ovarian cancer patients, improving prognosis and treatment outcomes. Understanding radon's potential impact on ovarian tumors could also contribute to broader public health efforts aimed at reducing exposure to this carcinogenic substance.

2. Methodology

2.1 Preparation of fresh blood samples for analysis

The samples were collected from 60 females suffering from benign and malignant ovarian tumors undergoing chemotherapy. Blood samples are obtained after being diagnosed by Gynecologists and hematologists from the Al-Furat Al-Awsat Center for Oncology in Najaf governorate. This investigation was predicated on a study of 30 females with benign ovarian (BO) tumors and 30 females suffering from malignant ovarian (MO) tumors which aged from 24 to 75 years for both groups. All patients were asked to fill out a questionnaire with their consent to use and share the results of the study for scientific purposes only. It also included information such as age, weight, marital status, type of disease, Menopausal status, and smoking. To prepare the sample, 3 ml of blood from volunteers were drawn by vein puncture using disposable syringes. immediately were transferred to a tube containing Ethylenediaminetetraacetic Acid (EDTA) to prohibit blood coagulation until they reached the laboratory. The samples were protected in an ice box and transferred to a lab for refrigeration in the fridge. To differentiate them from one another, each sample was assigned a unique code, and they were all kept in storage at 4 °C. in a deep freeze (without thawing) until the analysis process. then, the blood samples were allowed to thaw on the workbench. Then, the fresh blood samples were put in the PVC tubes. The

CR-39 detector sheet is cut into small parts, with (1.0 cm × 1.0 cm) dimensions with a density of 1.32 g/cm³ and thickness of 500 µm. The detector has two sides, one used only for measurement and the other can engrave code on it to distinguish it from other detectors. The samples were put in the end of PVC tubes and all detectors were steady by blu-tack at the top end of PVC tubes with a diameter of 3.8 cm and a length of 6 cm, as shown in Figure 1. After that, the samples were kept for 60 days at room temperature in a dry location to ensure they reached the radioactive state and to detect radon and its progenies in the blood samples.

2.2 Procedures of chemical etching, counting, and track visualization

Chemical etching is the common method used for detecting traces of primary damage. The etching technique consists of four steps: etching, washing, drying, and observing under an optical microscope. After a sixty-day exposure period, the detectors are removed from the PVC tube. Etching starts by heating an aqueous of 6.25 N sodium hydroxide (NaOH) solution and 250 ml distilled water at 98 °C for 1 hour and keeping it there using a thermostatically regulated water bath to ensure that the solution's temperature stays constant during the process (Ramu, 2020). Usually, the etching solution is added to a large glass beaker and submerged in the bath at a predetermined temperature. The top of the beaker is covered with a lid to prevent evaporation and the consequent rise in the solute concentration of the etchant solution(Kang, An, & Stockbridge, 2024). Normality is calculated using the formula below (Abboud & Almayahi, 2021)

$$W = Weq \times N \times V$$

Where: W is the weight in grams of NaOH; Weq is the equivalent weight of NaOH = 40; V is the volume of distilled water (250 ml); N is the normality (6.25)

To stop the etching process, the CR-39 detector was cleaned with running cold water for 20 minutes. After that, it was washed again with filtered water to get rid of any last traces of NaOH. After the detector was cleaned, hot air was utilized to dry it thoroughly (Mohammed, 2023). Visualization of CR-39 NTD data Following the three stages of etching, cleaning, and drying, an optical microscope was used (Olympus-type with a high accuracy power of 400X, an optic lens of 10X, and an objective lens of 40X) to count the alpha particles emitted by the radon gas to calculate the track density created on the CR-39 reagent (Salih & Hussein, 2022), as shown in Figure 2.

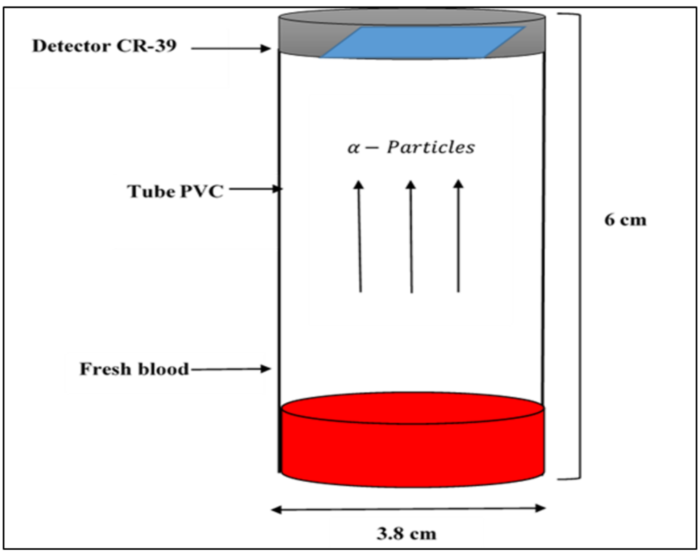
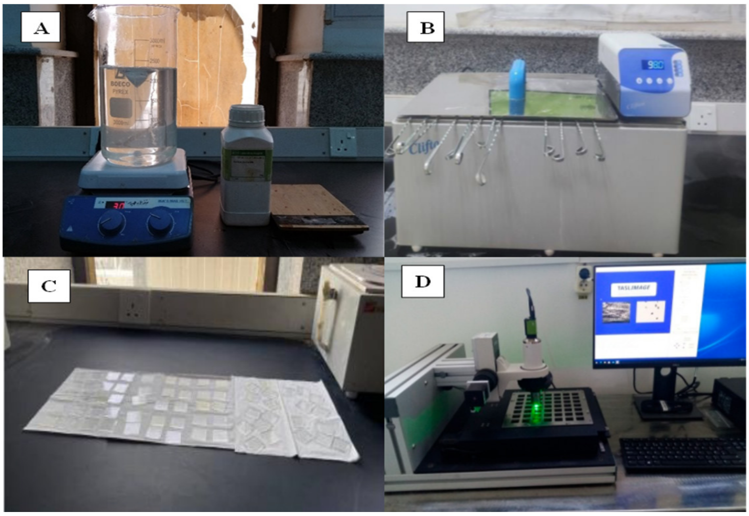


Figure 1. Diagram of the container used for measuring alpha concentrations in fresh blood samples



(A) Magnetic Stirrer; (B) The Clifton Digital bath; (C) Drying of reagents; (D) The TASLIMAGE system

Figure 2. Steps and equipment for etching and optical reading of the TASTRAK detectors exposed to radon

2.3 Calculations

After the four steps of the drilling and scanning process, the results are analyzed to determine the Radon and its progenies levels in fresh blood samples for patients with benign and malignant ovarian tumors connected to a programmed computer that was used to read the traces after the chemical scraping process. To measure the radon and its progenies concentrations determine the diffusion constant (K_{RC}) to system used of alpha particles. This factor was determined in this study via a formula adapted from the studies by Baskaran (2016)

$$K_{RC} = 0.25\ r\ (2\cos\theta C - r/\ R\alpha)$$

Where: $\boldsymbol{\theta c}$ = the critical angle (θc = 35°) of the CR-39 detector; r = (1.9 cm) radius of the tube; $R\alpha$ = (4.15cm) is the average of a range of alpha particle in the air to ^{222}Rn

Thus, the concentration calculations' calibration factor was 0.048 ($Tr.cm^{-2}/Bq{\cdot}m^{-3}{\cdot}d$). The measured $^{222}_{86}Rn$ concentrations in the air inside the can are represented according to the equation (Alrekabi, 2020)

$$C_{Rn}^{a}(Bq/m^3) = \rho/k\mathrm{t}$$

Where: ρ represents the track density of all tracks within a given area of the field view in units (Tr/cm^2); t denotes exposure time

Additionally, the following equations can be used to estimate the concentration of radon progeny, $^{218}_{84}PO$ and $^{214}_{84}PO$ that produce alpha particles and are deposited on the detector's face PO_F and can walls PO_W (Panigrahi & Mishra, 2016)

$$C^{218}_{84}Po_{\ wall} = C^{214}_{84}Po_{\ wall} = (C/4)\ (h/r+h)\ \cos\theta c$$
$$C^{218}_{84}Po_{\ face} = C^{214}_{84}Po_{\ face} = (C/4)\ (h/r+h)\ (\cos\theta c\ r/R\alpha)$$

2.4 Statistical Analysis

The descriptive statistical analyses were conducted via Statistical Package for Social Sciences (SPSS version 21.0, IBM, USA). The results were expressed as descriptive statistics, analysis of variance (ANOVA), independent samples T-test, and Pearson correlation coefficient were used to analyze data and compare between groups through determine the variations, relationships, and measure the strength of association of the variables under study among blood levels of female with benign and malignant ovarian tumors. A P-value of less than 0.05 was deemed statistically significant.

3. Results and Discussion

This study included 60 female patients with ovarian tumors (benign and malignant).

The results of radon concentrations (C_{Rn}^{a}), and its progenies (CPo^{214}, CPo^{218}) in blood samples for female patients with benign and malignant ovarian tumors by using a CR-39 detector are shown in Table 2, and Figure 3. The results showed that the concentration of radon gas in female with BO tumors, ranged from the lowest value, equal to 7.638 Bq/m³ while the highest concentration was 20.138 Bq/m³ with a mean (± SD) value 12.15 ± 3.52 Bq/m³. On the other hand, the lowest value of the concentration of radon in samples of blood for females with MO tumors 6.25 Bq/m³, while the highest concentration was 142.361 Bq/m³ with a mean (± SD) value of 42.731 ± 33.04 Bq/m³. Female patients with benign and malignant ovarian tumors had radon progenies (^{214}Po, ^{218}Po) deposited on the walls of the irradiation container (PO_W) and on the face of the detector (PO_F) by the highest concentrations of polonium 0.0582 and 0.0266 Bq/m³, female patient with age of 66 years. The lowest concentrations of polonium were 0.022 and 0.0101 Bq/m³, female patients with age of 40 years respectively, in patients with (BO). On the other hand, for patients with malignant tumors, according to Table 2 and Figure 3, the highest concentrations of polonium (PO_W) and (PO_F) were 0.411 and 0.188 Bq/m³, female patients with age 49 years. In comparison, the lowest concentrations were 0.018 and 0.008 Bq/m³, for female patients with age of 50 years, respectively. This occurs depending on the "critical angle of alpha particles" striking the CR 39 detectors. Also, the value of polonium concentration (PO_W = 0.0354 and PO_W = 0.123 Bq/m³) was greater than the average value of polonium concentration (PO_F = 0.0160 and PO_F = 0.056 Bq/m³) in patients with benign and malignant tumors, respectively, due to distribution on the chamber's surface, which is concentrated in a limited area and is therefore less than the tracks distribution on the chamber's walls. According to these values that were listed above, we find that the highest concentration of radon and its progenies were in the group of female suffering from (MO.) tumors compared to patients with (BO) tumors.

ANOVA and t-test were used to determine the variations and compare between groups, where the results showed a difference between the groups and statistical significance between all values with (p-value = 0.00).

Also, this study calculated the confidence interval (CI, 95%), which indicates the range for the average concentrations of both radon and its progeny (^{222}Rn, PO_W, PO_F) in blood samples for patients with BO and MO tumors. The average difference in concentrations was observed in 95% of the studied samples, ranging from the lower bound value 42.72, 0.12355, 0.05656 to the upper bound value 18.43, 0.05330, 0.02440, respectively as shown in Table 2. The Pearson correlation coefficient r, which measures the strength of association among the variables under study was calculated in blood samples of both groups. The Findings indicated a significant positive direct correlation (r = 0.40, Sig = 0.02) between radon concentration and age. Additionally, a non-significant positive

Table 1. Female patients' characteristics with benign and malignant tumors of the ovaries.

Groups	Parameters	Min.	Max.	Mean ± SD
Benign Ovarian Tumours (N = 30)	Age (year)	24	75	53.9 ± 12.66
	BMI (kg/m^2)	60	88	73.7 ± 6.55
	Menopausal status	53	75	64.4 ± 7.04
	Smoking habit	42	75	63.37 ± 10.32
	Non-Smoker	24	70	50.45 ± 11.80
Malignant Ovarian Tumours (N = 30)	Age (year)	29	75	54.5 ± 12.16
	BMI (kg/m^2)	60	95	78.3 ± 8.46
	Menopausal status	50	75	62.16 ± 8.51
	Smoking habit	40	75	59.57 ± 11.73
	Non-Smoker	29	69	50.06 ± 11.02

correlation (r = 0.25, Sig = 0.17) existed between radon concentration and body mass index (BMI). Furthermore, an insignificant inverse correlation (r = -0.09, Sig = 0.62) decreasing relationship between BMI and age was observed among female with BO tumors. Whereas, there was a positive, significant direct correlation (r = 0.54, Sig = 0.002) between radon concentration and body mass index, indicating that these factors tend to rise together (i.e., greater radon concentration is associated with greater BMI). There was a weak, non-significant positive correlation (r = 0.18, Sig = 0.32) among age and radon concentration for female with MO tumors as shown in Table 3 and Figure 4.

Table 2. Findings the level of radon and its progenies in fresh blood samples for female patients with benign and malignant ovarian tumors in Najaf governorate

Radionuclides	Cases (n = 30)	Min.	Max.	Mean ± SD	Std. Error	Levene's Test	p value	95% Confidence Interval of the Difference	
								Lower	Upper
^{222}Rn	BO.	7.63	20.13	12.15 ± 3.52	0.643	40.45	0.00	42.72	18.43
	MO.	6.25	142.36	42.73 ± 33.04	6.033				
PO_W	BO.	0.02	0.05	0.03 ± 0.01	0.001	40.45	0.00	0.12	0.05
	MO.	0.01	0.41	0.12 ± 0.09	0.017				
PO_F	BO.	0.01	0.02	0.01 ± 0.00	0.000	40.45	0.00	0.05	0.02
	MO.	0.008	0.18	0.05 ± 0.04	0.007				

BO: Benign Ovary; MO: Malignant Ovary; *p-values < 0.05 were considered significant

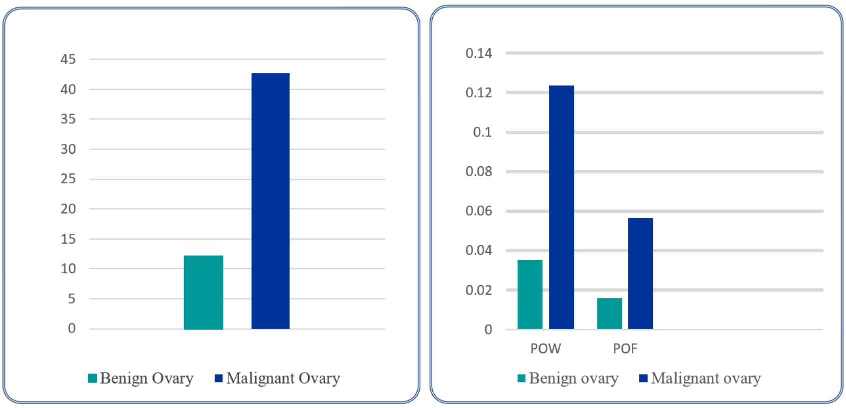


Figure 3. Comparison of the results between the patients with ovarian tumors (benign and malignant)

Table 3. Pearson Correlation between Radon, Age, and BMI in female patients' group with ovarian tumors (benign and malignant)

Benign ovarian tumors					Malignant ovarian tumors				
Statistical indicators		Con. of Radon	Age	BMI	Statistical indicators		Con. of Radon	Age	BMI
Con. of Radon	Pearson Correlation (r)	1	0.40*	0.25	Con. of Radon	Pearson Correlation (r)	1	0.18	0.54**
	Sig.		0.02	0.17		Sig.		0.32	0.002
Age	Pearson Correlation (r)	0.40*	1	0.09	Age	Pearson Correlation (r)	0.18	1	0.06
	Sig.	0.02		0.62		Sig.	0.32		0.73
BMI	Pearson Correlation (r)	0.25	0.09	1	BMI	Pearson Correlation (r)	0.54**	0.06	1
	Sig.	0.17	0.62			Sig.	0.002	0.73	
* Correlation is significant at the 0.05 level (2-tailed)					**Correlation is significant at the 0.01 level (2-tailed)				

The findings demonstrated that the blood samples' radon levels from 60 females suffering from benign and malignant ovarian tumors were lower than the maximum permitted by the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA) is 200 Bq/m^3, and EPA is 148 Bq/m^3 (Kurnaz, 2023). Also, the results indicated that the radon content for all females in fresh blood samples varies according to the type and nature of the tumor, from one patient to another as well as from one age to another, because of the body's allergic response to the radiation, which could account for their decreased radon levels. Women who stay at home for extended periods are more likely to experience significant radiation exposure. The rationale is that individuals who expend more time indoors have less ventilation rates than those who spend less time there; however, the difference could also be explained by the nature of the samples and the amount of nuclei in them (Kadhim *et al.* 2022). The sample size of 60 participants may not be sufficient to draw broad conclusions, which could significantly influence the results. Geographical limitations also come into play, as the study only includes participants from Najaf Governorate, which may not fully represent other regions with different radon exposure levels. Furthermore, the study's cross-sectional design limits the ability to establish causality between radon exposure and potential health effects, as it only captures data at a single point in time.

These factors highlight the need for further future studies on more cancer patients by using different biological samples in different parts of Iraq for a wider view of the results, grouping all available results from all studies conducted on this subject to be capable of finding correlations and patterns in the variation of radon concentrations and its progeniesin and explain its effect on the occurrence of carcinogenesis process, what may give human beings, a new tool on cancer diagnosis, which could, hopefully, be a step in the direction of its extinction.

Numerous investigations have been conducted to identify the concentration of radon in biological samples in different regions of Iraq by using various methods, allowing for a better understanding of radon and its short-lived progeny, as in table 4.

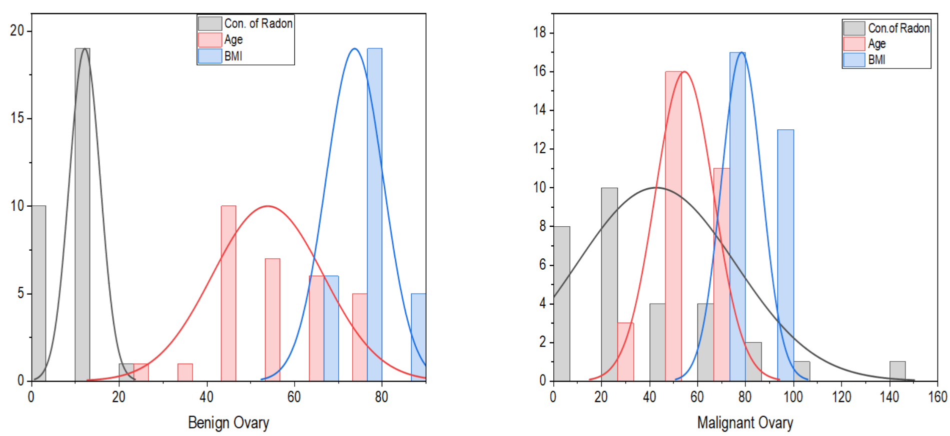


Figure 4. Correlation between radon concentration, age, and BMI in female patients with benign and malignant ovarian tumors

Table 4. Comparison of the results of the current study with Alpha particle concentrations of various cancerous diseases in different places in Iraq

no	Study area	Cancer type	Type of sample	Detector type	Radon concentration (Bq/m^3)	Ref.
1.	Karbala / Iraq	Cervical	Blood	ALR-115	23.67 ± 3.79	Hassan *et al*., 2019
2.	Erbil/ Iraq	Ovary	Blood	CR-39	15.882	Othman *et al*., 2023
3.	Sulaymaniya/ Iraq	Breast	Powdered blood	CR-39	28.790	Othman *et al*., 2022
4.	Najaf / Iraq	Skin	Blood	CN-85	15.77	Abdulwahidet al., 2020
5.	Kirkuk/ Iraq	Uterine	Urine	Rad7 CR-39	3060 3066	Ghayyib & Ibrahim, 2024
6.	Babylon/ Iraq	Breast	Blood	CR-39	69.983	Gufran & Al-Sadi, 2022
7.	Najaf/ Iraq	Benign Ovary Malignant Ovary	Blood	CR-39	12.152 42.731	This study
8.	UNSCEAR, ICRP				200-300	Marsh *et al*., 2021

4. Conclusion

The presence of radioactive materials in the human body especially alpha-emitting radionuclides like radon may play a vital role in predicting many disease like cancer. This study aimed to determine the levels of radon and its progeny in fresh blood samples of females with benign and malignant ovarian tumors. The current results indicate that females with benign ovarian tumors have a significantly lower rate of radon concentrations and its progeny (^{222}Rn, PO_W, and PO_F) compared to patients with malignant ovarian tumors. The data shows a clear distinction in the levels of these factors between the two types of tumors. A noticeable difference in the levels of PO_W and PO_F between the two groups, there is also a robust correlation among radon concentration, age, and body mass index. The results also showed that radon concentrations and its progeny are less than the acceptable UNSCEAR, ICRP, EPA, and IAEA limits. From this, we can conclude that alpha emitters differ in the human body from one person to another according to the type and nature of the tumor, as well as from age to another, and from place to place. Further studies on more cancer patients in different parts of Iraq are necessary for a wider view of the results. The determination of radon concentrations and its progeny in patients with ovarian tumors would also provide us with insight into a better understanding of the pathogenesis of the benign and malignant tumors and also to distinguish between them.

Compliance with Ethical Standards

The study's design was authorized by the relevant authorities, represented by the Najaf Health Directorate, the Al-Furat Al-Awsat Center for Oncology, the Najaf Teaching Hospital, and the Council of the College of Education for Girls at the University of Kufa. Written approvals were obtained, as well as informed consents were obtained from all participants.

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