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Research Article

Environmental Assessment for Radioactivity of Radon and Radium in Serum Blood Samples in Bladder Cancer Patients

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Abstract:

In this work, the CR-39 track detector was used to measure the levels of radon and radium in human blood samples for two groups, firstly healthy (control) and secondly bladder cancer patients. A total of fifty-six blood samples were obtained from Babylon Governorate, Iraq. The concentrations of radon and radium in the control group, which consisted of healthy adults, ranged from (62.121-233.333) Bq.m-3 and (1.207 - 4.533) Bq/kg respectively, according to our results. When comparing the blood samples between the two groups, we found a significant increase in the levels of radon and radium in the group of patients with bladder cancer as a result of their exposure to radioactive contamination, as the range of radon and radium concentrations in their blood serum samples ranged from (116.667-421.717) Bq.m-3 and (2.267-8.193) Bq/kg respectively. Smoking did not show any effect on increasing the levels of radon and radium in the study samples of the infected group, as the average concentrations were close in smokers and non-smokers, While smoking habit showed a clear effect on the blood samples of healthy individuals, as the results showed that the concentrations of radon and radium gas in smokers were higher than in non-smokers. Radon and radium concentrations were found to be significantly higher in the 50-64 age group in the patient group, while radon and radium concentrations were much lower in the healthy group compared to it. The older age group (65-79) recorded a higher concentration than the younger age group (50-64), as the concentration increases with the age of the people due to the occurrence of the accumulation condition, generally, most of the outcomes are above the acceptable international thresholds. There were statistically significant differences in the data obtained ($p<0.05$), and a strong positive significant correlation was found between the persons' age group and smoking habit and the concentrations of radon and radium.

1. Introduction

Radon is a member of the uranium decay series and is a colorless, odorless, inert gas. Occupational exposure to radon is most common in underground and surface workplaces. Radon is present in most enclosed spaces, such as homes or workplaces, such as the oil and gas industry, which has high exposure rates, and workers in phosphate fertilizer plants. Radon concentrations can be high in large proportions at the surface of the earth due to seepage from the ground or poor ventilation. Radon concentrations can also be high in groundwater, especially where granite rocks are present. Radon concentrations can also be high in natural waters [1,2]. Long-term exposure to radon can cause lung cancer. Radon decays into radioactive elements in the air, which are absorbed into the body. Radon is considered a human carcinogen by national and international organizations, including the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP), and the U.S. Environmental Protection Agency (EPA). Smoking can be a major source of high concentrations of radon in the body and a major cause of cancer [3,4].

Radium-226 is widely distributed in the environment and is found in varying concentrations in water, soil, sediments, and rocks. Its importance for radium is highlighted by its chemical organicity, such as calcium, which is deposited on bone surfaces and mineral activity areas as well [5,6]. When radium is ingested, even materials are rapidly excreted, and there is no clear behavior of elemental radium for the clear behavior of calcium, it is excluded from the blood by the disorder (gastrointestinal tract) or the lungs and follows the control of calcium and is deposited primarily in the bones [7,8]. During the past decade, there has been increasing interest in studying the radioactivity of radium in various types of food oils, because radium is a very radioactive chemical element and is the most important source of reading activity in a variety of foodstuffs. Radium is a common radioactive element under normal conditions of temperature and pressure [9]. The small number of interactions in the environment through which bone tissue interactions can be improved. And that ingestion or exposure of the body to radium as a result of psychological trauma, which includes ulcers, anemia, bone cancer, and other disorders [10,11].

All living organisms consist of microscopic structures known as cells and a vital part of the cell mass of the cytoplasm surrounded by the cell membrane and in the middle of it is the nucleus containing the chromosomes that carry the genetic traits [12]. The biological specialization of radiation in the entire living body depends on several factors, including: the type of radiation and its energy, the period of exposure, the ability of the different organs of the body to store radioactive materials, and finally the type of organ and the intensity of its sensitivity to radiation. Exposure to radiation affects the body's cells directly and indirectly [12,13]. In the direct method, the bonds between the components of the molecules of the compounds are broken and foreign molecules are formed. Examples of this include the effect of radiation on the nucleus of the cell, as it stimulates it to divide rapidly in an uncontrolled manner, which is known as cancerous growth. Radiation affects the genetic granules, causing a change in their composition and thus causing deformities in the embryos. As for the indirect effect, radiation targets cells indirectly, as radiation ionizes water molecules, and as a result of this ionization, hydrogen oxides are formed, which lead to the formation of free radicals. These oxides are toxic substances that combine with the components of the living cell, and this combination leads to damage to the components of the cell [14].

Many researchers have studied the levels of radioactivity in biological samples from cancer patients, Using an CR39 detector, In 2020, Inaam et al. conducted a study to ascertain the amount of uranium present in human blood samples. Using CR-39, the results showed that the average uranium content in blood was 1.38 ppb, with the highest concentration being 5.14 ppb and the lowest being 0.36 ppb [15]. Tabarek et al. in 2022, by using a CR-39 detector to quantify the amount of radon in the blood serum of patients with lung cancer. According to the findings, patients with lung cancer had mean radon concentrations of 19.2234 ± 2.15907 Bq/m3. Furthermore, radon concentrations in lung cancer patients are significantly higher than those in the healthy peoples [16]. Hassan et al. examined blood samples containing radon and radium concentrations. The results showed that radon gas values ranged from 147.36±0.08 $Bq.m^{-1}$ to 659.92±0.04 $Bq.m^{-1}$ with an average of 316.83±150.42 $Bq.m^{-1}$, and radium concentrations ranged from 13.55±0.27 Bq/kg to 60.70±0.13 Bq/kg with an average of 29.05±13.84 Bq/kg. Most of the results exceeded the accepted international limits[17]. The motivation behind the current work stems from a fundamental problem, which is the radioactive contamination in Iraq. Over 31,500 cases of cancer were reported in Iraq between 2017 and 2018, making it one of the country's major causes of death. According to some specialists, radioactive and environmental pollution by radioactive nuclei in Iraq is the primary cause of cancer in Iraq. Therefore, based on the promotion of periodic studies in this regard and for the purpose of providing data to researchers in the field of specialization and specialized research centers, a study was conducted on the radioactivity of radon and radium in blood serum samples from bladder cancer patients.

2. Experimental Methods

2.1 Samples Collection

In present work, 28 samples of bladder cancer patients and 28 samples of healthy individuals (control group) were collected, the total of samples in this study is 56. The samples of bladder cancer patients were obtained from Babylon cancer treatment center in Hillah teaching hospital, while the samples of the control group were taken from the same governorate, taking into account the factors affecting the concentration of radon and radium isotopes such as the average age between the two groups and smoking habit for comparison purposes.

2.2 The Preparation And Measurement Samples

The CR-39 tracer detector was used to measure the concentrations of radon and radium in blood serum samples. NaOH solution was prepared and used as a chemical etching for the CR-39 detector with a 6.25 N oscillation rate typically. Five milliliters of blood serum from both groups were taken and placed in a specially designed vacuum reaction chamber with drops of concentrated HCL added to ensure that no precipitates were formed [15]. Assay method is used in our work, where the CR-39 detector was divided into pieces of size (1×1) cm and fixed at the top of the reaction chamber used in the current work with the dimensions shown in Figure 1.

The samples were placed at the bottom of the chamber and then completely closed with a rubber cover. The samples were stored for 90 days, after which the CR-39 detectors were removed from the reaction chamber and washed well with distilled water, then washed in a water bath with NaOH solution for 6 hours at a temperature of 70 degrees Celsius.

The samples were washed again with distilled water and dried after cleaning and preparing them for microscopic examination using a light microscope at 400x magnification.

The concentration of ^{222}Rn in the air gap of the tube $C^{a}_{Rn}$was calculated using the following formula [16].

$$C^{a}_{Rn}\left(\frac{Bq}{m^3}\right) = \frac{p}{Kt} \qquad (1)$$

Where ρ is the detector path density (Tr/cm2), t is the exposure time, and K is the calibration factor (or sensitivity factor). This factor (K) can be determined using equation 2: [17]

$$K = 0.25r\left(2\cos\theta c - \frac{r}{ra}\right) \qquad (2)$$

where r is the radius of the reaction chamber, θ_c is the critical angle of the CR 39 detector (θ_c = 40°) and α_r is the range of the alpha particle in air (α_r= 4.15 cm). The radon concentration inside the sample C^{s}_{Rn}can be calculated by equation 3: [18].

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

Where λ_{Rn} is the decay constant (0.1814 d^{-1}), h the distance between the Surface of the sample and detector, t is the irradiation duration (90 d), and l Sample thickness in the reaction chamber. Radium concentration $C^{s,ac}_{Ra}$ was determined in samples by equation 4:[19,20]

$$C^{s,ac}_{Ra}\left(\frac{Bq}{Kg}\right) = \frac{C^{a}_{Rn}\; h\; A^s}{M^s} \qquad (4)$$

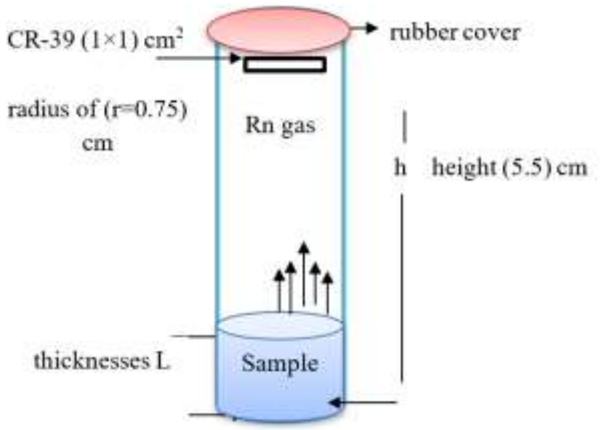

Figure 1. *Chamber reaction to determination of Radon and Radium concentrations in blood serum samples by CR-39 detector.*

3. Statistical analysis

Statistical methods in present works is used to identify the differences between the two study sample groups (bladder cancer patients and the control group), the SPSS statistical program, version 24, was used, the independent test (T) was used, and the statistical analysis was conducted to test the probability function at significance ($p<0.05$).

4. Results and Discussion

The radon and radium concentrations for all samples under the study was determined for (28) control group and (28) bladder cancer patients for different ages. Table 1 shows comparison in terms of C^{a}_{Rn} concentrations, habits, and age group.

The activities for radon $C^{a}_{Rn}$and radium $C^{s,ac}_{Ra}$ are varied, as shown in Table 1, in the control group (healthy individuals), the highest value were (233.333) Bq.m^{-3}, (4.533) Bq/kg respectively for a person 78-year-old smoker and the lowest value being (62.121) Bq.$m^{-3,}$ (1.207) Bq/kg respectively for a person 54-year-old non-smokers for the control group (healthy individuals). The concentrations in blood samples from bladder cancer patients ranged widely, from the lowest value (116.667) Bq.m^{-3}, (2.267) Bq/kg respectively, for a 77-year-old nonsmoker, to highest value (421.717) Bq.m^{-3}, (8.193) Bq/kg, respectively, for a 69-year-old smoker. The data for each group were compared and statistically examined (P value) to ascertain the significance of the probability coefficient. The results showed a significant difference when (P < 0.05), a substantial difference when (P<0.001), and a non-significant difference when (P> 0.05).

Table 1. *A comparison in terms of C_{Rn}^{a} and $C_{Ra}^{s,ac}$ concentrations, smoker habits, and age for two groups (patients and control)*

Characteristic of Radon Concentration	Patients	Sample No.	Control	Sample No.	*P* value < 0.05
All Samples	C_{Rn}^{a} (Bq.m^{-3})				
(mean ±SD)	238.290		150.812		0.013
Min. ±SD	116.667	28	62.121	28	
Max.± SD	421.717		233.333		
Smoking habit					
Smoking (mean ±SD)	239.214	14	186.111	14	0.022
Min. ±SD	116.667		100.505		
Max.± SD	421.717		233.333	14	
Nonsmoking (mean ±SD)	232.792	14	115.512		
Min. ±SD	151.515		62.121		
Max.± SD	363.636		182.323		
Age group					
50-64 ±(mean ±SD)	254.584	13	121.290	13	0.032
Min. ±SD	153.535		62.121		
Max.± SD	363.636		121.290		
65-79±(mean ±SD)	219.899	15	176.397	15	0.011
Min. ±SD	116.667		89.394		
Max.± SD	421.717		233.333		
Characteristic of Radium Concentration	**Patients**	**Sample No.**	**Control**	**Sample No.**	***P* value < 0.05**
All Samples	$C_{Ra}^{s,ac}$(Bq/Kg)				
(mean ±SD)	4.585		2.930		0.013
Min. ±SD	2.267	28	1.207	28	
Max.± SD	8.193		4.533		
Smoking habit					
Smoking (mean ±SD)	4.648	14	3.545	14	0.022
Min. ±SD	2.267		1.953		
Max.± SD	8.193		4.514	14	
Nonsmoking (mean ±SD)	4.523	14	2.244		
Min. ±SD	2.944		1.207		
Max.± SD	7.065		3.542		
Age group					
50-64 ±(mean ±SD)	4.272	13	2.357	13	0.031
Min. ±SD	2.267		1.207		
Max.± SD	8.193		2.357		
65-79±(mean ±SD)	4.946	15	3.427	15	0.011
Min. ±SD	2.983		1.737		
Max.± SD	7.065		4.533		

The difference in blood radon concentrations between the two groups is actual and statistically significant at the (P < 0.05) level. At a 95% confidence level, the results are considered acceptable when they reach statistical significance at the (P<0.05) level. The ICRP and IAEA permitted limit of 200 Bq.m^{-3} [21,22] was exceeded by the average radon concentration in blood samples from the cancer patients group compared to the control group of healthy individuals. Moreover, taking into account all of the samples gathered, it is evident that the alpha particle emission rate in the serum of the cancer group is higher than the comparable values of the healthy participants, suggesting that the cancer these people in Iraq developed was caused specifically by high levels of radon in their blood samples. The mean radon concentration in the group of patients aged 50–64 years was (254.584) Bq.m^{-3}, (4.272) Bq/kg respectively, while the mean radon concentration in the group of patients aged 65–69 years was (219.899) Bq.m^{-3}, (4.946) Bq/kg, respectively. Regarding the age of the healthy group, the mean radon and radium concentrations (121.290) Bq.m^{-3}, (2.357) Bq/kg respectively, were higher than the mean radon concentration in the group aged 65–79 years (176.397) Bq.m^{-3}, (3.427) Bq/kg, respectively, as the increase in the age group increases the probability of accumulation of concentrations with increasing exposure time, and the results were consistent with previous studies [21,22], these findings suggest that age is a significant factor in determining blood uranium levels. The mean radon and radium concentrations in smokers and non-smokers with cancer were (239.214) Bq.m^{-3}, (4.648) Bq/kg and (232.792)

Bq.m^{-3}, (4.523) Bq/kg respectively, there was no significant difference between the two concentrations. The mean radon concentrations in the healthy group were (186.111) Bq.m^{-3}, (3.545) Bq/kg for smokers and (62.121) Bq.m^{-3}, (2.244) Bq/kg for non-smokers. Overall, the findings indicate that both groups' radon and radium contents are higher in smokers. Figure 2 is radon C_{Rn}^{a} and Radium $C_{Ra}^{s,ac}$ concentrations in blood samples with healthy (control group) and cancers samples. When measuring radioactive nuclei in the presence of other influencing factors, it is important to look for correlations and analyze them statistically. Two key variables in our current work are the participants' age group and smoking status, and we definitely believe that these variables have a substantial impact on the particular radon and radium concentrations, as indicated in table 1. This is what we discovered: statistically significant differences were noted between the obtained data ($p<0.05$), and a strong positive significant association was discovered between the radon and radium concentrations and the age group of the individuals and their smoking habit**.** Figure 3: shows the correlation factors affecting on radon and radium activity. Table 2 is the correlation factors affecting on radon and radium activity for two groups (healthy and patients). Radon and also in general radiation is studied and reported widely in literature [23-30].

5. Conclusion

The average levels of radon and radium activity in blood samples from bladder cancer patients and healthy individuals in the Babylon governorate

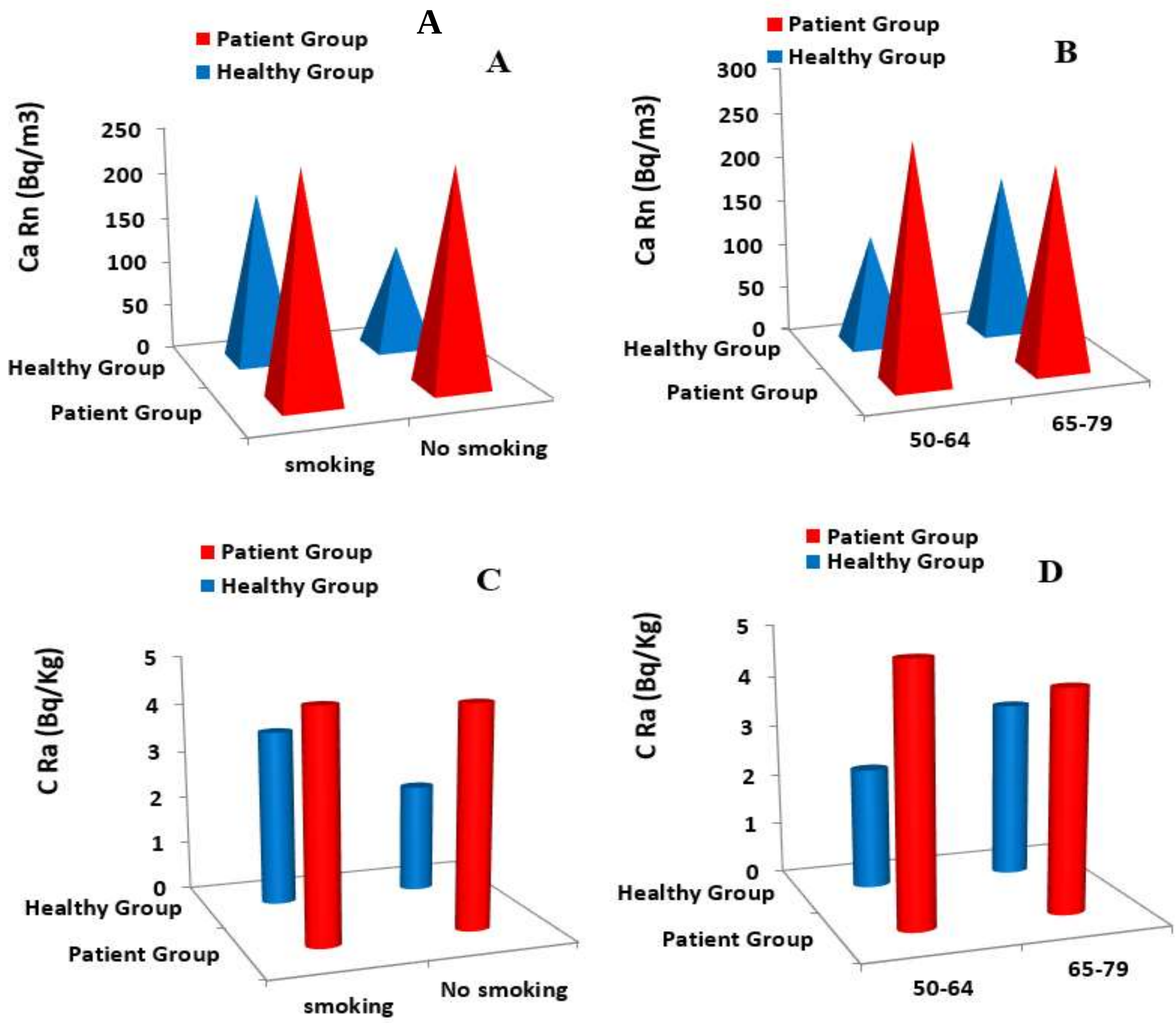

Figure 2. *Radon C_{Rn}^{a} and Radium $C_{Ra}^{s,ac}$ activity in blood samples with healthy (control group) and cancers samples .A= C_{Rn}^{a} activity as a function smoking habit. B= C_{Rn}^{a} activity as a function aged group. C= $C_{Ra}^{s,ac}$ activity as a function smoking habit. D= $C_{Ra}^{s,ac}$ activity as a function aged group.*

***Table 2.** Correlation factors affecting on radon and radium activity for two groups (healthy and patients)*

Healthy individuals (control group)				
Correlation factors		**Age**	**Smoking habit**	
			Smoking	**No-smoking**
Radon C_{Rn}^{a}	Pearson Correlation	0.911*	0.802*	0.213
	p value	0.014	0.013	0.112
Radium $C_{Ra}^{s,ac}$	Pearson Correlation	0.921*	0.829*	0.209
	p value	0.014	0.013	0.112
	samples No.	N = 28	14	14
Patient group				
Correlation factors		**Age**	**Smoking habit**	
			Smoking	**No-smoking**
Radon C_{Rn}^{a}	Pearson Correlation	0.957*	0.832*	0.193
	p value	0.011	0.012	0.132
Radium $C_{Ra}^{s,ac}$	Pearson Correlation	0.966*	0.819*	0.119
	p value	0.011	0.012	0.132
	samples No.	N = 28	14	14
	Total sample No.	N=56	* Correlation is significant at the 0.05 level.	

were measured in this study. The results showed that the concentrations of radon gas and radium in the patients group increased with mean (238.290) Bq.m^{-1}, (4.585)Bq.Kg^{-1} compared to the healthy group with a mean (150.812) Bq.m^{-1}, (2.930) Bq.Kg^{-1} for radon and radium respectively for all samples under our study, which indicates that their blood contains additional amounts of radon and radium gases, which may be a direct cause of their infection with bladder cancer. Because they have bladder cancer, the smoking habit did not show any effect on the increase in radon and radium levels in the study samples of the infected group, as the concentrations mean were close for smokers and non-smokers, with concentrations reaching (239.214) Bq.m^{-1}, (232.792) Bq.m^{-1} for radon gas and (4.641) Bq.Kg^{-1}, (4.523) Bq.Kg^{-1} for radium respectively. While, smoking habit showed a clear effect on blood samples of healthy people, as the results showed that smokers have higher concentrations than non-smokers, as the values of radon gas and radium concentrations were recorded at a mean (186.111) Bq.m^{-1}, (115.512) Bq.m^{-1} and (3.542) Bq.Kg^{-1}, (2.244) Bq.Kg^{-1} for healthy smokers and healthy non-smokers, respectively.Our results showed that the concentrations of radon gas and radium recorded a significant increase for the age group (50-64) year, compared to the older age group (65-79) year, which contradicts the logical condition that states that the concentration rate increases with age as a result of the accumulation condition due to circumstances related to their living and professional status, which explains that the younger age group received higher amounts of radon and radium gas compared to the older age group. The values of radon and radium gas concentrations showed a significant decrease in the healthy group compared to the patient group, and the older age group recorded (65-79) a higher concentration than the younger age group (50-64) due to the accumulation of radioactive nuclei with advancing age. There were statistically significant differences in the data obtained ($p<0.05$), and a strong positive significant correlation was found between the persons' age group and smoking habit and the concentrations of radon and radium.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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