Measuring of Radon Gas Concentrations in serum samples of Lung cancer patients in Babylon governorate, Iraq

Tabarek F. Naji, Samah O. Hassoon

Department of Physics, College of Science, University of Kufa, Iraq

Corresponding author e-mail: tabarkfalah19@gmail.com

Abstract. The current study aims to assess the radon concentration in blood serum of lung cancer patients in Babylon governorate and compared the measured values to the values of healthy people. Radon (222Rn) is one of typical alpha-particle emitters. Cancer cases, especially lung cancer, have been increased in a notable way in Babylon Governorate particularly after gulf wars in 1991 and 2003. So, measuring the concentration of Radon gas in serum of lung cancer patients is important to find out the relations between these cases and the war effect. This has been done in this work using a CR-39 detector to measure the alpha particles emitted from radon. Thirty samples of patients and healthy people (15 from each group) were collected. Some of these samples are collected from Babylon oncology center and some from the oncology center in Imam Al-sadiq hospital. At the end of the exposure time (70 days), track density was calculated by using TASLIMAGE system. The results showed that the mean concentrations of radon for lung cancer patients were 19.2234 ± 2.15907 Bq/m³. Further, the concentration of radon in people with lung cancer is considerably larger than that in healthy group. Interestingly, the results, also, showed that all the measured values of radon concentration (whether of patients or healthy people) are within the acceptable limit (200 Bq/m³) which is designated by both International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA).

Keywords: Lung cancer – Serum samples – Babylon Governorate – Radon gas

1. Introduction

Mainly, there are two sources of radiation that may a person expose to. These are artificial and natural sources. The former is a human made source while the latter include terrestrial radiation, internal radioisotopes and cosmogenic origins. In both cases (i.e. sources), alpha or beta particles are emitted by radionuclides. These particles can enter human body either through inhalation or indigestion process. Normally, the decay process of uranium, thorium and their daughters produce alpha particles. These particles have a detrimental effect and can damage human body cells [1]. In more details, once alpha particles are inhaled, they enter the lungs and affect their cells, causing in some cases lung or blood (leukemia) cancer [2].

Radon is a natural radioactive gas. It has no color and odor and considered as one of the poisonous gases. Naturally, Radon has three isotopes. These are 222Rn, 219Rn and 220Rn and they are produced through the
decay process of $^{238}$U, $^{235}$U and $^{232}$Th, respectively. Among those types, $^{222}$Rn is classified as the most effective isotope. This is mainly because it has a longer half-life with respect to other isotopes and that is 3.82 days [3]. Furthermore, radon as a gas, it has an ability to escape quickly from the ground to the atmosphere and can easily decay producing other short-life elements known as called radon daughters. As mentioned above, once radon gas enter a human body through inhalation process its can cause a lung cancer if it resides in the lungs or causes leukemia (blood cancer) if it transferers to the blood [4]. Accordingly, the International Agency for Research on Cancer (IARC) classifies radon as a carcinogenic agent [5].

Biologically, there are three consequences of exposing living cells to radiation. First, radiation can injury or damage the cells leading to non-residual damage or death of cells. This effect occurs normally every day to thousands and millions inside our bodies. Second, through a biological process, the affected cells are replaced systematically. Third, cells that cannot repair themselves properly can lead to biophysical changes [6, 7]. So, it can be inferred that the radiation effect is a function of the period between exposing and appearance. This means that the short-term effects are mainly due to exposing to an acute dose while chronic dose exposing causes long-term effects [8]. So, knowing the concentration of radon gas concentration in our body is important to evaluate its radiation effect. Starting from this fact, this study is designed to explore the level of Rn$^{222}$ in serum of patients suffering from cancer and healthy people at Babylon Governorate using solid state nuclear track method, finding out whether the concentrations of heavy metals and the radon concentrations are within the permissible limits globally or not.

2. Materials and methods

The lung cancer patients blood samples were collected from Babylon oncology center and Imam Al-Sadiq hospital-oncology center, and blood samples of healthy individuals from different regions of the governorate. The serum of blood samples had been taking from lung cancer patients and healthy individuals for each type 15 samples. The simple questionnaire of volunteers which including age and gender revealed within Table 1. It important to note here the patients mentioned in Table 1 were not started radiotherapy yet. Four milliliters (4ml) of blood were collected for each individual group by disposable syringe and the sample was put in a clean and dry test tube without any anti-coagulant and allowed to clot for 10 minutes at room temperature. The serum was centrifuged at 6000 rpm for 10 minutes to be separated. The separated serum, then, are put in a disposable test tubes [9]. The serum tubes are marked with codes. Each code represents a certain person, including both patient and healthy people. Following these steps, the serum samples were stored temporarily at 4°C in an icebox and then were stored in a fridge until the digestion process starts [9]. In this technique, the serum samples are put in an emanation chamber. To reach an equilibrium state between radium and radon, the emanation chamber was closed tight for about one month (4 weeks) [9].

| Table 1. Descriptive statistics of the two groups |
|-----------------|----------|------------------|
| **Classification** | **Healthy people** | **Lung Cancer Patients** |
| Males number     | 6        | 8                |
| Females number   | 9        | 7                |
| Age range (years)| 23-62    | 23-64            |
Males average age (years) | 35.8 | 49.75
Females average age (years) | 40.4 | 44.42
Average age total (years) | 38.1 | 47.08

To measure radon concentrations, CR-39 detector with a thickness of 1 mm and 2.5×2.5 cm² (from Track Analysis Systems Ltd., UK) was fixed at the top end of a plastic cup of serum sample. The dimensions of plastic cup are 3.5 cm (diameter) and 5 cm (length) as shown in Figure 1. The samples are stored in the plastic cups for about 10 weeks. After this exposure period, the chemical etching was carried out by putting CR-39 detector in a beaker containing a chemical agent solution. The chemical solution is prepared by dissolving 50 gm of NaOH (6.25 N) in 200 ml of deionized water. After immersing the detector, the beaker is heated in a water bath (type, HH-420, Germany) at a temperature of 85°C for 3 hours. In this step, the beaker is sealed tightly to prevent any changes in NaOH concentrations due to evaporation. The detectors were then washed using distilled water. Track density as detected by CR-39 detector (track/cm²) was computed using TASLIMAGE system (Figure 2). Since the background has an effect on the track density, it was subtracted from the recorded track density.

3. Calculations
As mentioned, track detector technique (CR-39) is used in this work to measure radon concentration (Alpha particles) in blood of patients and healthy people. This can be done by recording the tracks of these particles on CR-39 surface and according to these relations [10].

Figure 1. Radon Gas Estimation by CR-39 Detector.

Figure 2. TASLIMAGE System
The first relation is the track density ($\rho$) and is expressed in track / cm$^2$. The density is the tracks of radon $\alpha$ particles that are emitted when the radon is exposed to the extracted blood serum. This term is determined using equation (1).

$$\rho \left( \frac{\text{Track}}{\text{cm}^2} \right) = \frac{\text{Number of Track}}{\text{Area of view}} \ldots \ldots (1)$$

To specify alpha particles concentration ($C_{\alpha Rn}^a$, measured in Bq/m$^3$) in blood serum, equation (2) may be used [11].

$$C_{\alpha Rn}^a \left( \frac{\text{Bq}}{\text{m}^3} \right) = \frac{\rho}{K} \ldots \ldots (2)$$

Where $\rho$ is the track density expressed in Tr/cm$^2$, $t$ is the sample exposing time and it is taken to be 10 weeks (70 days) and $K$ is the diffusion constant. This constant is known in some literature as calibration factor or sensitivity factor.

It is useful to note that $K$ value is a function of test tube parameters and can be determined mathematically using equation (3) as follows [12]:

$$K = 0.25 r \left( 2 \cos \theta_c - \frac{r}{r_a} \right) \ldots \ldots (3)$$

where $r = 1.75$ cm and is the tube radius, $\theta_c = 35^\circ$ and represents the detector critical angle [12], and $r_a$ (the range of alpha particle in air) is taken to be 4.15 cm [13]. Consequently theoretical $K$ value = 0.5733 cm.

Here, it is important to note that $K$ value has a unit of cm, while the experimental $K$ is measured in Track.cm$^{-2}$/Bq.m$^{-3}$-day. Therefore, these values must be unified through 1 Bq = Disintegration/second = track/second, 1 day = 86,400 sec and 1 m$^3 = 10^6$ cm and hence 1 cm = 0.0864 (Track.cm$^{-2}$/Bq.m$^{-3}$-day) [14]. Consequently, the diffusion constant for CR-39 detectors is 0.049 Tr.cm$^{-2}$/Bq.m$^{-3}$-d.

4. Result and Discussion

The concentration of radon was determined in the serum samples using the CR-39 detector for lung cancer patients and healthy people. Table 2 reveals Radon Concentration in serum samples for healthy individuals in Babylon governorate. The value of Radon concentration finds to be range (0.4868 - 2.8192 Bq/m$^3$, Mean±SD = 1.7890 ± 0.8012 Bq/m$^3$, with Std.Error of Mean = 0.2068). The highest value obtained was 2.8192 Bq/m$^3$ for H2 and H6, female and male, 50 and 32 years old, from hilla and AL-Mahawil, and the lowest value obtained was 0.4868 Bq/m$^3$ for H1 and H10 ,male and female, 27 and 31 years old, from AL-Hashimiya and AL-Qasim.

| SC  | Age/Weight/Gender | Location       | Smoking habit | $C_{\alpha Rn}^a$ (Bq/m$^3$) |
|-----|------------------|----------------|---------------|-----------------------------|
| H1  | 27/72/M          | AL-Hashimiya   | N             | 0.4868                     |

Table 2. Radon Concentration in serum samples for healthy individuals in Babylon governorate
Table 3 reveals Radon Concentration in serum samples for lung cancer patients in Babylon governorate. The value of Radon concentration finds to be range (5.7346 - 88.8250 Bq/m$^3$), Mean±SD = 19.2234 ± 5.5747 Bq/m$^3$, with Std.Error of Mean = 5.7547. The highest value obtained was 88.8250 Bq/m$^3$ for LC2, female, 39 years old, from AL-Musayiab, and the lowest value obtained was 5.7346 Bq/m$^3$ for LC14, female, 49 years old, from Hilla.

### Table 3. Radon Concentration in serum samples for Lung Cancer patients in Babylon governorate

| SC  | Age/ Weight/Gender | Location    | Smoking habit | Duration of infection/ No. of chemotherapy doses | $C_{Kn}$ (Bq/m$^3$) |
|-----|--------------------|-------------|---------------|-----------------------------------------------|---------------------|
| LC1 | 63/60/ M           | Hilla       | N             | ND /0                                         | 35.4723             |
| LC2 | 39/74/ F           | AL-Musayiab | S             | ND /0                                         | 88.8250             |
| LC3 | 50/100/ M          | Hilla       | N             | ND /0                                         | 12.4402             |
| LC4 | 57/45/ F           | AL-Musayiab | S             | 2 months /3                                    | 11.2740             |
| LC5 | 64/70/ M           | Hilla       | N             | 4 months /7                                    | 10.9825             |
| LC6 | 36/70/ M           | AL-Mahawil  | S             | 2 months /4                                    | 10.1078             |
| LC7 | 56/74/ F           | AL-Qasim    | N             | ND /0                                         | 7.1924              |
| LC8 | 61/85/ F           | Hilla       | N             | ND /0                                         | 7.4839              |
LC9  49/77/ M  AL-Mahawil  N  3 months /6  8.0670
LC10  48/72/M  Hilla  S  2 weeks /1  24.3935
LC11  26/83/ F  AL-Qasim  N  ND /0  15.0641
LC12  32/67/ M  Hilla  S  ND /0  9.5247
LC13  56/77/ M  AL-Musayiab  S  ND /0  35.4723
LC14  49/78/ F  Hilla  N  3 months /5  5.7346
LC15  23/80/ F  Hilla  N  ND /0  6.3177

| Permissible limit | 200 |
|-------------------|-----|
| Mean              | 19.2234 |
| Min.              | 5.7348 |
| Max.              | 88.825 |

Figure 3 shows clearly that the average radon concentration in lung of cancer patients is larger than that of healthy people.

Figure 4, on the other hand, showed that radon concentration (alpha particles) is slightly higher in females than that measured in male, in general.

![Figure 3](image-url)  
**Figure 3.** Radon concentration of two different groups Healthy group (H) and Lung cancer (LC).
In general, the presented data indicated that all radon levels measured in this work are below the allowed limit specified by both ICRP and IAEA which is 200 Bq/m$^3$ [4, 15]. Further, one can note that the rate of emission of alpha particles in the serum of cancer group is higher than the corresponding values of healthy peoples, taking into account all the collected samples. This could be attributed to the high level of radon found in the blood of patient people which may work as an internal source of radiation [16]. In terms of gender, the results indicate that the average alpha emission rate in female is higher than that the measured in the serum of male. It is known that people staying at home for long period of time are likely to have higher radiation exposure. This is mainly because the difference in level of ventilation between those staying at home and those spending more time outside [17]. Since, females are relatively spending more time at home, this habit could attribute the slight deference in alpha particles concentration between females and males observed in this current study.

Figure 4. Radon concentrations in serum samples for males and females.

Figure 5. Comparison of the Mean of Radon in Serum Samples between the City Center and Other Districts

Figure 5 shows the comparison of the radon concentration emission from serum sample between the city center and other districts. The mean of radon emission in the city center (2.624 Bq/m$^3$) is higher than
the mean of radon emission in other districts (1.580 Bq/m³). While, the mean of radon emission in the city center (14.043 Bq/m³) is lower than the mean of Radon emission in other districts (25.143 Bq/m³) this is may be due to the use of depleted uranium weapons during the Gulf Wars I and II in 1991 and 2003 respectively in this region [18], As the highest radon concentration (88.8250 Bq/m³) was in AL-Musayiab district, and this may be due to this district were the centers of intensive military activities during 2014, and the discarded weapons are still lying around in these regions.

Table 4 shows person correlation between (Rn, Age, Weight) in healthy people. Radon have weak correlation with weight and Age. According to person correlation test, analysis of the result of these study reached the Rn is affected by Age more than Weight.

**Table 4. Pearson Correlation between Radon, Weight and Age in Healthy People.**

| Person correlation | Rn     | Weight | Age  |
|--------------------|--------|--------|------|
| N=15               |        |        |      |
| Rn                 | 1      | 0.160  | 0.195|
| Weight             | 0.160  | 1      | 0.434|
| Age                | 0.195  | 0.434  | 1    |

Table 5 shows person correlation between (Rn, Age, Weight, Infection period and Number of Chemotherapy) in Lung Cancer patient group. There are negative weak correlation between Rn with age and weight, but there are no correlation between Rn and Number of Chemotherapy. There are positive strong correlation between Number of Chemotherapy and infection period that is because at the beginning of the diagnosis of the disease, the patient is given chemotherapy to prevent the spread of the cancerous tumor further.

**Table 5. Pearson Correlation between Radon, Weight, Age, Infection Period and Number of Chemotherapy in Lung Cancer Patient Groups.**

| Person correlation | Rn  | Infect period | No.Chemotherapy | Weight | Age  |
|--------------------|-----|---------------|-----------------|--------|------|
| N= 60              |     |               |                 |        |      |
| Rn                 | 1   | -0.090        | -0.016          | -0.323 | -0.321|
| Infect period      | -0.090 | 1            | 0.660           | -0.264 | -0.227|
| No. Chemotherapy   | -0.016 | 0.660       | 1               | 0.284  | 0.257 |
| Weight             | -0.323 | -0.264       | 0.284           | 1      | 0.994 |
| Age                | -0.321 | -0.227       | 0.257           | 0.994  | 1    |

Comparing the results of this study to other relevant studies, the Alpha particles concentration measured in this study (19.2234 Bq/m³) is considerably lower than those measured other places (Karbala Governorate, and Malaysia) as shown in table 6.
Table 6. Alpha particles concentrations in different places in Iraq and other countries reported in the relevant literature

| PLACE          | Alpha particles concentration (Bq/m$^3$) | Reference |
|----------------|----------------------------------------|-----------|
| Malaysia       | 734.50                                 | [4]       |
| Iraq/ Karbala  | 64.3                                   | [9]       |
| UNSCEAR        | 200                                    | [19]      |
| Iraq/ Babylon  | 19.2234                                | Present study |

5. Conclusions

In this work, different serum samples are collected from people with lung cancers and healthy people in Babylon governorate. In these samples, the alpha particles concentrations are measured using CR-39 detector. The results indicated that people with lung cancer have higher alpha particles concentration in relation to the healthy ones, the average concentrations are 19.2234 and 1.7890, respectively. Further, the result found that the females have relatively a higher radon concentration comparing to male, considering all the measured sample (patients and healthy people). Finally, the data (average concentration) are compared with to data reported in the relevant literature. The results show that the concentration reported in Karbala Iraq, Malaysia and UNSCEAR are larger than that reported here and the concentration monitored in Babayan governorate is below 200 Bq/m$^3$ which is the allowed limit specified by both International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA).

Acknowledgement

The authors would like to thank to the Babylon oncology center and Imam Al-sadiq hospital- oncology center. special thanks to Prof. Hayder Hamza , Prof. Ali Abojassim and faculty of Science, University of Kufa, for his assistance in completing this research.

6. References

[1] Aswood M Sh, Jaafar M S and Salih N 2017. Estimation of annual effective dose due to natural radioactivity in ingestion of vegetables from Cameron Highlands, Malaysia. Envi. Techno. & Innov. 8, 96-102.
[2] Hamza Z V, Kumar V P R, Jeevanram R K, Santanam R, Danalaksmi B, and Mohankumar M N 2008. A simple method to irradiate blood cells in vitro with radon gas. Radi. Prot. Dosi.130, 343.
[3] Okeji M C and Agwu K K 2012. Assessment of indoor radon concentration in phosphate fertilizer warehouses in Nigeria. Radi. Phys. and Chem. 81, 253.
[4] Salih N F, Jafri Z M and Aswood M Sh 2016. Measurement of radon concentration in blood and urine samples collected from female cancer patients using RAD7. Jour. of Radi. Rese. and Appl. Scie. 9, 332.
[5] IARC 1988. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol. 44, Alco Drin. Lyon IARCpp 416.
[6] Ford, J. (2004). Radiation, people and the environment.
[7] Saleh, A., & Mohamed, R. (2005). Measurement of Radiation in Soil in the Middle of Gaza Strip.
[8] Abojassim, A. (2018). Alpha particles concentrations from soil samples of Al-Najaf/Iraq. *Polish Journal of Soil Science*, 50(2), 249.

[9] Hassan, A., Mohsen, A. A. H., Zahed, H., & Abojassim, A. A. (2019). Determination of alpha particles levels in blood samples of cancer patients at Karbala governorate, Iraq. *Iranian Journal of Medical Physics*, 16(1), 41-47.

[10] Karim M S, Mohammed A H and Abbas A A 2010. Measurement of Uranium Concentrations in Human Blood in Some the Regions of Baghdad Governorate Experimental Part The present study of uranium concentration in human blood from different. Ibn Al-Hait. Jour. For Pure And Appl. Scie. 23 , 25.

[11] Aswood M Sh, Jaafar M S and Bauk S 2014 Measuring Radon Concentration Levels in Fertilizers Using CR-39 Detector. *Adv. Mate. Res*. 925, 610-614.

[12] Barillon, R., Klein, D., Chambaudet, A., & Devillard, C. (1993). Comparison of effectiveness of three radon detectors (LR115, CR39 and silicon diode pin) placed in a cylindrical device-theory and experimental techniques. *Nuclear Tracks and Radiation Measurements*, 22(1-4), 281-282.

[13] Ewaid, S.H.; Abed, S.A.; Al-Ansari, N.; Salih, R.M. Development and Evaluation of a Water Quality Index for the Iraqi Rivers. *Hydrology* 2020, 7, 67.

[14] Fleischer, R. L., & Mogro-Campero, A. (1978). Mapping of integrated radon emanation for detection of long-distance migration of gases within the Earth: Techniques and principles. *Journal of Geophysical Research: Solid Earth*, 83(B7), 3539-3549.

[15] Salam Hussein Ewaid et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 722 012008

[16] Ismail, A. H., & Jaafar, M. S. (2009). Experimental measurements on CR-39 response for radon gas and estimating the optimum dimensions of dosimeters for detection of radon. In *Proceedings of the 3rd Asian Physics Symposium, Bandung, Indonesia* (pp. 22-23).

[17] Salam Hussein Ewaid et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 790 012075

[18] Salih, N. F. (2014). *Impact of alpha emitters on uterus, blood, urine and hormones of infertile woman of Iraqi Kurdistan* (Doctoral dissertation, Universiti Sains Malaysia).

[19] Salih, N. F., Jaafara, M. S., Al-Hamzawi, A. A., & Aswood, M. S. (2013). The Effects of Alpha Emitters on Powder Blood for Women’s Infertility in Kurdistan–Iraq. *International Journal of Scientific and Research Publications*, 57.

[20] Almayahi, B. A. (2015). Quantification of Alpha Particle Emission in Human Blood Samples in the City of Najaf, Iraq. *Journal of Environmental Indicators*, 9(26).

[21] Al-Hamzawi, A. A., Jaafar, M. S., & Tawfiq, N. F. (2014). Uranium concentration in blood samples of Southern Iraqi leukemia patients using CR-39 track detector. *Journal of radioanalytical and nuclear chemistry*, 299(3), 1267-1272.

[22] Ahmed Alaa Kandoh et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 790 012073

[23] Salam Hussein Ewaid et al 2020 J. Phys.: Conf. Ser. 1664 012143.

[24] Asano, T., Sato, K., & Onodera, J. I. (2001). United nations scientific committee on the effects of atomic radiation 2000 report. *Japanese Journal of Health Physics*, 36(2), 149-158.