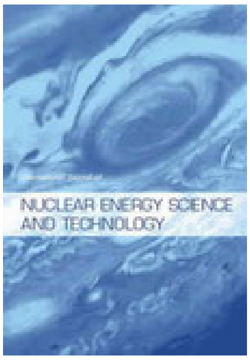
INDERSCIENCE PUBLISHERS
Linking academia, business and industry through research



International Journal of Nuclear Energy Science and Technology

ISSN online: 1741-637X - ISSN print: 1741-6361
https://www.inderscience.com/ijnest

Radon concentrations in the serum of blood and urine of smokers using RAD-7 detector

Abdulhussein A. Alkufi, Mohanad H. Oleiwi, Ali Abid Abojassim

DOI: 10.1504/IJNEST.2024.10064095

Article History:

Received:	22 August 2023
Last revised:	27 September 2023
Accepted:	30 December 2023
Published online:	14 June 2024

Radon concentrations in the serum of blood and urine of smokers using RAD-7 detector

Abdulhussein A. Alkufi

Department of Physics,
College of Education for Pure Sciences,
University of Babylon,
Babylon, Iraq
and
Education Directorate of Najaf,
Ministry of Education,
Al-Najaf, Iraq
Email: abdulhussein.alkufi@gmail.com

Mohanad H. Oleiwi

Department of Physics,
College of Education for Pure Sciences,
University of Babylon,
Babylon, Iraq
Email: pure.mohanad.hussein@uobabylon.edu.iq

Ali Abid Abojassim*

Faculty of Science,
Department of Physics,
University of Kufa,
Al-Najaf, Kufa, Iraq
Email: ali.alhameedawi@uokufa.edu.iq
*Corresponding author

Abstract: In this work, radon concentrations (^{222}Rn) for smokers in the Najaf Governorate /Iraq in some biological samples (serum of blood and urine) were measured using a RAD-7 detector (Durridge Company Inc, made in the USA). Fifty samples of serum blood (twenty-five (25)) and urine (twenty-five (25)) were collected for smokers and people aged (21–70) years for all samples. Samples were classified into five age groups (21–30), (31–40), (41–50), (51–60) and (61–70) to compare the results and determine their effects on the radon concentrations. The average value of radon concentrations in (Bq/m^3) unit was (11.82±3.81) in serum samples, while in urine samples was (11.96±6.01). The results and comparisons indicate that radon concentrations depend on the variables on which this study was based. By comparing the radon concentrations for serum and urine with the age groups, the *p*-value was increased significantly statistically. Also, it was found that there is a positive and good correlation for radon concentrations between serum and urine. Therefore, it can be concluded radon concentrations were within the limits allowed globally, and thus, serum and urine were free from environmental pollution.

Keywords: ^{222}Rn concentrations; serum; urine; smokers; RAD-7 detector; Najaf governorate.

Reference to this paper should be made as follows: Alkufi, A.A., Oleiwi, M.H. and Abojassim, A.A. (2024) 'Radon concentrations in the serum of blood and urine of smokers using RAD-7 detector', *Int. J. Nuclear Energy Science and Technology*, Vol. 17, No. 1, pp.18–27.

Biographical notes: Abdulhussein A. Alkufi is BSc in Physics from the University of Al-Qadisiyah, College of Education, Department of Physics (2010), MSc in Nuclear Physics from the University of Kufa, Faculty of Education for Women, Department of Physics (2016), student of PhD in Nuclear Physics and Environmental from University of Babylon, College of Education for Pure Sciences, Department of Physics (2022). He worked in the University of Kufa Faculty of Education for Women Department of Physics from 2013 up to now and Ministry of Education.

Mohanad H. Oleiwi is BSc in Physics from Al-Nahrain University, College of Science, Department of Physics (2001), MSc in Nuclear Physics from Al-Nahrain University, College of Science, Department of Physics (2004), PhD in Nuclear Physics and Environmental from University of Baghdad, College of Science, Department of Physics (2013). He worked in University of Babylon, College of Education for Pure Sciences, Department of Physics from 2005 up to now.

Ali Abid Abojassim is BSc in Physics from the University of Kufa, Faculty of Science Department of Physics (2003), MSc in Nuclear Physics from the University of Babylon College Science Department of Physics (2006), PhD in Nuclear Physics and Environmental from Baghdad College Science Department of Physics (2013). He worked in the University of Kufa, Faculty of Science Department of Physics from 2006 up to now.

1 Introduction

Radon, denoted as (^{222}Rn), is an inert gas with radioactive properties found in nature. It is produced as a result of the decay of radium-226. The decay process of every nucleus of (^{222}Rn) ultimately transforms into lead (^{210}Pb). Radon-222, a radioactive isotope, undergoes alpha decay with a half-life of 3.824 days. It is widely believed that the elimination of radon from the body occurs rapidly after inhalation and ingestion. Radon that is consumed is eliminated from the body via the process of breathing. Nevertheless, the process by which radon is absorbed into the human body occurs via its dissolution in the blood inside the gastrointestinal system and other bodily tissues (Bignall and Caldwell, 2021; Abojassim et al., 2021). Among the noble gases, radon has the greatest solubility ratio in adipose tissue relative to blood, making adipose tissue the primary site of radon accumulation inside the body. Furthermore, the primary source of radiation exposure inside the human body arises from the inhalation of radon progeny (Paquet et al., 2017). When individuals inhale radon gas, a significant portion of it is expelled before undergoing decay. However, a fraction of the inhaled radon and its offspring may be carried from the lungs to the bloodstream and distributed throughout the body. This distribution enables the delivery of a dosage to various organs inside the body (Oleiwi et al., 2021). Renal problems have also been documented in individuals who have been exposed to radon. The primary factor contributing to the elevated dosage received by the kidney, in comparison to other organs within the body, is the transport of radon from the lung to the kidney through the bloodstream (Dosh et al., 2022). Based on the findings of the (BEIR IV) study published by the National Academies of Sciences, it has been determined that male individuals who are occupationally exposed to radon and engage in smoking are at a much higher risk of developing lung cancer, with a likelihood that is tenfold more compared to their non-smoking counterparts. Moreover, it has been predicted that those who smoke and reside in households with elevated radon levels (>200 Bq/m^3) have a 6-8-fold increase in risk compared to those who do not smoke (Ibrahim et al., 2021). Numerous studies have provided compelling evidence supporting a multiplicative synergistic relationship between radon exposure and smoking. Estimates derived from these studies suggest that the risk of developing lung cancer may increase up to 18 times when individuals are exposed to both radon and engage in cigarette smoking (Salih et al., 2016). Therefore, the relationship between smoking and radon in risk assessment continues to be debated and uncertain. Cytogenetic biomarkers have shown their efficacy as reliable techniques for identifying and quantifying DNA damage caused by radon and its offspring in the cells of miners. Structural chromosomal abnormalities are considered to be the most sensitive cytogenetic indicators, demonstrating a dose-response. As a result, they are extensively used in the field of biological dosimetry (Abojassim et al., 2021). Radon concentrations in liquid and solid samples were measured using RAD-7 by several studies (Salih et al., 2016; Abojassim, 2020; Muhammad et al., 2023). So, this research aimed to evaluate radon (^{222}Rn) concentrations in liquid biological samples (serum and urine) for smoking persons in Najaf Governorate, Iraq, using a new method that depends on the RAD-7 device.

2 Materials and method

In the current investigation, blood and urine samples were taken from a cohort of twenty-five smokers between the ages of 21 and 70. Blood samples were extracted from a peripheral vein and then processed to get serum. Urine samples were collected from the same individuals as well. The samples were obtained from the clinic, namely the health laboratory, located in Najaf Governorate, Iraq. Each sample was stored in distinct tubes designed for this purpose. The tubes were marked with the numbers for each sample, after which the serum and urine samples were placed in (Eppendorf tubes) and transferred to the freezer for cooling until the start of the analysis. The RAD-7 detector was used to analyse the level of radon concentration in the samples (serum and urine). The RAD-7 detector was introduced into a plastic cup that contained the serum and urine samples, each with a volume of (1 ml), to quantify the radon concentration in each respective sample. The device settings were in the sniff mode for four cycles; each time was 10 minutes. This research uses a new connection method to measure radon concentration in the serum of blood and urine samples using the RAD-7 device. Figure 1 shows the RAD-7 system used for measuring radon concentration in this study. (^{222}Rn) concentrations were measured in the plastic cup, once without the samples present (as a radiation background) and another time with the samples present, then calculated net of (^{222}Rn) concentration.

Figure 1 Radon concentration in serum and urine samples using RAD-7 (see online version for colours)

The radon concentration in the aforementioned samples was determined using the calibrated alpha spectrometer RAD-7 by the testing technique established by the Environmental Protection Agency (EPA) (Ahmad et al., 2015). The RAD-7, a radon detector developed by the Durridge Company (Model 711, Serial 00512), is a multifunctional instrument that may serve as the fundamental component of a complete radon measuring system (Dosh et al., 2023). The sample's measurement cycle lasts 10 minutes since the equipment is configured to execute five cycles. After each cycle, a printout is acquired, including the recorded radon concentration's average, standard deviation, lowest and maximum values. In order to analyse several subsamples from a given sample, the reagent was purged until the relative humidity reached a level below 6%, after which the subsequent subsample was subjected to analysis. Following the measurement of each sample, a process known as purging is undertaken to cleanse the instrument from radon plankton (Pervin et al., 2022). The RAD-7 device has an air pump and a solid-state alpha detector comprising a semiconductor substance. Silicon is often used as a semiconductor material that directly transforms alpha radiation into an electrical signal. The standard unit used in this investigation was (Bq/m^3) (Hamzah et al., 2022).

3 Results and discussion

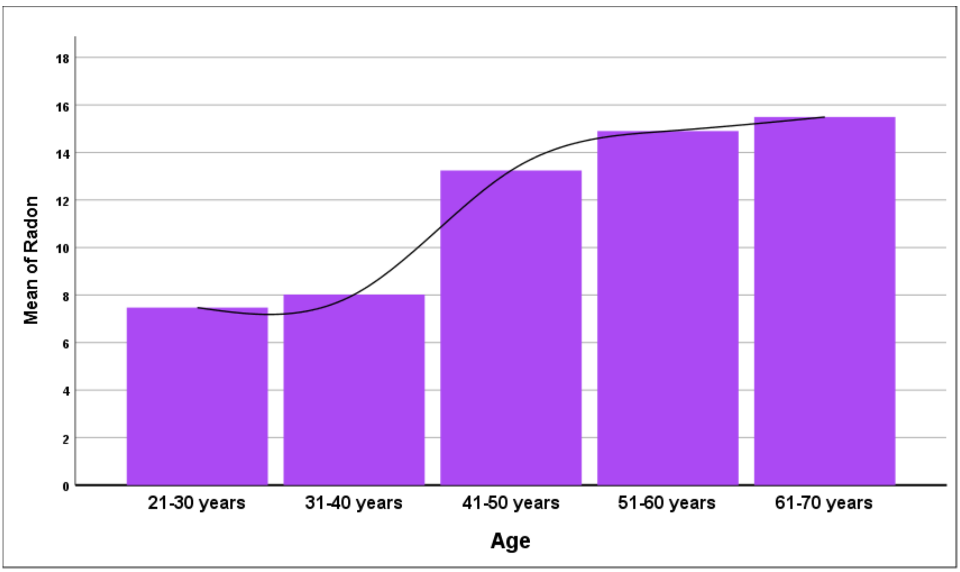
The statistical analysis using the ANOVA test is presented in table form, including the standard error and significant difference ($p < 0.01$). The results of radon concentrations were obtained from 25 serum samples from smoker people in different sites in Najaf governorate, as shown in Table 1. The highest radon concentrations were 15.49 ± 2.27 (Bq/m^3) in the age range 61–70 years, while the lowest was 7.47 ± 3.47 (Bq/m^3) in the age range 20–31 years. Generally, the mean radon concentrations for serum samples are increased with age, as shown in Figure 2. Statistically, radon concentrations from serum samples in the study area are represented in Table 1. Independent test results for the differences between radon with age indicate high significant (p-value<0.01) differences at level 0.01.

Table 1 Results of the average of radon concentrations in serum samples of smokers in five age groups

Age range	*No. of samples*	*^{222}Rn Concentrations (Bq/m^3)*	*P-value*
21–30 years	5	7.47 ± 3.47	0.006 HS
31–40 years	5	8.02 ± 3.71	
41–50 years	5	13.24 ± 1.79	
51–60 years	5	14.90 ± 6.27	
61–70 years	5	15.49 ± 2.27	
Total	25	11.82 ±3.81	

Note: HS: High significant difference between groups (*p*-value <0.01).

Figure 2 Relation between smokers and radon concentrations for five age groups in serum samples (see online version for colours)



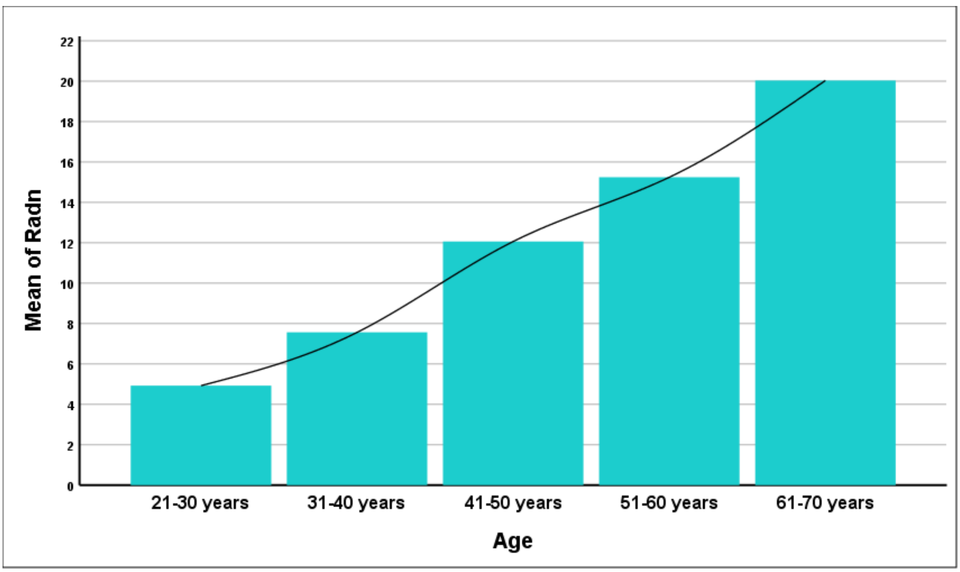
The results of radon concentrations were obtained from twenty-five urine samples from smoker people in different sites in Najaf governorate, as shown in Table 2. The highest radon concentrations were 20.03 ± 3.56 (Bq/m^3) in the age range 61–70 years, while the lowest was 4.92 ± 0.71 (Bq/m^3) in the age range 20–31 years. The results display a highly significant increase ($p<0.01$) in radon concentrations compared to an increase in age. Generally, the mean radon concentrations for urine samples are increased with the increase of age, as shown in Figure 3.

Table 2 Results of the average of radon concentrations in urine samples of smokers in five age groups

Age range	*No. of samples*	^{222}*Rn Concentrations (Bq/m^3)*	*P- value*
21–30 years	5	4.92 ± 0.71	
31–40 years	5	7.56 ± 1.91	
41–50 years	5	12.06 ± 2.30	0.0001 HS
51–60 years	5	15.24 ± 1.73	
61–70 years	5	20.03 ± 3.56	
Total	25	11.96 ±6.01	

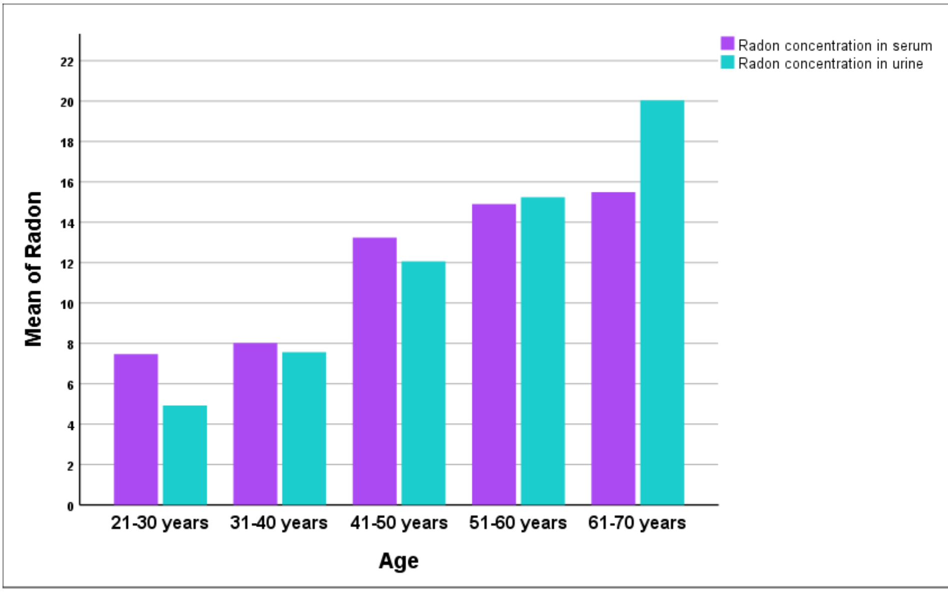
Note: HS: High significant difference between groups (*p*-value <0.01).

Figure 3 Relation between smokers and radon concentrations for five age groups in urine samples (see online version for colours)



The relation of radon concentrations in serum and urine samples with age is shown in Figure 4. From Figure 4, it is found that the radon concentrations in serum are higher than in urine at the first three age ranges (21–30, 31–40 and 41–50), and lower in other age ranges (51–60 and 61–70). The average value of radon concentrations in all age ranges of urine (11.96 ±6.01) was higher than in serum samples (11.82 ±3.81).

Figure 4 Relation between serum and urine for five age groups (see online version for colours)



The findings indicate that elevated radon levels impact a significant proportion of individuals who smoke due to the intake of air contaminated by cigarette smoke and anthropogenic sources in the Al-Najaf governorate of Iraq. Various suggested values for radon gas concentrations in air have been published, including the International Commission on Radiological Protection (ICRP) recommendation of 300 Bq/m^3 (Tirmarche et al., 20210). The US Environmental Protection Agency (EPA) has established three distinct categories for measuring radiation levels: high level, defined as exceeding 148 Bq/m^3; low level, set at 74 Bq/m^3 and an acceptable range falling between 74 and 148 Bq/m^3. Additionally, the low level is reiterated as 74 Bq/m^3 (Zdrojewicz and Strzelczyk, 2006), the World Health Organisation (WHO) established a reference level of 100 Bq/m^3 (World Health Organization, 2009), and the Code of Federal Regulations, United Nations Scientific Committee on the Effects of Atomic Radiation (CFR U.) was 39 Bq/m^3 (CFR, 2009). Hence, the concentrations of radon gas in serum and urine samples obtained in this investigation were found to be below the suggested thresholds established by authoritative bodies such as the International Commission on Radiological Protection (ICRP), the United States Environmental Protection Agency (USEPA), the World Health Organisation (WHO) and the Code of Federal Regulations (CFR) of the USA. Overall, the data reported in this study demonstrates that all tested radon levels are within the permissible threshold.

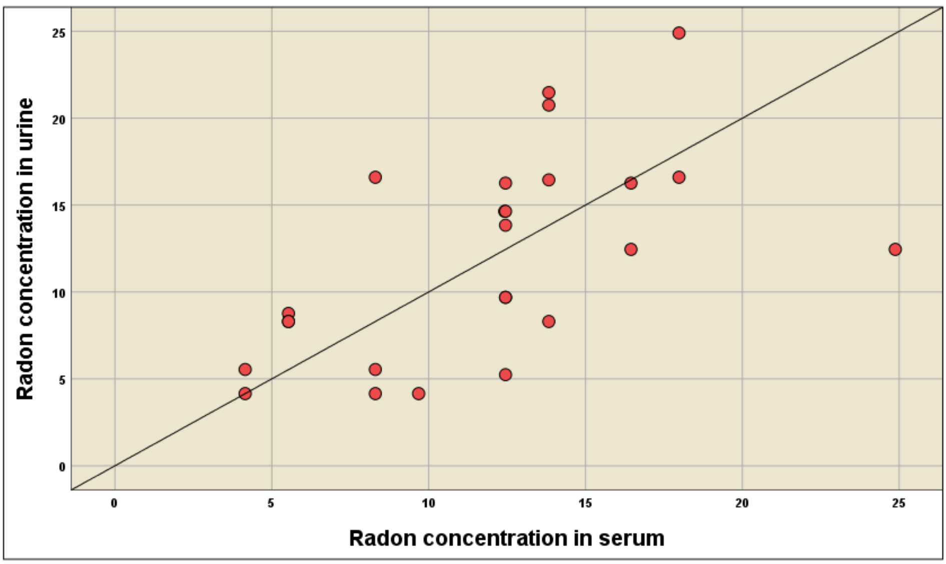
Table 3 and Figure 5 illustrate the correlation between the participants' radon concentrations in serum and urine samples. Independent sample ANOVA test confirmed a significant difference in radon concentrations between the serum and urine groups ($p < 0.01$).

Table 3 The correlation between urine and serum results

Correlation		^{222}*Rn in Urine*	^{222}*Rn in Serum*
^{222}Rn in Urine	Pearson Correlation	1	0.577**
	Sig. (2-tailed)		0.003
^{222}Rn in Serum	Pearson Correlation	0.577**	1
	Sig. (2-tailed)	0.003	

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

Figure 5 Correlation between urine and serum results (see online version for colours)



When comparing the findings of this research about radon concentrations in blood and urine to comparable studies conducted on smokers, it is evident that the radon concentrations seen in this study are much lower than those reported in other locations such as Karbala Governorate (Hassan et al., 2019), Babylon (Naji and Hassoon, 2021) and Al-Najaf (Al-Mashhadani et al., 2020). This phenomenon may be attributed to the elevated uranium levels in those who smoke. The presence of uranium in tobacco is the primary mechanism via which it enters the body, facilitated by smoking. Al-Hamzawi et al. (2015) and Almayahi et al. (2014) shown elevated concentrations of alpha emitters and uranium inside many organs of smokers, including teeth, blood, hair and soft tissues.

4 Conclusions

The study of radon concentration levels in healthy smokers' serum and urine samples has provided baseline data in Al-Najaf governorate, Iraq. These results indicated that the highest average radon concentrations of all samples were in the high age range (61–70 years). Also, the results show the radon concentrations in urine samples are higher than in the serum samples. The results showed the concentrations of radon serum have a good correlation with the concentrations of radon in urine samples for smokers. Moreover, the results showed that radon concentrations in serum and urine have high significance (p-value<0.01) in all age groups. Also, it was concluded that the radon concentrations in all samples in the present study were within global limits, according to most of the World of the Organisation reports.

References

Abojassim, A.A. (2020) 'Comparative study between active and passive techniques for measuring radon concentrations in groundwater of Al-Najaf city, Iraq', *Groundwater for Sustainable Development*, Vol. 11.

Abojassim, A.A., Hashim, R.H. and Mahdi, N.S. (2021) 'Basics of nuclear radiation', *Basics of Nuclear Radiation*, pp.1–86.

Ahmad, N., Jaafar, M.S. and Alsaffar, M.S. (2015) 'Study of radon concentration and toxic elements in drinking and irrigated water and its implications in Sungai Petani, Kedah, Malaysia', *Journal of Radiation Research and Applied Sciences*, Vol. 8, No. 3, pp.294–299.

Al-Hamzawi, A.A., Jaafar, M.S. and Tawfiq, N.F. (2015) 'Concentration of uranium in human cancerous tissues of Southern Iraqi patients using fission track analysis', *Journal of Radioanalytical and Nuclear Chemistry*, Vol. 303, pp.1703–1709.

Al-Mashhadani, A.H., Saleh, D.S. and Razzaq, D.F. (2020) 'Measurement the uranium, radon and radium concentrations in urine samples for diabetics in Najaf city', *IOP Conference Series: Materials Science and Engineering*, IOP Publishing, Vol. 928, No. 7.

Almayahi, B.A., Tajuddin, A.A. and Jaafar, M.S. (2014) 'Radiobiological long-term accumulation of environmental alpha radioactivity in extracted human teeth and animal bones in Malaysia', *Journal of Environmental Radioactivity*, Vol. 129, pp.140–147.

Bignall, O.N. and Caldwell, T. (2021) 'Radon (^{222}Rn) concentration in fresh and processed coconut water using a RAD7 detector', *Natural Science*, Vol. 13, No. 9, pp.425–436.

CFR, U. (2009) *Code of Federal Regulations Title 40: Protection of Environment*, Part 136 – Guidelines establishing test procedures for the analyses of pollutants, Appendix B to Part 136 – definition and procedure for the determination of Method Detection Limit rev. 1.11.

Dosh, R.J., Hasan, A.K. and Abojassim, A.A. (2022) 'Background radiation in primary schools of Al-Najaf City, Iraq', *International Journal of Nuclear Energy Science and Technology*, Vol. 15, Nos. 3/4, pp.283–301.

Dosh, R.J., Hasan, A.K. and Abojassim, A.A. (2023) 'Health effect of radon gas in water on children at Al-Najaf schools', *International Journal of Nuclear Energy Science and Technology*, Vol. 16, No. 2, pp.143–156.

Hamzah, Z.S., Hashim, A.K. and Abojassim, A.A. (2022) 'Assessment of annual effective dose and excess lifetime cancer risk due to alpha emitters in some grain samples in Kerbala Governorate, Iraq', *International Journal of Nuclear Energy Science and Technology*, Vol. 15, Nos. 3/4, pp.271–282.

Hassan, A., Mohsen, A.A.H., Zahed, H. and Abojassim, A.A. (2019) 'Determination of alpha particles levels in blood samples of cancer patients at Karbala governorate, Iraq', *Iranian Journal of Medical Physics*, Vol. 16, No. 1, pp.41–47.

Ibrahim, A.A., Hashim, A.K. and Abojassim, A.A. (2021) 'Determination of alpha radioactivity in soil samples collected from University of Kerbala, Iraq', *International Journal of Nuclear Energy Science and Technology*, Vol. 15, No. 1, pp.1–15.

Muhammad, Y.M.Y., Fatah, P.K. and Yaba, S.P. (2023) 'Measurement of radon activity concentration in soils samples of Shaqlawa Region in Erbil City/Iraqi Kurdistan using RAD7 detector', *Zanco Journal of Pure and Applied Sciences*, Vol. 35, No. 2, pp.58–62.

Naji, T. F. and Hassoon, S. O. (2021) 'Measuring of Radon Gas Concentrations in serum samples of Lung cancer patients in Babylon governorate, Iraq', *Journal of Physics: Conference Series*, IOP Publishing, Vol. 1999, No. 1.

Oleiwi, M.H., Ibrahem, S.H. and Abojassim, A.A. (2021) 'Natural alpha emitters in some types of medical of parenteral solutions (domestic and imported) samples in Iraqi Hospitals', *NeuroQuantology*, Vol. 19, No. 5, pp.139–143.

Paquet, F., Bailey, M.R., Leggett, R.W., Lipsztein, J., Marsh, J., Fell, T.P. and Harrison, J.D. et al. (2017) 'ICRP publication 137: occupational intakes of radionuclides: part 3', *Annals of the ICRP*, Vol. 46, pp.1–486.

Pervin, S., Yeasmin, S., Khandaker, M.U. and Begum, A. (2022) 'Radon concentrations in indoor and outdoor environments of Atomic Energy Centre Dhaka, Bangladesh, and Concomitant Health Hazards', *Frontiers in Nuclear Engineering*, Vol. 1, 901818.

Salih, N.F., Jafri, Z.M. and Aswood, M.S. (2016) 'Measurement of radon concentration in blood and urine samples collected from female cancer patients using RAD7', *Journal of Radiation Research and Applied Sciences*, Vol. 9, No. 3, pp.332–336.

Tirmarche, M., Harrison, J.D., Laurier, D., Paquet, F., Blanchardon, E. and Marsh, J.W. (2010) 'ICRP Publication 115. Lung cancer risk from radon and progeny and statement on radon', *Annals of the ICRP*, Vol. 40, No. 1, pp.1–64.

World Health Organization (2009) *WHO Handbook on Indoor Radon: a Public Health Perspective*, World Health Organization.

Zdrojewicz, Z. and Strzelczyk, J. (2006) 'Radon treatment controversy', *Dose-Response*, Vol. 4, No. 2.