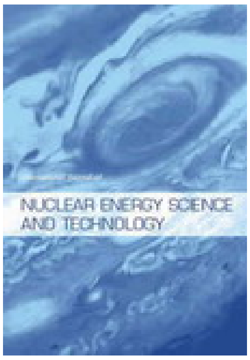


International Journal of Nuclear Energy Science and Technology

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

Health effect of radon gas in water on children at Al-Najaf schools

Rukia Jabar Dosh, Ali K. Hasan, Ali Abid Abojassim

DOI: 10.1504/IJNEST.2023.10057077

Article History:

Received:	16 November 2022
Last revised:	02 March 2023
Accepted:	03 April 2023
Published online:	07 August 2023

Health effect of radon gas in water on children at Al-Najaf schools

Rukia Jabar Dosh

Faculty of Science,
Department of Physics,
University of Kufa,
Al-Najaf, Kufa, Iraq
Email: ruqayaj.salim@uokufa.edu.iq

Ali K. Hasan

Faculty of Education for Girls,
Department of Physics,
University of Kufa,
Al-Najaf, Kufa, Iraq
Email: alikh.alsinayyid@uokufa.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: The concentrations of radon (^{222}Rn) in water samples of 37 districts of Al-Najaf province, Iraq collected from primary schools were measured. Also, Annual Effective Dose (AED) in children age groups (7–12 year), that used this water as drinking water was calculated. ^{222}Rn concentrations were measured using portable detector with RAD-7 (RAD-7 H_2O). The range and average of concentrations were from 0.1 Bq/L to 0.4 Bq/L and 0.12±0.08 Bq/L, respectively. Also, the range and average of annual effective dose were from 0.1 nSv/y to 0.4 nSv/y and 0.12±0.08 nSv/y, respectively. The concentrations levels for ^{222}Rn most samples were lower than the internationally recommended standard of (0.5 Bq/L), while the results of AED in all samples were lower than of the internationally recommended standard of (0.002 mSv/y). So, it can be noted that, the children who used water as drinking water were safe according to radon concentrations risks.

Keywords: radon gas; drinking water; schools; RAD-7; Najaf city.

Reference to this paper should be made as follows: Dosh, R.J., Hasan, A.K. and Abojassim, A.A. (2023) 'Health effect of radon gas in water on children at Al-Najaf schools', *Int. J. Nuclear Energy Science and Technology*, Vol. 16, No. 2, pp.143–156.

Biographical notes: Rukia Jabar Dosh is employed in University of Kufa Faculty of Science, Department of Physics from 2000 until the present. She is PhD at Faculty of Education for Girls.

Ali K. Hasan received a BSc degree in Physics from Basrah University in 1982 and a MSc in Nuclear Physics from Baghdad in 1989. He finished his PhD in Nuclear Physics from Basrah University in 2009. He received degree of Professor in 2002.

Ali Abid Abojassim received BSc in Physics from University of Kufa Faculty Science Department of Physics (2003), MSc in Nuclear Physics from 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 University of Kufa College Science Department of Physics from 2006 up to now.

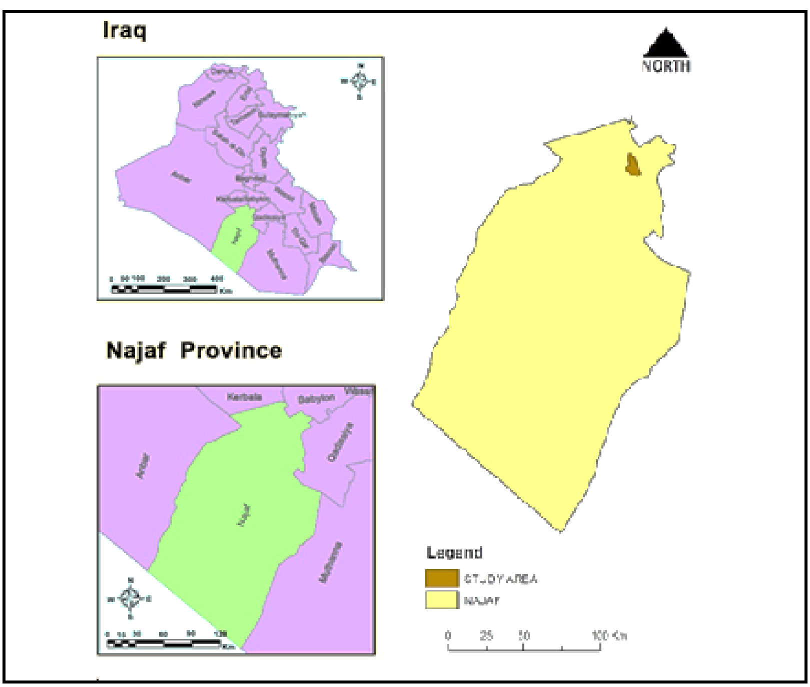
1 Introduction

The most important source of life is water. Despite the fact that water covers 70% of the Earth's surface, only 0.3% of the total water supply can be used and is fit for everyday use. Water accounts for 70-75 percent of a person's entire body weight. Radiation can come from a variety of sources, including natural radionuclides as well as man-made ones. The immense benefits of water cannot be counted, but its reception of pollutants in the environment and then get pollution, which is described as any change in the characteristics or the basic components of the environmental component and causes for many of the health problems (Ajibade et al., 2021). Incorporating radioactive materials, whether liquid, solid or gas, with the environmental elements of water, air and soil leads to the rapid spread of intrusive materials in the air, with more of them becoming liquid or solid, resulting in air pollution and soil and water contamination (Nuccetelli and Trevisi, 2018). As a result of rainfall, leaks of radioactive materials in liquid form enter the soil and spilled into rivers and groundwater. The geological and topographical features of the location determine the ordinary radioactive isotopes in rivers' water. The amount of uranium in water is hundreds of times lower than that found in soil and rocks. The concentration of uranium in some natural water (save in specified regions) can be exceedingly high, and the isotope of radon must also be considered (^{222}Rn). Radon levels in surface waters are lower than those in groundwater (Cothern, 2019). Interactions with aquifer rock, near-by uranium tailing, oil uptake and fertiliser leaching may be the result of uranium, radium and radon in groundwater (Baumstark-Khan et al., 2013). Various health agencies pay close attention to the quantities of dangerous radioactive elements in drinking water, including radon. The radioactive elements can enter the human body in a number of ways, both direct and indirect. The direct method entails drinking or eating radionuclide-contaminated vegetables from groundwater, whereas the indirect route entails drinking polluted water or feeding contaminated hay to livestock. Indirect ingestion, on the other hand, is widely thought to be safe for health due to the minimal dose obtained (Harrison, 2001). Readily, radon gas is emitted from water or plutonium tailings and ingested by people. Radon isotopes mostly produce radioactivity in the form of radiation, that cannot break through the skin's outer layers. Thus, these radionuclides are dangerous only if swallowed or inhaled into the body. The health concerns could include radioactive dust accumulation from mining, aggregation in the reins and bones or cancer (Al-Hamidawi, 2014). The US Environmental Protection Agency (EPA) categorises uranium, radium and radon as 'carcinogenic to humans'. Lung cancer may be increased by inhaling uranium and radium dust and radon gas from water or uranium tailings as well. Water is indispensable for life therefore monitoring water radioactive pollution (radon) is of high importance. Many researchers have estimated radon concentrations in different types of water samples of Iraq using RAD-7 detector (Abojassim et al., 2017, 2018; Abojassim, 2020, 2021a). The aim of the present research is to measure radon concentrations in water samples from different districts that contained schools at Al-Najaf governorate using RAD-7 detector. Also, the annual effective dose for children age (7–12 year) was estimated using stranded equations according to UNSCEAR.

2 Materials and methods

Thirty-seven districts in AL-Najaf governorate (see Figure 1) were the site of this study. Achools were chosen the Najaf district centre to study effect of radon gas on children. Table 1 displays the districts name, code and the numbers of the chosen schools. One hundred samples of water from schools were collected from 37 districts in Najaf city. Samples of volume 250 ml were coded to determine radon directly as same day using portable RAD-7 detector at same time that collected it. All experimental measurements were done during February 2022.

Figure 1 Map of the study area



Tables 1 The information about samples in the present study

No.	*Name of districts*	*Code*	*Location*
1	old city	D1	15
2	Al.Karama	D2	3
3	Alshueara	D3	1
4	Imam Mahdi	D4	1
5	Al.Moalmen	D5	3
6	Alsaad	D6	1
7	Alhussein	D7	3
8	Alhanana	D8	1
9	Al.Ameer	D9	3
10	Alishtiraki	D10	1
11	Al.Ansar	D11	4
12	Technical Institute	D12	1
13	Alkudos	D13	1
14	Al.Zahraa	D14	2
15	Alhawraa zainab	D15	2
16	Alqadisiya	D16	2
17	AL gari	D17	4
18	Aloroba	D18	4
19	Al.Askan	D19	2
20	Al.Mothana	D20	2
21	Aladala	D21	2
22	Campus	D22	1
23	Alwafaa	D23	5
24	Alyarmuk	D24	4
25	Almakrama	D25	2
26	Alnasor	D26	2
27	Aljameea	D27	1
28	Alresalah	D28	2
29	Almilad	D29	3
30	Alnidaa	D30	2
31	Aljamea	D31	4
32	Alsalam	D32	5
33	Alforat	D33	2
34	Algahdeer	D34	1
35	Abotalib	D35	2
36	Alrahma	D36	4
37	Algahdeer village	D37	2

Measurements of radon concentration in water were carried out using a calibrated alpha spectrometer Durridge RAD-7, with special accessories for radon measurement in water. The detector converts alpha radiation directly to an electric signal and has the possibility of determining electronically the energy of each particle, which allows the identification of the isotopes (218Po, 214Po) produced by radiation, so it is possible to instantaneously distinguish between old and new radon, radon from thoron and signal from noise. The operational number, the 4-circuit diagram, the cumulative spectrum and the number of turnings is also included (IAEA, 1996). In a sample of 250 ml, the ratio of radon elimination from water in the air ring is 95%, which is quite high. The schematic diagram of the RAD-H_2O supplement is shown in Figure 2 (Abojassim, 2021a, 2021b).

Figure 2 RAD-H_2O detector

^{222}Rn concentrations were measured in water samples of schools in the present study using RAD-7 detector (Durridge Co. Ltd, USA manufactured). RAD-7 detector was used to determine radon concentrations in unit Bq/L by taking four readings for each site during 30 minutes (Abojassim, 2021b). Therefore, after measurement of radon concentrations in water samples (C_{RnW}) in all schools in this study, we were able to calculate the Annual Effective Dose (AED) due to intake of ^{222}Rn in water using the formula presented by UNSCEAR (2000) (UNSCEAR, 2000):

$$\text{AED} = C_{Rnw} \times C_W \times DCF \tag{1}$$

where C_{Rnw} is the average value of radon concentrations that measured using RAD-7 detector in unit (Bq/L), C_W is the rate of annual consumption of water which given 350 L/y in children at age from 7 to 12 year (ICRP, 2000; IAEA, 1996), and DCF is dose conversion factor in children (7 to 12 year) given as 5.9 nSv/Bq (ICRP, 2000; Hashim and Nayif, 2019).

3 Results and discussion

One hundred samples of tap water were gathered from various primary schools in Najaf city at Al-Najaf governorate, with the goal of measuring radon concentrations released from the water. Radon concentrations as well as annual effective dose in terms of ingestion, inhalation and total in the water, are shown in Table 2. ^{222}Rn concentrations varied from 0.007 to 0.567 Bq/L, with an average value of 0.114±0.009 Bq/L. The radon gas concentrations in tap water were determined to be below the acceptable limit established by the 'World Health Organisation' in water (0.5 Bq/L) (WHO, 2011), except for sample P20 (school Al-Safi Najafi at Alhawraa region). Furthermore, the ^{222}Rn content in tap water samples utilised as drinking water was lower than the ICRP-recommended concentration limit (0.4 Bq/L) (ICRP, 1993), except for samples P20 (school Al-Safi Najafi at Alhawraa region) and P16 (school Mustafa Jawad at Al Karama region).

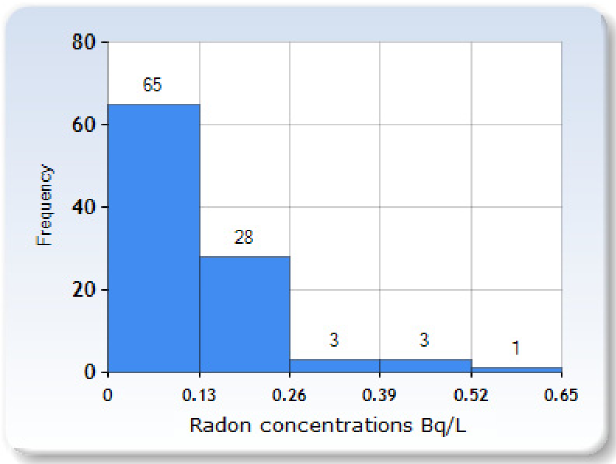
The results of AED due to ingestion of ^{222}Rn gas in tap water samples (see Table 2) were ranged 0.015 to 1.171, with an average value of 0.236±0.020 μSv/y, while due to inhalation were ranged from 0.001 to 0.074, with an average value of 0.015±0.0001 nSv/y. Also, it is found that the results of AED total from Table 2 were same values of AED due to ingestion. The typical radiation exposure to people from normal sources is approximately 0.002 mSv/y due to ingestion of water and drink via normal routes (UNSCEAR, 2000). The overall suggested radiation dosage is kept to less than 0.1 mSv/y by ingesting radionuclides via drinking water (Ljujic and Sundac, 1998; World Health Organization (WHO) and World Health Organisation Staff, 2004). Therefore, the results of AED due to ingestion of water for ^{222}Rn concentrations were less than the action limit of 0.022 mSv/y. Also, the results of the total AED for all samples of tap water were less than the action limit of 0.1 mSv/y. The source of tap water in these schools is same water networks from Najaf governorate. So, it is found radon concentrations for some schools are same. However, many other tap water samples have different values of radon concentrations. This may be caused by the presence of cracks in the tap water transmission pipes, which causes the entry of radon into them. The results of radon concentrations differed across all water samples examined, which can be attributed to the difference in the geological nature of each area as well as to the movement of water and its speed. On the other hand, radon gas concentration varies due to factors such as temperature, air pressure, humidity and changes in the Earth's layers. As a result, the radon concentration varies in these schools. The concentration of radon in majority of the samples under investigation was determined to be low and insignificant in terms of health risk.

Table 2 Results ^{222}Rn concentrations and AED

No.	*Sample code*	*^{222}Rn concentrations (Bq/L)*		*AED (µSv/y)*
		Average	*S. D*	
1	D1	0.078	0.035	0.161
2	D2	0.224	0.059	0.463
3	D3	0.142	0.047	0.293
4	D4	0.035	0.023	0.072
5	D5	0.225	0.059	0.465
6	D6	0.035	0.023	0.072
7	D7	0.153	0.049	0.316
8	D8	0.035	0.023	0.072
9	D9	0.106	0.041	0.219
10	D10	0.106	0.041	0.219
11	D11	0.074	0.034	0.153
12	D12	0.071	0.033	0.147
13	D13	0.071	0.033	0.147
14	D14	0.053	0.029	0.109
15	D15	0.355	0.074	0.733
16	D16	0.075	0.034	0.155
17	D17	0.055	0.029	0.114
18	D18	0.098	0.039	0.202
19	D19	0.195	0.055	0.403
20	D20	0.178	0.053	0.368
21	D21	0.057	0.030	0.118
22	D22	0.035	0.023	0.072
23	D23	0.071	0.033	0.147
24	D24	0.098	0.039	0.202
25	D25	0.110	0.041	0.227
26	D26	0.089	0.037	0.184
27	D27	0.035	0.023	0.072
28	D28	0.213	0.058	0.440
29	D29	0.094	0.038	0.194
30	D30	0.071	0.033	0.147
31	D31	0.252	0.063	0.520
32	D32	0.106	0.041	0.219
33	D33	0.248	0.062	0.512
34	D34	0.177	0.053	0.366
35	D35	0.089	0.037	0.184
36	D36	0.089	0.037	0.184
37	D37	0.053	0.029	0.109

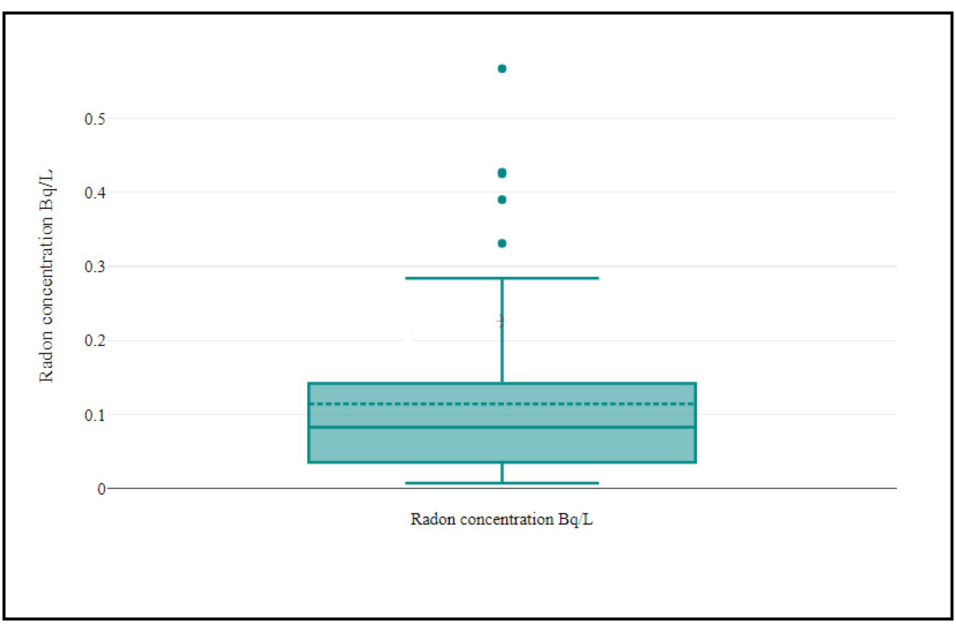
Figure 3 shows the histogram of the probability distribution of a continuous variable for radon concentrations of tap water in the selected schools. It is noted the means that 65% of the school samples contain the lowest ^{222}Rn levels.

Figure 3 Histogram of dose rate levels



A type of graph that gives a visual representation of location, variability and outliers is the box-whisker plot, or simply called the box plot. Figure 4 shows the box plot for ^{222}Rn concentration in the present study. The median is closer to the bottom of the box, then the data are likely to be left-skewed.

Figure 4 Box plot of ^{222}Rn concentrations of the investigated tap water samples



The numerical statistical values of the correlation coefficient (r) and *p*-value for the results of radon concentrations with type of school (boys or girls) on the one hand, and with date of establishment of schools on the other were determined using *T*-test program. Figure 5 shows relation between radon concentrations with type of school, while Figure 6 shows relation between radon concentrations with date of establishment of schools. From Figure 5, the correlation coefficient and *p*-value are –0.0527 and 0.62129, respectively. That means, technically a negative correlation, there is no relationship between results, as well as the result is not significant at $p < 0.05$. From Figure 6, the correlation coefficient and *p*-value are 0.1028 and 0.477453, respectively. That means, although technically a positive correlation, the relationship between results is only weak, as well as the result is not significant at $p < 0.05$.

Figure 5 Correlation between radon concentrations and date of establishment of schools

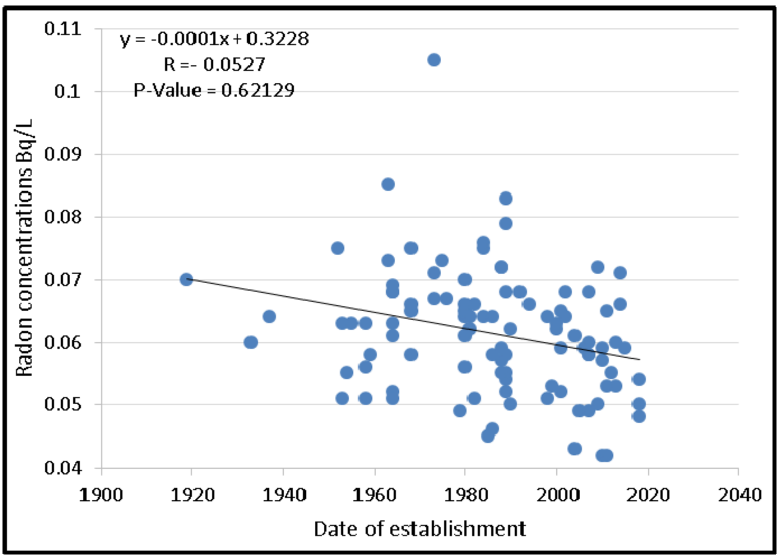
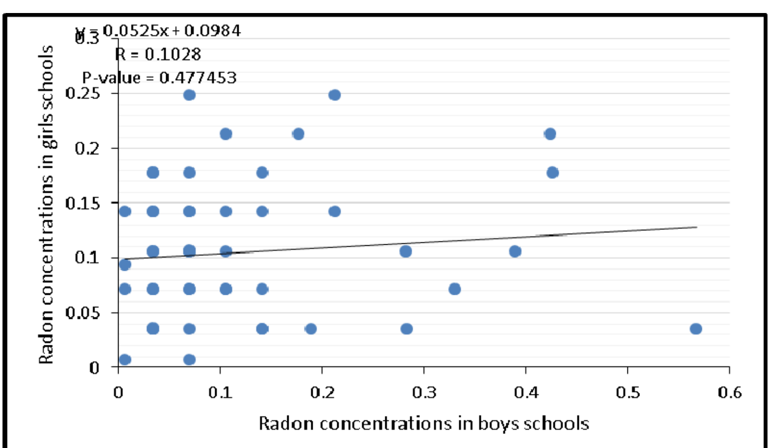


Figure 6 Correlation between dose rate and types of school



The maps illustrated in the Figures 7, 8 and 9, represent the radon concentrations, AED for inhalation and AED for ingestion due to radon gas in tap water samples. The technique which used to draw the maps is GIS with ArcGIS 10.7.1. The colour gradation in the maps indicates the different concentrations of radon as well as annual effective dose in the tap water samples by in all schools of the present study.

Figure 7 Distribution of the results of radon concentrations in tap water samples of schools (see online version for colours)

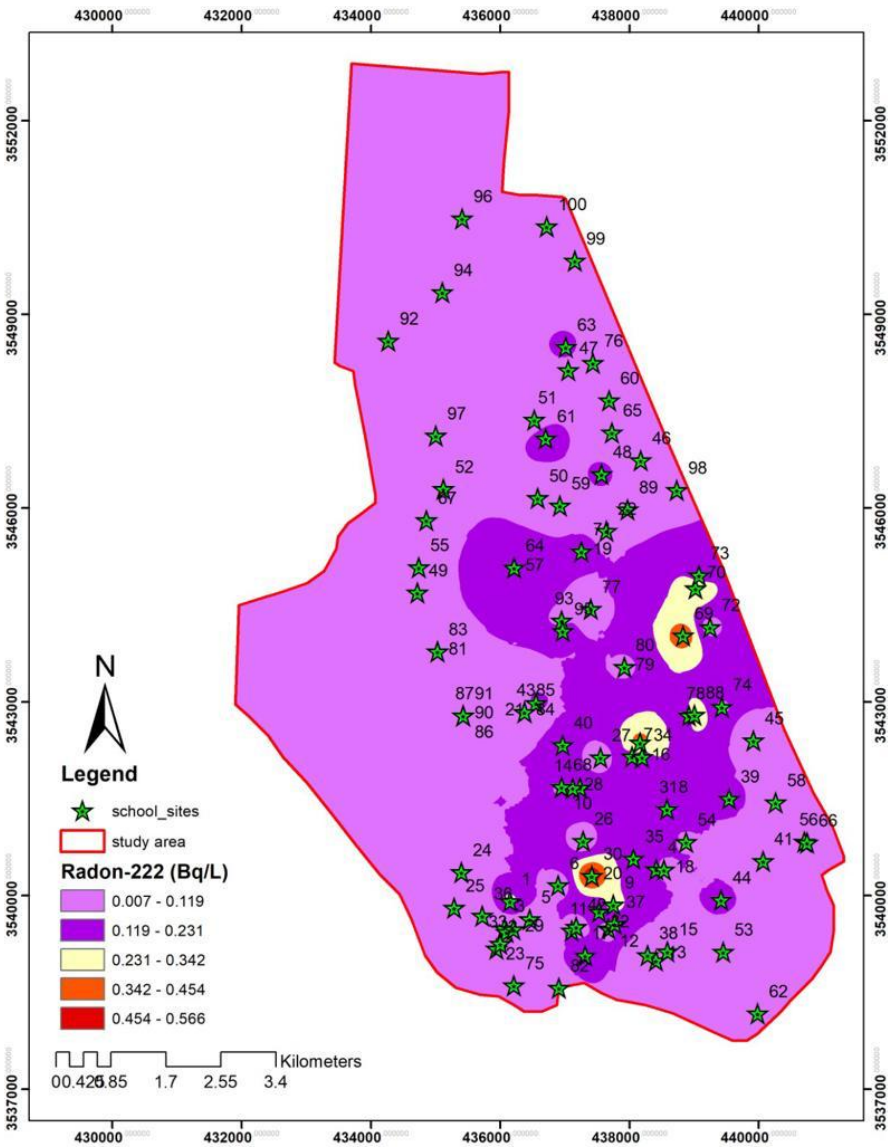


Figure 8 Distribution of the results of AED for ingestion radon gas in tap water samples of schools (see online version for colours)

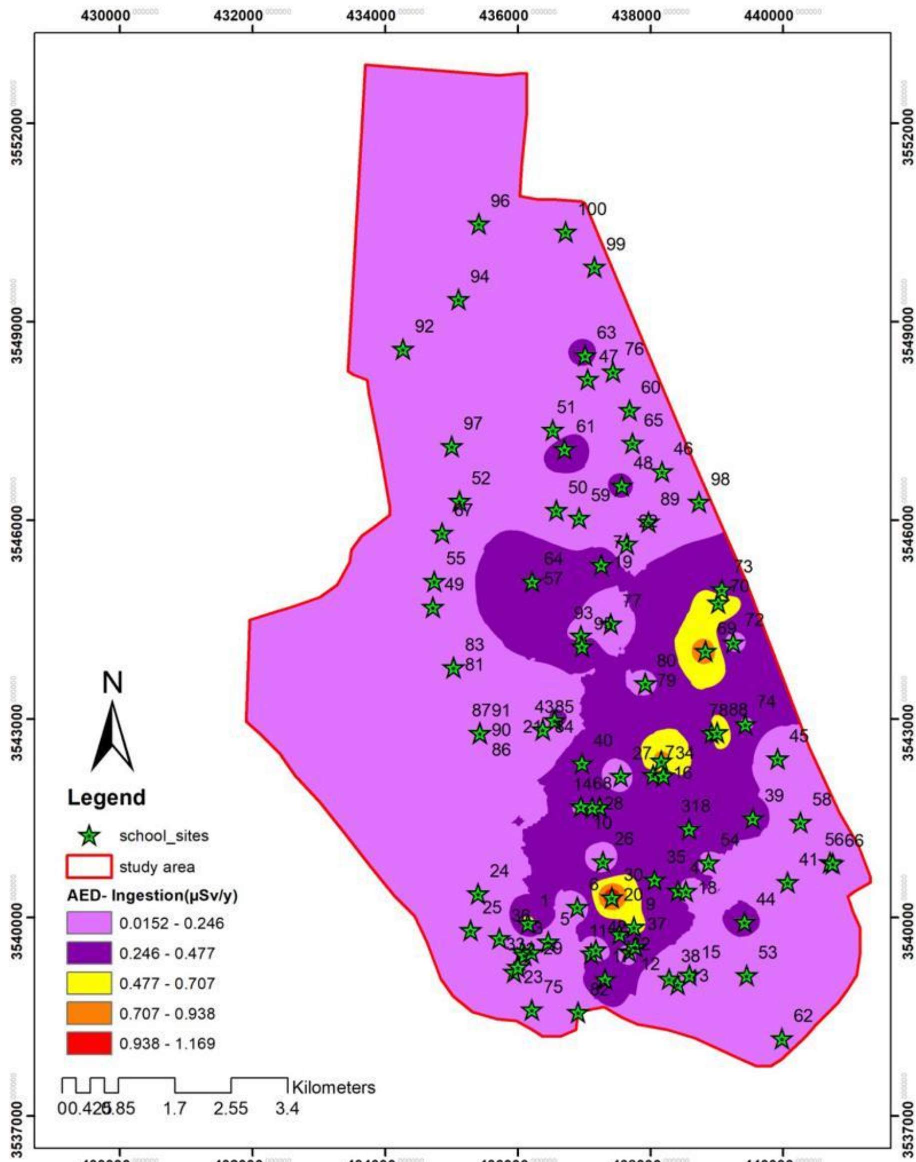


Figure 9 Distribution of the results of AED for inhalation radon gas in tap water samples of schools (see online version for colours)

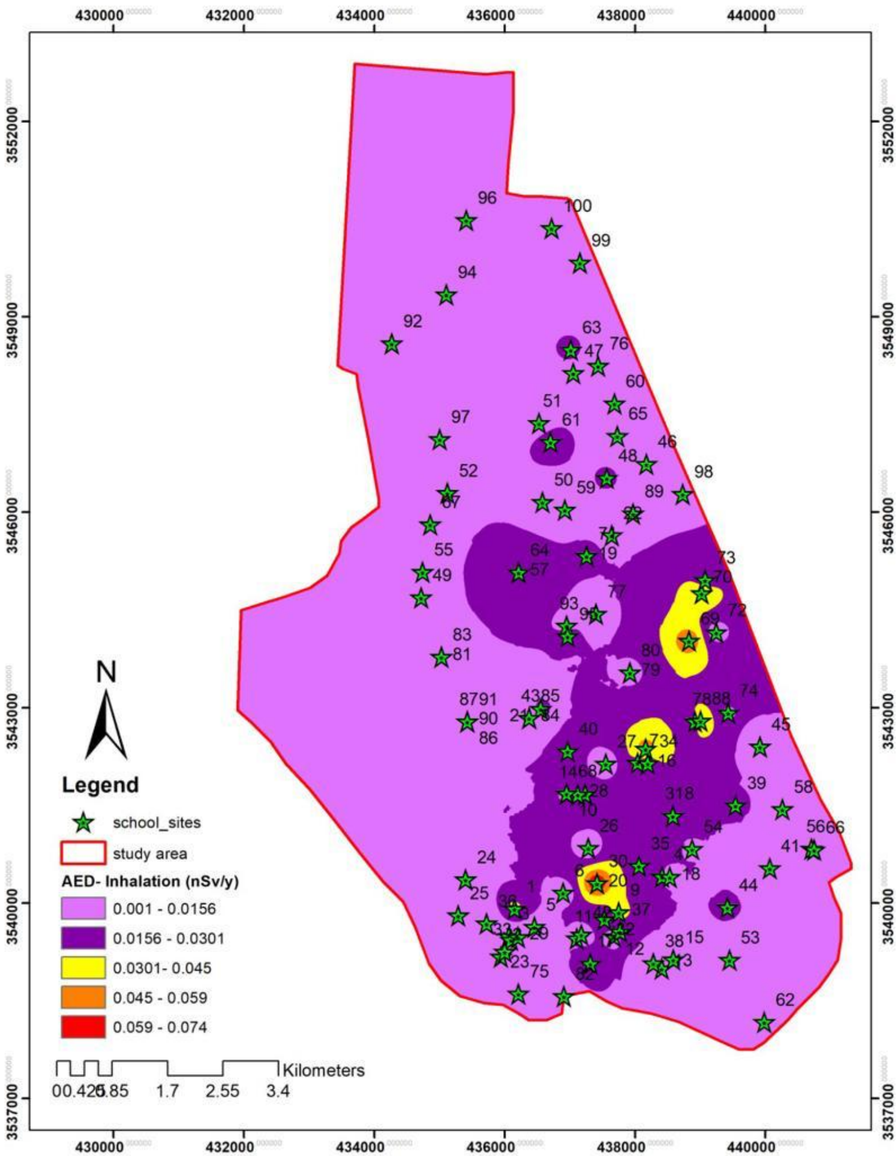


Table 3 shows comparison between the results of ^{222}Rn concentrations in tap water samples collected from schools of Najaf city at Al-Najaf governorate with several countries around the world. It is found the average of ^{222}Rn concentrations in the present study was lower than all previous studies shown in Table 3.

Table 3 Comparison of ^{222}Rn concentrations for tap water in the present study with others studies of many different countries

No.	*Country*	*^{222}Rn (Bq/L)*	*Reference*
1	Italy	6.80	Rusconi et al. (2004)
2	Iran	0.93	Fakhri et al. (2016)
3	Turkey	14.13	Büyükuslu et al. (2018)
4	China	0. 543	Yong et al. (2021)
5	Malaysia	1.95	Ismail et al. (2021)
6	Iraq (Al-Muthanna)	3.22	Al-Zaalimiu et al. (2022)
7	Iraq (Najaf)	0.114	Present study

Finally, from these findings for radon concentrations, the tap water samples for most schools in this work can be considered as safe drinking water in terms of radiation risks.

3 Conclusions

The concentrations of radon gas in all samples of tap water studied in this work are found below worldwide limits according to ICRP 1993 (0.5 Bq/L) and WHO 2011 (0.4 Bq/L), except two samples P16 and P20. The results of annual effective dose for inhalation due to radon concentrations in all samples is very low, so it may be neglected. The results of annual effective dose for ingestion due to radon concentrations and total for children age (7–12 year) in all samples were lower than the permissible limit by UNSCEAR2000, EC 1998 and WHO 2004, respectively. Statistically using *T*-test program, it is found no significant (p-value 0.05) between radon concentrations with date of establishment (old and new) and type (for girls and boys) of school. As a result, the natural radioactivity for ^{222}Rn concentrations in the most samples of tap water samples studied in this work does not result in significant changes in the internal radiation dose.

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. Doi: 10.1016/j.gsd.2020.100476.

Abojassim, A.A. (2021a) 'Age-dependent health risk assessment for radon concentrations from drinking water available in the Iraqi markets', *Egyptian Journal of Chemistry*, Vol. 64, No. 4, pp.3–4.

Abojassim, A.A. (2021b) 'Radon concentrations in canned liquid juice', Atom Indonesia, Vol. 47, No. 1, pp.1–4.

Abojassim, A.A., Alzurfi, S.K.L. and Mraity, H.A.A. (2018) 'Monthly monitoring of physicochemical and radiation properties of Kufa River, Iraq', *Pakistan Journal of Scientific & Industrial Research Series A: Physical Sciences*, Vol. 61, No. 1, pp.43–50.

Abojassim, A.A., Kadhim, S.H., Ali Mraity, H.A. and Munim, R.R. (2017) 'Radon levels in different types of bottled drinking water and carbonated drinks in Iraqi markets', *Water Science and Technology: Water Supply*, Vol. 17, No. 1, pp.206–211.

Ajibade, F.O., Adelodun, B., Lasisi, K.H., Fadare, O.O., Ajibade, T.F., Nwogwu, N.A. and Wang, A. (2021) 'Environmental pollution and their socioeconomic impacts', *Microbe Mediated Remediation of Environmental Contaminants*, Woodhead Publishing, pp.321–354.

Al-Hamidawi, A. (2014) 'Assessment of radiation hazard indices and excess life time cancer risk due to dust storm for Al-Najaf, Iraq', *WSEAS Transactions on Environment and Development*, Vol. 10, p.312.

Al-Zaalimiu, T.H., Al-Hamzawi, A.A. and Ali, A.A. (2022) 'Radon gas determination and radiological risk in tap water of Al-Muthanna governorate, Iraq', *AIP Conference Proceedings*, AIP Publishing LLC, Vol. 2386, No. 1. Doi: 10.1063/5.0067123.

Baumstark-Khan, C., Kozubek, S. and Horneck, G. (Eds) (2013) *Fundamentals for the Assessment of Risks from Environmental Radiation*, Vol. 55, Springer Science & Business Media.

Büyükuslu, H., Özdemir, F.B., Öge, T.Ö. and Gökce, H. (2018) 'Indoor and tap water radon (222Rn) concentration measurements at Giresun University campus areas', *Applied Radiation and Isotopes*, Vol. 139, pp.285–291.

Cothern, C.R. (Ed.) (2019) *Handbook for Environmental Risk Decision Making: Values, Perceptions, and Ethics*, CRC Press.

Fakhri, Y., Kargosha, M., Langarizadeh, G., Zandsalimi, Y., Amirhajeloo, L.R., Moradi, M. and Mirzaei, M. (2016) 'Effective dose Radon 222 of the tap water in children and adults people: Minab City, Iran', *Global Journal of Health Science*, Vol. 8, No. 4, pp.234–243.

Harrison, R.M. (Ed.) (2001) *Pollution: Causes, Effects and Control*, Royal Society of Chemistry.

Hashim, A.K. and Nayif, S.S. (2019) 'Assessment of internal exposure to radon in schools in Karbala, Iraq', *Journal of Radiation and Nuclear Applications*, Vol. 4, No. 1, pp.25–34.

IAEA (1996) *International Atomic Energy Agency – International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources*, Vienna, Safety Series-115.

ICRP (International Commission on Radiological Protection) (2000) *Protection of the Public in Situations of Prolonged Radiation Exposure*, ICRP Publication 82. Ann. ICRP 29 (1–2) (Elsevier).

ICRP. (1993) 'Protection against radon-222 at home and at work', *Annals of the ICRP*, Vol. 23, No. 2, ICRP Publication 65.

Ismail, N.F., Hashim, S., Sanusi, M.S.M., Abdul Rahman, A.T. and Bradley, D.A. (2021) 'Radon levels of water sources in the Southwest Coastal Region of Peninsular Malaysia', *Applied Sciences*, Vol. 11, No. 1, Doi: 10.3390/app11156842.

Ljujic, B. and Sundac, L. (1998) '[[Council] Directive 98/83/EC [of 3 November 1998] on the quality of water intended for human consumption: review and integral translation [from English into Serbian]]', *Voda i sanitarna tehnika (Serbia and Montenegro)*.

Nuccetelli, C. and Trevisi, R. (2018) 'Radon and NORM: naturally occurring radioactive materials', *Physical Agents in the Environment and Workplace*, CRC Press, pp.277–286.

Rusconi, R., Forte, M., Badalamenti, P., Bellinzona, S., Gallini, R., Maltese, S. and Sgorbati, G. (2004) 'The monitoring of tap waters in Milano: planning, methods and results', *Radiation Protection Dosimetry*, Vol. 111, No. 4, pp.373–376.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) (2000) *Sources and Effects of Ionizing Radiation*, Report to the General Assembly with Scientific Annexes, 1.

WHO, G. (2011) 'Guidelines for drinking-water quality', *World Health Organization*, Vol. 216, pp.303–304.

World Health Organization (WHO) and World Health Organisation Staff (2004) *Guidelines for Drinking-Water Quality*, Vol. 1, World Health Organization.

Yong, J., Liu, Q., Wu, B., Hu, Y. and Feng, G. (2021) 'Assessment of radiation dose hazards caused by radon and its progenies in tap water by the human dosimetric model', *Journal of Water and Health*, Vol. 19, No. 6, pp.933–945.