Check for updates

Radon levels in different types of bottled drinking water and carbonated drinks in Iraqi markets

Ali Abid Abojassim, Suha H. Kadhim, Hussien Abid Ali Mraity and Rua R. Munim

ABSTRACT

In the present work, radon concentration was measured for different types of bottled drinking water and carbonated drink samples that are available in Iraqi markets. Radon measurements were carried out using a RAD-7 electronic radon detector. Annual effective dose was also calculated. The measured radon concentration in samples of bottled drinking water ranged from 0.0354 to 0.248 Bq/l with a mean value of 0.11265 Bq/l and the measured radon concentration in the samples of the carbonated drinks lay between 0.0354 and 0.283 Bq/l with a mean value of 0.1418 Bq/l. The mean values of the effective dose in all samples of bottled drinking water and carbonated drinks were found to be 0.410844 and 1.022 μSv/y respectively. The results of this work revealed that the radon concentrations were lower than the recommended limits indicated by the World Health Organization and by the regulatory bodies of the European Union.

Key words | annual effective dose, bottled water, carbonated drinks, Iraqi markets, radon concentrations

Ali Abid Abojassim (corresponding author)
Suha H. Kadhim
Hussien Abid Ali Mraity
Rua R. Munim
Department of Physics box (221),
University of Kufa, Faculty of Science,
Najaf,
Iraq
E-mail: *ali.alhameedawi@uokufa.edu.iq*

INTRODUCTION

Nuclear radiation naturally exists in the environment in which humans live. This means that human beings receive exposure from naturally occurring radiation in soil, water, air and food. In this context, radium-226 is the fifth decay product of uranium-238; it decays into radon-222, which is the heaviest gaseous element in the natural decay series of uranium, thorium and actinium (ICRP 1999). Radon gas is characterized by naturally emitting alpha particles. Radon is a chemically inert, colorless, tasteless and odorless gas which results from the natural radioactive decay of the uranium, radium and thorium that exist everywhere in traces in the rocks and soils of the earth's crust (Reid 1986; Gillmore & Jabarivasal 2010). Naturally, radon can be classified into three isotopes: first, ^{222}Rn, which is produced from the decay of ^{238}U with a natural abundance of about 99.3% of the total uranium within the earth's crust; second, thoron, ^{220}Rn, which is produced in nature during the decay of ^{232}Th; and finally ^{219}Rn, which is formed during the decay of ^{235}U (Gillmore & Jabarivasal 2010). The isotope ^{222}Rn has a half-life of 3.8 days and is the most stable and abundant isotope of radon in nature. It decays by emitting an α-particle of (5.49 MeV) and creates radioactive daughters (Reid 1986; Gillmore & Jabarivasal 2010). The radon can be dissolved and transported into water by pores in rock and soil. The associated health hazard gives rise to a radiation dose which results from either inhalation or ingestion. In this sense, radon gas can be transmitted from water to the air, and when inhaled, this leads to the exposure of the lungs to radiation risk. From the other side, ingestion of water containing radon is considered to directly impact the stomach (Khursheed 2000). It should be noted that around 1–2% of radon in the air comes from drinking water (USEPA 1991). Therefore breathing radon increases the risk of lung cancer over the course of a lifetime. Furthermore,

doi: 10.2166/ws.2016.127

Downloaded from http://iwaponline.com/ws/article-pdf/17/1/206/410457/ws017010206.pdf
by guest

drinking water containing radon presents a risk of developing internal organ cancers, primarily stomach cancer (USEPA 1991). Some people believe that the dissolved minerals in the water could be good whereas others do not. There are some scientists who have recently used the RAD-7 detector to measure the concentration of radon in water (Abdalsattar & Abbas 2012; Ali 2013; Ali & Ahmed 2013; Guida *et al.* 2013, 2015; Ali *et al.* 2015a, 2015b). For this purpose, it is fundamental to have regulations regarding the natural radioactivity in bottled water and carbonated drinks. The aim of this study was to measure the radon concentrations in different types of bottled water and carbonated drinks that are commonly used in Iraq. Additionally, this study included the calculation of annual effective dose in all samples.

MATERIAL AND METHODS

Collection of samples

Thirty-three samples (i.e. 15 bottled water and 18 carbonated drinks) were collected from Iraqi markets. These samples were divided into two groups according to the trademark and the country of manufacturing as shown in Tables 1 and 2.

Laboratory procedure

The RAD-7 can be defined as a true, real-time, continuous monitoring device for radon. This means that variability in the radon concentration levels can be observed during the period of measurement. This is very useful, in the sense that one can investigate the factors influencing the radon concentration over time. These factors include changes in temperature, wind speeds, and relative humidity and may also give an insight into air movements inside a room (Durridge 2012).

Radon concentrations in the study samples were measured using a RAD-7 electric radon detector that connected to the RAD-H_2O accessory for a period of 1 month. Figure 1 shows a schematic diagram of the RAD-H_2O setup. The RAD-7 was used for measuring radon in water by connecting it to a bubbling kit that enabled gas to be released from the sample of water into the air existing in a closed loop. The water sample was taken into a radon-tight reagent bottle of 250 ml capacity connected to a glass bulb containing calcium to absorb the moisture and to the closed circuit of a zinc-sulphide-coated detection chamber.

Table 1 | Bottled water samples used in the current study

No.	Sample code	Trade name of sample	Producing country
1	B1	Nawar	Iraq (Najaf)
2	B2	Sanan	
3	B3	Al-tour	
4	B4	Mazaya	
5	B5	Bratha	
6	B6	Al-saqi	
7	B7	Sawa	Iraq (Babylon)
8	B8	Alwaha	
9	B9	Aljanen	Iraq (Baghdad)
10	B10	Venazya	
11	B11	Mina	Iraq (Kirkuk)
12	B12	Karwan	
13	B13	Life	Iraq (Zakho)
14	B14	Zalal	Iraq (Duhok)
15	B15	Alrawdhatan	Kuwait

Table 2 | Carbonated drink samples used in the current study

No.	Sample code	Trade name of sample	Producing country
1	C1	Shani	Iraq (Kufa)
2	C2	7 Up	
3	C3	Frei	
4	C4	Diet Pepsi	
5	C5	Miranda apple	
6	C6	Miranda	
7	C7	7 Up	Iraq (Babylon)
8	C8	Akad oranges	
9	C9	Pepsi Cola	
10	C10	Pepsi	
11	C11	Sprite	
12	C12	Crystal Up	Iraq (Karbala)
13	C13	Crystal Pepsi	
14	C14	Shani	Iraq (Kirkuk)
15	C15	Diet Kazhoz	Iraq (Arbel)
16	C16	Sprite	Turkey
17	C17	Frida	Saudi Arabia
18	C18	Fimto	Saudi Arabia

Downloaded from http://iwaponline.com/ws/article-pdf/17/1/206/410457/ws017010206.pdf
by guest

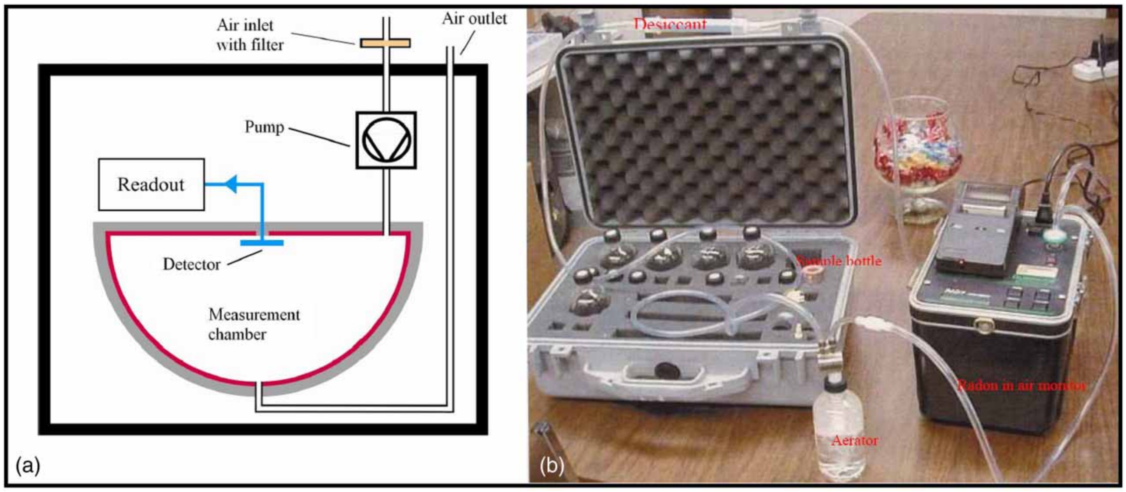

Figure 1 | Schematic representation of the RAD-7 instrument (Durridge 2012) for measuring radon in water.

This chamber acted as a scintillator to detect alpha particles. The air was then circulated in a closed circuit for a period of 5–10 min until the radon was uniformly mixed with the air where the resulting alpha particles were then recorded. It should be noted that the high humidity reduced the efficiency of collection of the polonium-218 atoms that formed when radon decayed inside the chamber. However, the 3.05 min ^{218}Po half-life indicates that almost all the decays were

Table 3 | The concentrations of radioactive radon gas rate and the annual effective dose in samples of bottled drinking water used in the current study

No.	Sample code	Radon concentration (Bq/m^3) Mean	Radon concentration (Bq/m^3) ± Errors	Radon concentration (Bq/l) Mean	Radon concentration (Bq/l) ± Errors	The annual effective dose rate (mSv/y) Mean	The annual effective dose rate (mSv/y) ± Errors
1	B1	70.9	8.42	0.0709	0.008	0.25	0.0009
2	B2	94.6	9.72	0.0946	0.009	0.34	0.0012
3	B3	212.5	14.57	0.2125	0.014	0.77	0.0028
4	B4	106.5	10.31	0.1065	0.010	0.38	0.0013
5	B5	177.25	13.31	0.1772	0.013	0.64	0.0023
6	B6	141.5	11.89	0.1415	0.011	0.51	0.0018
7	B7	71	8.42	0.071	0.008	0.26	0.0009
8	B8	95	9.74	0.095	0.009	0.34	0.0012
9	B9	35.4	5.94	0.0354	0.005	0.12	0.0004
10	B10	132.75	11.52	0.1327	0.011	0.48	0.0017
11	B11	96	9.79	0.096	0.009	0.35	0.0012
12	B12	89	9.43	0.089	0.009	0.32	0.0011
13	B13	248	15.75	0.248	0.015	0.91	0.0033
14	B14	BLD[a]	–	BLD[a]	–	BLD[a]	–
15	B15	118	10.86	0.118	0.010	0.43	0.0015
Mean		112.65		0.11265		0.410844	

[a]BLD: This refers to the detected value being less than the detection limit of the device used, which is 4 Bq/m^3.

Downloaded from http://iwaponline.com/ws/article-pdf/17/1/206/410457/ws017010206.pdf
by guest

actually counted at the first 20 min of measurement. So, an increase in humidity above 10% across the last 10 min of the counting period would not have a considerable effect on the accuracy of the measurement. Nevertheless, if the humidity increased above 10% before the end of the first counting cycle, then there would be an error whose level is hard to define (RAD-7, RAD-H_2O). This therefore gives a direct measure for the radon concentration.

The annual effective dose

The annual effective dose for an individual consumer due to the radon intake from bottled water was evaluated using the following equation (Alam *et al.* 1999):

$$D_w = C_w C_{Rw} D_{cw} \quad (1)$$

D_w is the annual effective dose (Sv/y) due to ingestion of radionuclides from the consumption of water; C_w is the concentration of ^{222}Rn in the ingested drinking water (Bq/l); C_{Rw} is the annual intake of drinking water (l/y) and D_{cw} is the ingested dose conversion factor for ^{222}Rn (Sv Bq^{-1}). For the purpose of effective dose calculation, a dose conversion factor of 5×10^{-9} Sv/Bq was used (UNSCEAR 1999). The annual effective dose due to intake of ^{222}Rn from drinking water is calculated considering that an adult (age 18 years), on average, takes 730 l water annually (Cevik *et al.* 2006). Following ingestion of ^{222}Rn dissolved in drinking water, mean effective doses per litre (nSv/l) and annual effective doses (mSv/y) were calculated (UNSCEAR 2000). In addition to this, the annual effective dose can be calculated from the carbonated drink samples using Equation (1); however, the annual intake of carbonated drinks (l/y) is different, and is equal to about (66 l/y) (Abdalsattar & Abbas 2012).

Table 4 | The concentrations of radioactive radon gas rate and the annual effective dose in samples of carbonated drinks used in the current study

		Radon concentration (Bq/m^3)		Radon concentration (Bq/l)		The annual effective dose rate (mSv/y)	
No.	**Sample code**	**Mean**	**± Errors**	**Mean**	**± Errors**	**Mean**	**± Errors**
1	C1	212.5	14.57	0.2125	0.014	0.07	0.0048
2	C2	176.9	13.30	0.1769	0.013	0.058	0.0043
3	C3	82	9.05	0.082	0.009	0.027	0.0029
4	C4	88.7	9.41	0.0887	0.009	0.029	0.0031
5	C5	BLD[a]	–	BLD[a]	–	BLD[a]	–
6	C6	BLD[a]	–	BLD[a]	–	BLD[a]	–
7	C7	190	13.78	0.19	0.013	0.063	0.0045
8	C8	177.2	13.31	0.177	0.013	0.059	0.0043
9	C9	122	11.04	0.122	0.011	0.04	0.0036
10	C10	106.4	10.31	0.106	0.010	0.035	0.0034
11	C11	135	11.61	0.135	0.011	0.044	0.0038
12	C12	35.4	5.94	0.035	0.005	0.011	0.0019
13	C13	94.66	9.72	0.094	0.009	0.031	0.0032
14	C14	BLD[a]	–	BLD[a]	–	BLD[a]	–
15	C15	283	16.82	0.283	0.016	0.093	0.0055
16	C16	BLD[a]	BLD[a]	BLD[a]	BLD[a]	BLD[a]	–
17	C17	142	11.91	0.142	0.011	0.047	0.0039
18	C18	140	11.83	0.14	0.011	0.046	0.0039
Mean		141.98		0.1418		0.036	

[a]BLD: This refers to the detected value being less than the detection limit of the device used, which is 4 Bq/m^3.

Downloaded from http://iwaponline.com/ws/article-pdf/17/1/206/410457/ws017010206.pdf
by guest

RESULTS AND DISCUSSION

The results for the radon concentration and the average of the annual effective dose in different types of bottled water and carbonated drink samples are shown in Tables 3 and 4. The results for radon concentration in samples of bottled drinking water varied from 0.0354 ± 0.005 Bq/l in sample code B9 (Alganaean) to 0.248 ± 0.015 Bq/l in sample code B13 (Life) with an average value of 0.11265 Bq/l. However, in sample code B14 (i.e. Zalal) no measurement was found, as shown in Table 3. All samples in Table 4 had radon concentrations except samples C5, C6, C14 and C16, which were not detected by the detector; therefore we excluded them from the results. The radon concentration varied from 0.0354 ± 0.005 Bq/l in sample code C12 (Crystal Up) to 0.283 ± 0.016 Bq/l in sample code C15 (Diet Kazhoz) with an average value of 0.1418 Bq/l.

The values of radon concentrations in bottled water and carbonated drink samples under study are lower than the maximum allowed concentration, which is 0.5 Bq/l (500 Bq/m^3) as set by the WHO Guidelines for drinking water quality (WHO 2008) (Figures 2 and 3). The effective annual dose was calculated using Equation (1), and can be seen in Tables 3 and 4; for those people who are drinking bottled water and carbonated drinks annually the effective doses ranged from 0.12 mSv/y to 0.91 mSv/y and from 0.011 mSv/y to 0.093 mSv/y respectively. We found that all results of the effective annual dose for radon concentrations in the studied samples were lower than the reported normal limits for the world (i.e. 1 mSv/y) (UNSCEAR 2000).

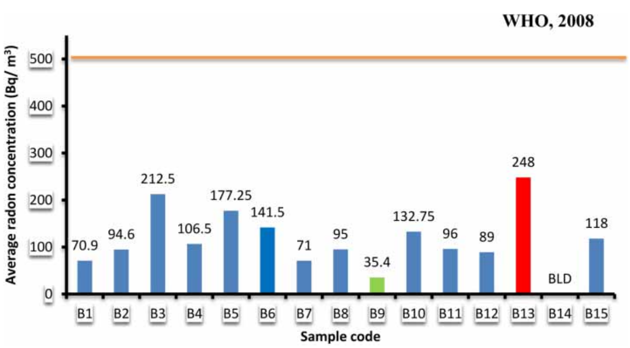

Figure 2 | This figure compares the mean of radon concentrations in bottled water with WHO published values.

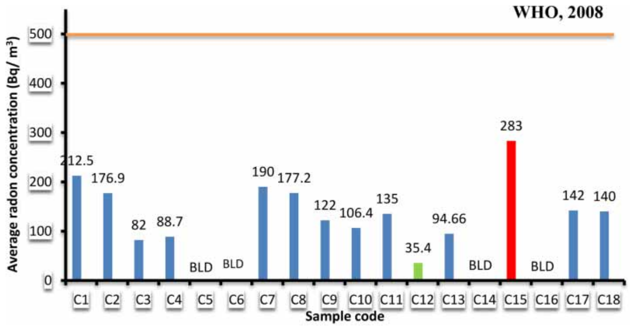

Figure 3 | This figure compares the mean of radon concentrations in carbonated drinks with WHO published values.

By way of comparison, the results of this study with relevant studies conducted in Iraq are tabulated in Table 5. From this table it can be seen that the average concentrations of radon in the present study are lower in comparison with these studies.

CONCLUSION

According to the resulting data from this study, we can conclude that all radon concentrations and the annual effective dose which were obtained from different types of bottled drinking water and carbonated drinks are less than that allowed as the maximum concentration level according to

Table 5 | The mean of radon concentration in the water for some countries compared with the present research

No.	Government and year	Sample type	Radon concentrations (Bq/l)	References
1	Karbala, 2012	Carbonated drinks	0.17–0.56	Abdalsattar & Abbas (2012)
2	Najaf, 2013	Drinking water	0.0243–0.2255	Ali *et al.* (2015a, 2015b)
3	Babylon, 2014	Drinking water	0.29	Wasan (2014)
4	Karbala, 2015	Bottled mineral water	2.594	Abdalsattar & Rajaa (2015)
5	Baghdad, 2015	Drinking water	0.012–0.283	Ali *et al.* (2015a, 2015b)
6	Present study	Bottled water	0.0354–0.248	–
7	Present study	Carbonated drinks	0.0354–0.283	–

Downloaded from http://iwaponline.com/ws/article-pdf/17/1/206/410457/ws017010206.pdf
by guest

the World Health Organization and EU Council (i.e. indicative dose, 1.0 mSv per annum; parametric value, 100 Bq/l). Finally, it may be argued that there is no significant radiological risk to inhabitants resulting from radon ingestion by way of the bottled drinking water and carbonated drinks available in Iraqi markets.

REFERENCES

Abdalsattar, K. H. & Abbas, J. A. 2012 Radon measurements in different types of carbonated drinks in Iraq. *Journal of Karbala University* **10** (14), 41–46.

Abdalsattar, K. H. & Rajaa, H. A. 2015 Measurement of annual effective doses of radon in plastic bottled mineral water samples in Iraq. *Australian Journal of Basic and Applied Sciences* **9** (5), 31–35.

Alam, M. N., Chowdhry, M. I., Kamal, M., Ghose, S., Islam, M. N. & Awaruddin, M. 1999 Radiological assessment of drinking water of the Chittagong region of Bangladesh. *Radiation Protection Dosimetry* **82**, 207–214.

Ali, A. A. 2013 Radon concentrations measurement for drinking water in Kufa City /Iraq using active detecting method. *Advances in Physics Theories and Applications* **26**, 30–35.

Ali, A. A. & Ahmed, R. S. 2013 Estimated the mean of annual effective dose of radon gases for drinking water in some locations at Al-Najaf city. *Journal of Kufa Physics* **5** (2), 53–58.

Ali, A. A., Hussain, H. G., Mohammed, H. A. & Suha, H. K. 2015a Radon concentrations in selected samples of tap water in Baghdad Government/Iraq. *Research Journal of Applied Sciences, Engineering and Technology* **11** (12), 1358–1364.

Ali, A. A., Hussain, H. G., Faeq, A. T. & Muntathar, A. A. 2015b Study of time measured factor on measuring radon concentrations in groundwater. *Theoretical and Applied Science* **1** (21), 16–21.

Cevik, U., Damla, N., Karahan, G., Celebi, N. & Kobya, A. I. 2006 Natural radioactivity in tap waters of eastern Black Sea region of Turkey. *Radiation Protection Dosimetry* **118**, 88–92.

Durridge, RAD7 Radon Detector 2012 *Owner's Manual* Bedford, MA, USA.

Gillmore, G. K. & Jabarivasal, N. 2010 A reconnaissance study of radon concentrations in Hamadan city, Iran. *Natural Hazards and Earth System Sciences* **10**, 857–863.

Guida, M., Guida, D., Guadagnuolo, D., Cuomo, A. & Siervo, V. 2013 Using Radon-222 as a naturally occurring tracer to investigate the streamflow-groundwater interactions in a typical Mediterranean fluvial-karst landscape: the interdisciplinary case study of the Bussento river (Campania region, Southern Italy). *WSEAS Transactions on Systems* **12** (2), 85–104.

Guida, M., Guida, D. & Cuomo, A. 2015 Space-time distribution of Radon-222 from groundwater–streamflow–atmosphere interactions in the karst systems of the Campania region (Southern Italy). In: *Radon: Geology, Environmental Impact and Toxicity Concerns* (Audrey M. Stacks, ed.), Nova Science Publishers, New York, USA.

ICRP 1999 *Age Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5. Compilation of Ingestion and Inhalation Dose Coefficients*. Annals of the ICRP, Pergamon Press, Oxford, UK.

Khursheed, A. 2000 Doses to systemic tissues from radon gas. *Radiation Protection Dosimetry* **88** (2), 171–181.

Reid, J. M. 1986 *The Atomic Nucleus,* 2nd edn. Manchester University Press, Manchester, UK.

UNSCEAR 1999 *Sources and Effects of Ionizing Radiation.* UN, New York, USA.

UNSCEAR(B) 2000 *Sources and Effects of Ionizing Radiation, Annex B: Exposures from Natural Radiation Sources.* New York, USA.

USEPA 1991 National primary drinking water regulation; radionuclides: proposed rule. US Government Printing Office Federal Register 40 Parts 141 and 142.

Wasan, M. M. 2014 Measurement and study of radioactive radon gas concentrations in the selected samples of water for AL-Shomaly/Iraq. In: *Proceedings Book of ICETSR, Malaysia. Handbook on the Emerging Trends in Scientific Research*, PAK Publishing Group, pp. 699–704.

WHO 2008 *Guidelines for Drinking-Water Quality*, 3rd edn. World Health Organization, Geneva, Switzerland.

First received 8 May 2016; accepted in revised form 19 July 2016. Available online 29 July 2016

Downloaded from http://iwaponline.com/ws/article-pdf/17/1/206/410457/ws017010206.pdf
by guest