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Assessment of Annual effective Dose for Different Age Groups based on Radon Concentrations in the Groundwater of Qassim, Saudi Arabia

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ABSTRACT

Introduction: Given that the groundwater is a radon contaminated and used as a source for drinking water, then measuring the amount contamination is of high necessity.
Material and Methods: The measurement was performed using RAD-7 detector.
Results: The measured radon concentration values ranged 1.20-15.43 Bq/l with the mean of 5.18±0.39 Bq/l. The estimated total annual effective doses based on radon concentrations in drinking water were within the range of 6.34-81.62 µSv/y for infants, 2.34-30.04 µSv/y for children, and 3.07-39.42 µSv/y for adults. Moreover, the corresponding mean values were estimated at 27.41±2.06, 10.08±0.76, and 13.23±0.99 µSv/y, respectively.
Conclusion: The total annual effective dose in all samples were within the global average level of ingestion exposure dose value (0.1 mSv/y from radon concentrations) reported by the United Nations Scientific Committee on Effects of Atomic Radiations. Therefore, there are no risks for the consumption of these water samples.

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Introduction

The measurement of natural radioactivity in the environment allows the assessment of the population's exposure to radiation [1]. The existence of natural radionuclides in water dated back to the origin of the water as well as human activities in specific areas, where fertilizers were used for agricultural purposes [2]. Certain products usually contain some trace elements, such as radon gas, which can increase the level of natural radionuclides in soil. The industrial activities in the extraction and processing of earth materials or their subsequent products can, to certain extent, contribute to the increase of radionuclides in the hydrosphere through surface and/or groundwater. For groundwater (boreholes and wells), radionuclides can be found in lithological solid aquifers or surrounding rocks, where groundwater is stored. These solid aquifers or rocks known as geological materials usually contains some trace amounts of radioactive elements, such as radon gas, which can be dissolved into the groundwater during water/rocks-soils interaction mechanism [3-5].. As a result, the present study sought to evaluate the radon concentrations in the groundwater samples of Al Qassim region, located in Saudi Arabia. The reasons to select this region were firstly the effect of groundwater on the geological nature of this area, secondly the lack of radiation environmental studies in this region, and finally the agricultural nature of this site. Therefore, certain chemicals and pesticides are frequently used in this areas, compared to other regions in this province. In this regards, the process of radon level assessment has become one of the major issues of radiation protection that attracts the interest of researchers worldwide. Radon exposure is expected to happen when using water for showering, washing dishes, cooking, and drinking purposes. RAD-7 and Rad H_20 accessories are used to measure the radon concentration in water sample [6]. Many countries have recently aimed to measure radionuclide concentration in water samples through the implementation of different techniques [7-11]. In the present study, RAD-7 detector was used to assess the radon concentrations in groundwater samples that were collected from certain locations in Al Qassim area. Additionally, the annual effective dose was evaluated in all water samples with regard to different age groups.

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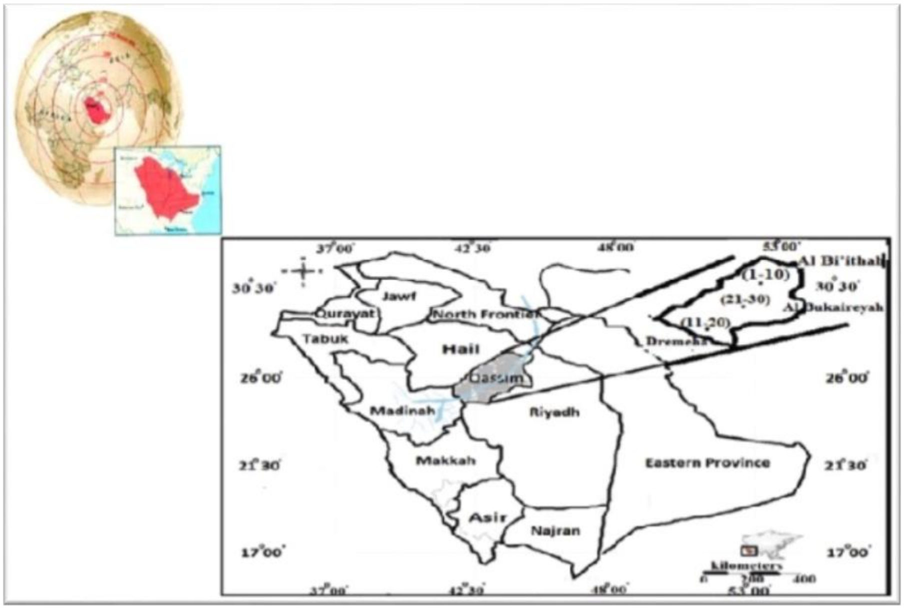

Figure 1. Location of Al-Qassim

Site of Study

Al-Qassim is one of the administrative regions (1 out of 13 regions) located in Saudi Arabia (see Figure 1). It is situated at the heart of the country, and in the center of the Arabian Peninsula Al-Qassim is located at latitude 26° 5' 38.7168'' N and longitude 43° 58' 24.4344'' E. . It has an area of about 58,046 km^2.Al-Qassim region is well known by “alimental basket” of Saudi Arabia for its agricultural nature. Moreover, Al-Qassim is considered as the richest region per capita in Saudi Arabia [12].

Materials and Methods

In the present study, 61 water samples from different areas of Al-Qassim were chosen to provide a comprehensive representation of groundwater in this region. The employed methods to collect the sample were as follows. First, a sample of groundwater was taken from each location at a depth of 5-10 m. The samples were then kept in a plastic container of 250 ml volume. Afterwords, the radon concentrations were measured using portable RAD-7 detector. The RAD H_2O is an accessory with the RAD-7 detector that enables the measurement of radon in water with the concentration of less than 10 pCi/l [13]. This detector is a portable battery-based device with a very fast measurement. Therefore, it takes around an hour for this system to detect the radon in the water sample accurately. As a result, it gives the reading after about 30 min of analysis considering a sensitivity level that is close to or even exceeding that of liquid scintillation techniques [14]. Finally, over than 95% of the existed radon were removed from the water during 5 min of aeration.

The radon concentration in the internal cell of RAD-7 was determined by the following differential *Equations.*

$$dC(t) / dt = -\lambda\, C(t)\,, \tag{1}$$

$$dC_{Po}(t) / dt = \lambda_{Po}C(t) - \lambda_{Po}C_{Po}(t), \tag{2}$$

where, *C(t)* refers to the radon concentration in the internal cell of RAD-7, λ is the decay constant of radon, C_{po} *(t)* denotes ^{218}Po concentration, and λ_{po} signifies ^{218}Po decay constant that equals to 0.0037 s^{-1}.

After a certain time of pumping, the radon concentration in the internal cell of RAD-7 equals to that of the environment C_0. *Equation 2* can be rewritten as follows:

$$dC_{Po}(t)\, dt = \lambda_{Po}C_0 - \lambda_{Po}C_{Po}(t). \tag{3}$$

The initial condition is: $C_{Po}(0) = 0$ (4)

By solving *Equation 4*, one can obtain the following

$$C_{Po}(t) = C_0(1 - e^{-\lambda_{Po}\, t}) \tag{5}$$

In case the time is much longer than the half-life of ^{218}Po, *Equation 5* can be rewritten as follows:

$$C_{Po}(t) = C_0. \tag{6}$$

Radon concentration can be obtained from *Equation 6*, and this is the measurement principle of RAD-7.

The estimation of annual effective dose E_d (Sv/y) for an individual with regard to the consumption of ^{222}Rn in the sachet groundwater as drinking water was calculated according to the following relationship [15]:

$$E_d = A_c\, A_i\, C_f \tag{7}$$

where, A_c is the activity concentration of the radionuclide in the sachet water (Bq/l), A_i refers to the annual intake of sachet drinking water (l/y), and C_f signifies the ingested dose conversion factor for radionuclides (Sv/Bq). This estimation was calculated by the United Nations Scientific Committee on Effects of Atomic Radiations (UNSCEAR) in 2000 at 23, 5.9, and 3.5 nSv/Bq for the individuals in the age groups of ≤ 1 (infants), 2–17 (children), and ≥ 17 (adults) years, respectively [16]. The annual intake of sachet drinking water for the age groups of ≤ 1, 2–17, and ≥ 17 years were 230, 330, and 730 liters, respectively [17].

Results

The Measurements of radon level in each of the 61 groundwater samples using RAD-7 are indicated in Table 1. Generally, the obtained results of radon concentrations ranged 1.20-15.43 Bq/l with the mean of 5.18±0.39 Bq/l. According to Table 2, the total annual effective doses received by infants through drinking water ranged 6.34-81.62 µSv/y. For children, the radon level was within the range of 2.34-30.04 µSv/y. Furthermore, the obtained results for adults ranged 3.07-39.42 µSv/y, and the corresponding mean values were 27.41±2.06, 10.08±0.76, and 13.23±0.99 µSv/y, respectively. The findings demonstrated significant variations in the dose rate across different age groups as can be seen in Table 2.

Table 1. Radon concentrations in the investigated region

No.	Sample code	Radon concentrations (Bq/l)
1	Q1	2.05
2	Q2	2.15
3	Q3	3.3
4	Q4	7.15
5	Q5	4.6
6	Q6	3.75
7	Q7	6.75
8	Q8	4.42
9	Q9	4.52
10	Q10	4.24
11	Q11	4.44
12	Q12	3.2
13	Q13	4.49
14	Q14	2.05
15	Q15	2.15
16	Q16	3.3
17	Q17	7.15
18	Q18	4.6
19	Q19	4.49
20	Q20	9.15
21	Q21	8.26
22	Q22	5.12
23	Q23	5.52
24	Q24	7.88
25	Q25	3.4
26	Q26	3.12
27	Q27	1.51
28	Q28	1.45
29	Q29	2.6
30	Q30	2.05
31	Q31	2.15
32	Q32	3.3
33	Q33	5.69
34	Q34	1.22
35	Q35	2.05
36	Q36	2.15
37	Q37	5.44
38	Q38	1.2
39	Q39	4.52
40	Q40	5.24
41	Q41	4.24
42	Q42	4.76
43	Q43	5.2
44	Q44	2.05
45	Q45	5.42
46	Q46	12.58
47	Q47	5.52
48	Q48	2.85
49	Q49	11.12
50	Q50	10.17
51	Q51	6.34
52	Q52	9.28
53	Q53	7.02
54	Q54	7.76
55	Q55	11.08
56	Q56	15.43
57	Q57	5.12
58	Q58	5.6
59	Q59	4.52
60	Q60	6.24
61	Q61	11.96
Max		1.20
Min		15.43
Mean±S.D		5.18±0.39

Table 2. Annual effective dose in three age groups

No.	Sample Code	Total annual effective dose (µSv/y)		
		≤ 1 y	(2-17)y	≥ 17 y
1	Q1	10.84	3.99	5.24
2	Q2	11.37	4.19	5.49
3	Q3	17.46	6.43	8.43
4	Q4	37.82	13.92	18.27
5	Q5	24.33	8.96	11.75
6	Q6	19.84	7.30	9.58
7	Q7	35.71	13.14	17.25
8	Q8	23.38	8.61	11.29
9	Q9	23.91	8.80	11.55
10	Q10	22.43	8.26	10.83
11	Q11	23.49	8.64	11.34
12	Q12	16.93	6.23	8.18
13	Q13	23.75	8.74	11.47
14	Q14	10.84	3.99	5.24
15	Q15	11.37	4.19	5.49
16	Q16	17.46	6.43	8.43
17	Q17	37.82	13.92	18.27
18	Q18	24.33	8.96	11.75
19	Q19	23.75	8.74	11.47
20	Q20	48.40	17.82	23.38
21	Q21	43.70	16.08	21.10
22	Q22	27.08	9.97	13.08
23	Q23	29.20	10.75	14.10
24	Q24	41.69	15.34	20.13
25	Q25	17.99	6.62	8.69
26	Q26	16.50	6.07	7.97
27	Q27	7.99	2.94	3.86
28	Q28	7.67	2.82	3.70
29	Q29	13.75	5.06	6.64
30	Q30	10.84	3.99	5.24
31	Q31	11.37	4.19	5.49
32	Q32	17.46	6.43	8.43
33	Q33	30.10	11.08	14.54
34	Q34	6.45	2.38	3.12
35	Q35	10.84	3.99	5.24
36	Q36	11.37	4.19	5.49
37	Q37	28.78	10.59	13.90
38	Q38	6.35	2.34	3.07
39	Q39	23.91	8.80	11.55
40	Q40	27.72	10.20	13.39
41	Q41	22.43	8.26	10.83
42	Q42	25.18	9.27	12.16
43	Q43	27.51	10.12	13.29
44	Q44	10.84	3.99	5.24
45	Q45	28.67	10.55	13.85
46	Q46	66.55	24.49	32.14
47	Q47	29.20	10.75	14.10
48	Q48	15.08	5.55	7.28
49	Q49	58.82	21.65	28.41
50	Q50	53.80	19.80	25.98
51	Q51	33.54	12.34	16.20
52	Q52	49.09	18.07	23.71
53	Q53	37.14	13.67	17.94
54	Q54	41.05	15.11	19.83
55	Q55	58.61	21.57	28.31
56	Q56	81.62	30.04	39.42
57	Q57	27.08	9.97	13.08
58	Q58	29.62	10.90	14.31
59	Q59	23.91	8.80	11.55
60	Q60	33.01	12.15	15.94
61	Q61	63.27	23.29	30.56
Max		81.62	30.04	39.42
Min		6.34	2.34	3.07
Average±S.D		27.41±2.06	10.08±0.76	13.23±0.99

Discussion

Nowadays, a large number of national and international organizations have established their own radon levels worldwide. For instance, the United States Environmental Protection Agency in its report of 1998 set the value of radon concentration limit in water at 11.1 Bq/l [18]. The UNSCEAR has defined a value of 40 Bq/l in its published report of 2009 [19], while the World Health Organization has defined the 100 Bq/l as an action limit in 2012 [20]. In the present study, the obtained results of 5 samples (Q46, Q49, Q55, Q56, and Q61) exceeded the recommended level of radon in groundwater. In this regards, the spatial variability in the radon concentration could be attributed to the geological structure of the investigated region, depth of the water source, differences in the climate, and geo-hydrological processes that occurs in the area. As observed, the measured levels of radon in most of the samples were below those limits. Around 95% of the samples were far less compared radon levels which have been reported by literature [21-24]. Furthermore, the estimated radon concentrations in the present study were comparable to those found in the rest of Saudi Arabia regions [25-28]. In this regard, the European Council [29] recommends the identification of the reference level of an effective dose received from drinking water at a level of 0.1 mSv/y. However, this value excludes the doses received from ^{222}Rn concentrations. Although infants are drinking less water than adults, the total annual effective doses to infants were significantly higher than that of adults. This issue can be due to the differences in infants' metabolism and smaller organ weights resulting in higher doses for many radionuclides. In addition, different dose coefficient and water consumption rate of different age groups can lead to differences among the groups (see Table 1). The total annual effective dose from all the locations of the investigated region was reported at less than 0.1 mSv/y (as recommended by the European Council). Finally, it can be concluded that the radiation dose resulted from the exposure to radon in groundwater consumed as drinking water is very low for public health in metropolitan cities (e.g., Qassim), especially for consumers who directly use bore well water with very high radon concentration in the household.

Conclusion

The results of the present study indicates that the radon concentrations in most of groundwater samples taken from Al Qassim, were below the action levels recommended by USEPA, UNSCEAR, EU Council, and WHO organizations. Therefore, it can be argued that most samples are safe for drinking and other domestic purposes. Radon concentrations which were measured in the water samples of the present study generally lie well below the level that reported by other investigators. The estimated age-dependent annual effective doses were reported as lower than 100 µSv/y for all the investigated sites.

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References

1. IAEA. Extent of Environmental Contamination by Naturally Occurring Radioactive Material (NORM) and Technological Options for Mitigation, Technical Reports Series. 2003:419.
2. Ghetti F, Checcucci G, Bornman JF, editors. Environmental UV Radiation: Impact on Ecosystems and Human Health and Predictive Models: Proceedings of the NATO Advanced Study Institute on Environmental UV Radiation: Impact on Ecosystems and Human Health and Predictive Models Pisa, Italy, June 2001. Springer Science & Business Media; 2006.
3. Ahmed NK. Natural radioactivity of ground and drinking water in some areas of upper Egypt. Turkish Journal of Engineering and Environmental Sciences. 2004; 28(6):345-54.
4. Bonotto DM, Bueno TO, Tessari BW, Silva A. The natural radioactivity in water by gross alpha and beta measurements. Radiation Measurements. 2009; 44(1):92-101.
5. Povinec P, Hirose K, Aoyama M. Fukushima accident: radioactivity impact on the environment. Newnes; 2013 Jul 9.
6. Malik MF, Rabaiee NA, Jaafar MS. Determination of radon concentration in water using RAD-7 with RAD H2O accessories. InAIP Conference Proceedings. AIP Publishing. 2015; 1657(1): 120005.
7. Saidu A, Bala A. Assessment of the Specific Activity of Alpha-and Beta-emitting Radionuclides in Groundwater, Anka, Nigeria. Iranian Journal of Medical Physics. 2018; 15(4): 285-94.
8. El-Taher A, Al-Turki A. Radon activity measurements in irrigation water from Qassim Province by RAD-7. Journal of environmental biology. 2016; 37(6):1299.
9. Pourimani R, Nemati Z. Measurement of Radionuclide Concentration in Some Water Resources in Markazi Province, Iran. Iranian Journal of Medical Physics. 2016;13(1):49-57.
10. Abojassim AA. Natural Radioactivity and Radon Concentrations in Parenteral Nutrition Samples Utilized in Iraqi Hospitals. Iranian Journal of Medical Physics. 2019;16(1):1-7.
11. Parhoudeh M, Khoshgard K, Zare MR, Ebrahiminia A. Natural Radioactivity Level of 226Ra, 232Th, and 40K Radionuclides in Drinking Water of Residential Areas in Kermanshah Province, Iran using Gamma Spectroscopy. Iranian Journal of Medical Physics. 2019;16(1):98-102.
12. Milton DI. Geology of the Arabian peninsula. Kuwait: US Geological Survey, Professional Paper. 1967;560:1-147.
13. Abojassim AA, Kadhim SH, Mraity A, Abid H, Munim RR. Radon levels in different types of bottled drinking water and carbonated drinks in Iraqi markets. Water Science and Technology: Water Supply. 2017;17(1):206-11.
14. Alzurfi SK, Abojassim AA, Mraity HA. Monthly Monitoring of Physicochemical and Radiation Properties of Kufa River, Iraq. Pakistan Journal of Scientific and Industrial Research Series A: Physical Sciences. 2018;61(1):43-51.
15. Alam MN, Chowdhury MI, Kamal M, Ghose S, Islam MN, Anwaruddin M. Radiological assessment of drinking water of the Chittagong region of Bangladesh. Radiation protection dosimetry. 1999;82(3):207-14.
16. United Nations. Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation: sources. United Nations Publications; 2000.
17. World Health Organization. Guidelines for drinking-water quality: second addendum. Vol. 1, Recommendations. World Health Organization; 2011.
18. USEPA. United States Environmental Protection Agency Office of Water: 40 CFR Parts 141, and 142 : National Primary Drinking Water Regulations ; radon-222: proposed rule. US Environmental Protection Agency; 1999.
19. United Nations. Scientific Committee on the Effects of Atomic Radiation. Effects of ionizing radiation: UNSCEAR 2006 report to the general assembly, with scientific annexes. United Nations publications; 2009.

20. WHO/UNICEF Joint Water Supply. Sanitation Monitoring Programme. Progress on drinking water and sanitation: 2014 Update. World Health Organization; 2014.
21. Eleftheriou G, Tsabaris C, Androulakaki EG, Patiris DL, Kokkoris M, Kalfas CA, et al. Radioactivity measurements in the aquatic environment using in-situ and laboratory gamma-ray spectrometry. Applied Radiation and Isotopes. 2013; 82:268-78.
22. Küsters M, Schraven W. Determination and differentiation of 226Ra and 222Rn by gamma-ray spectrometry in drinking water. Journal of radioanalytical and nuclear chemistry. 2009; 280(3):475-80.
23. Mauring A, Gäfvert T. Radon tightness of different sample sealing methods for gamma spectrometric measurements of 226Ra. Applied Radiation and Isotopes. 2013; 81:92-5.
24. Wójcik M, Zuzel G. 226Ra, 210Pb, 210Bi and 210Po deposition and removal from surfaces and liquids. Journal of radioanalytical and nuclear chemistry. 2013; 296(2):639-45.
25. Aleissa KA, Alghamdi AS, Almasoud FI, Islam MS. Measurement of radon levels in groundwater supplies of Riyadh with liquid scintillation counter and the associated radiation dose. Radiation protection dosimetry. 2012; 154(1):95-103.
26. Alabdula'aly AI. Occurrence of radon in Riyadh groundwater supplies. Health physics. 1996 ;70(1):103-8.
27. Shabana ES, Abulfaraj WH, Kinsara AA, Rizaiza OS. Natural radioactivity in the groundwater of Wadi Nu'man, Mecca Province, Saudi Arabia. Radiochimica Acta International journal for chemical aspects of nuclear science and technology. 2013;101(7):461-70.
28. Alabdula'aly AI. Occurrence of radon in groundwater of Saudi Arabia. Journal of environmental radioactivity. 2014 ;138:186-91.
29. Directive EC. Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment, WEEE. Official Journal of the European Union L. 2012;197:38-71.