Dose assessment and radioactivity of the mineral water resources of Dimeh springs in the Chaharmahal and Bakhtiari Province, Iran

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Abstract. One of the main sources of public exposure from natural radioactivity is radium and radon and its short lived decay products. The aim of this study is focused on determining the concentration of mentioned radionuclides in the mineral water resources in one of the highest altitude regions (Zagros Mountains), the Chaharmahal and Bakhtiari province, in South-West Iran, namely the Dimeh springs. Eighty drinking spring water samples were taken from the Dimeh springs (ten samples for each spring) to determine radium-226 (^{226}Ra) and radon-222 (^{222}Rn) concentrations using the emanation method and a liquid scintillation counting method, respectively. The results of this study showed that the effective dose from the consumption of drinking water of Dimeh springs (6.4 μSv/y) is not comparable to the other annual effective dose such as inhalation of radon and its products in cosmic and terrestrial rays published by one of the authors previously. Also, the annual effective dose measured here is much lower than the worldwide mean value 0.45 mSv reported by USCEAR, 2000 and is also low enough and below the proposed limits in other countries and this is the reason why this sources of water may be considered as safe drinking water in the region.

Key words: radium-226 • radon-222 • radioactivity • effective dose • Dimeh springs • Chaharmahal and Bakhtiari

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Introduction

Since natural radiation is the main source of human exposure, studies of the dose from this source and its effects on health can improve the understanding of radiation damage and are of great value as a reference when standard and regulatory control actions on radiation protection are established. Investigations and measurements of natural radiation and radioactivity are also of great importance and interest in health physics not only for many practical reasons, but also for more fundamental scientific reasons. The presence of natural radiation is due to the distribution of radionuclides on earth and causes exposure to all living organisms. Resources of mineral waters such as springs may contain different concentrations of radionuclide besides the numerous other contaminants [8]. The regulation and assessment of these radionuclides are very important and the regulation of alpha emitting radionuclide is outstanding among them. There are many naturally occurring radionuclides whose have half-lives is at least of the same order of magnitude as the estimated age of earth and have been present since its formation. They uranium and thorium series and singly occurring radionuclides such as ^{40}K. Of course, one of the main sources of public exposure from natural radioactivity is radium-226 (^{226}Ra) and radon-222 (^{222}Rn) and its short lived decay products, in particular their concentrations in drinking or mineral water.

The decay products of ^{222}Rn have a major role in human exposures. The most important aspect of ^{222}Rn in high concentrations can be heath hazards for human, in particular it causes lung cancer. Moreover, a very high level of ^{222}Rn in drinking water can lead to a significant risk of stomach and gastrointestinal cancer [9].

The radionuclide ^{226}Ra emits alpha particles with an energy 4.77 MeV. High solubility of this element compared with uranium causing penetration through fractures into bedrock and can leak out into groundwater. Radium-226 is a bone seeker element and can cause bone marrow cancer [16]. Because of importance of concentrations of these two elements to human health, investigation of their concentrations in drinking and mineral water resources has been a matter of worldwide concern [1–4, 6, 7, 10, 12, 13].

The aim of this study is focused on determining the concentration of the mentioned radionuclides (^{222}Rn and ^{226}Ra) in drinking spring water resources in one of the highest altitude regions (Zagros Mountains), the Chaharmahal and Bakhtiari province, in the South-West Iran, namely the Dimeh springs (the main bottled drinking water of these springs is exported to consumers of countries around of the Persian Gulf). In this study, investigation of drinking water samples was carried out according to the assessment process recommended by relevant organizations, and finally the annual effective dose of consumers is calculated and compared with the results obtained from other countries, and also the recommended doses are based on other relevant organizations.

Materials and methods

Dimeh springs are located in the Chaharmahal and Bakhtiari Province, in South-West Iran, the province being called the roof of Iran or the highest altitude region of Iran. Map of the Chaharmahal and Bakhtiari Province, Farsan region, where the Dimeh springs are located, is shown in Fig. 1.

Eighty drinking spring water samples were taken from the Dimeh springs (ten samples for each spring)

Fig. 1. Map of the Chaharmahal and Bakhtiari Province, Farsan region, where the Dimeh springs are located.

to determine ^{226}Ra and ^{222}Rn concentrations using the emanation method and using a liquid scintillation counting method, respectively.

The water samples were collected in various points of each spring using a glass syringe or from a plastic container filled gently with water. Concentration of ^{226}Ra was measured using an emanation method as follows.

To measure the emanated radon gas in a sample or source, the following procedure was used. A water sample was sealed in an initially radon-free container and, after a certain period of time the radon content of the air inside the container was measured by scintillation detectors according to the Chereji method [5]. Radon-222 concentration was measured using liquid scintillation counting (Quantulus Model LSC 122, Perkin Elmer). The instrument was calibrated using a series of standard samples consisting of various known ^{226}Ra activities. For this reason, a known activity of ^{226}Ra combined with a mineral oil (liquid scintillator) with a ratio of 10 to 10 mL was used. The calibration samples were counted after 20 days to allow ^{222}Rn to reach secular equilibrium with ^{226}Ra in the vials, both background and standard samples were examined for a 50 min counting period.

To calculate the ^{222}Rn concentration, the net count rate was divided by a calibration factor of 27.03 and sample volume (since 1 pCi = 0.037 Bq, the calibration factor was multiplied by 27.03 to reach a conversion factor in cpm/Bq).

The effective dose from the consumption of drinking water was also calculated using UNSCEAR, 2000 recommendation for all different consumer age [17].

Results

The results of eighty water samples (10 for each spring) to measure both ^{226}Ra and ^{222}Rn concentrations are shown in Table 1.

As indicated in Table 1, the mean concentrations of ^{226}Ra and ^{222}Rn obtained were 41.1 ± 0.5 mBq/L and 2.3 ± 0.1 Bq/L, respectively.

The annual effective doses for ingestion and inhalation of ^{222}Rn for adults were calculated according to the parameters introduced by UNSCEAR, 2000.

For ingestion, the following parameters were used:
– The effective dose coefficient from ingestion is equal to 3.5 nSv/BqL.
– Annual intakes by adults are 50 L.
– The annual effective doses due to ingestion, corresponding to 1 Bq/L, is equal to 0.18 μSv/y.

Table 1. ^{226}Ra and ^{222}Rn concentrations (mean ± SD) in water samples of Dimeh springs

No. of spring	^{222}Rn (Bq/L)	^{226}Ra (mBq/L)
1	3.6 ± 0.3	35.0 ± 0.4
2	0.6 ± 0.3	47.5 ± 0.1
3	2.5 ± 0.4	56.8 ± 0.3
4	3.7 ± 0.2	8.00 ± 0.6
5	0.6 ± 0.4	39.4 ± 0.3
6	2.7 ± 0.5	61.2 ± 0.3
7	3.5 ± 0.3	37.7 ± 0.2
8	1.2 ± 0.2	43.2 ± 0.3

Table 2. Comparison of results of the present work with other relevant works

Effective equivalent dose (μSv/y)	^{222}Rn (Bq/L)	^{226}Ra (mBq/L)	Country/State
1–220 (^{226}Ra)	0.12–18	0.23	Austria
–	1.2×10^2	1.8×10^3	Brazil (Aguas de Prata)
86	–	6–412	Croatia
4.1	–	11.3	Pakistan
–	3.9	–	Jordan
–	50	–	Macedonia & Greece
–	74	–	Poland
3.9 (^{226}Ra), 5.8 (^{222}Rn)	10.82	19.16	Turkey
14	–	52	US (New York)
10	3.7	–	Iran (Teheran)
6.4	2.3	41.1	present work

For inhalation, the following parameters were used:
– Ratio of ^{222}Rn in air to ^{222}Rn in water is about 4–10 (mean 7).
– Indoor occupancy is 7000 h/y.
– Equilibrium factor between ^{222}Rn and its progency is 0.4.
– Dose conversion factor for ^{222}Rn exposure is equal to 2.5 μSv/y.

The annual effective dose due to inhalation of 1 Bq/L causes total effective doses of about 2.5 μSv/y.

Thus, the waterborne radon concentration of 1 Bq/L causes a total effective dose of about 2.68 μSv/y. Using the mean ^{222}Rn concentration 2.3 Bq/L, the effective dose from the consumption of drinking water (both ingestion and inhalation) from the Dimeh springs was found to be 6.4 μSv/y (using 2.3×2.68 μSv/y).

Discussion

The results obtained in this study are compared with the reported values from other countries of the world (Table 2) and it was observed that the measured activity concentrations of ^{222}Rn and ^{226}Ra in drinking water of the Dimeh springs were lower than all these values. As the literature indicated, natural radionuclide concentrations in environmental samples can be very different due to geographical and geological factors. Another reason for this difference may depend on the time of sampling as well as on the location, and this may cause different results in different studies.

A study of possible effect of background radiation on cancer incidence in this region was done in 2003 [15], and the results showed that the prevalence of skin, breast, thyroid and lung cancers and leukemia, as compared with total recorded cancers, was about 20.5, 7.5, 2.6, 1.1 and 16.2%, respectively. The possibility of skin and thyroid cancers and leukemia was high due to the high levels of the natural background radiation in this region [14].

The results of this study showed that the effective dose from the consumption of drinking water from the Dimeh springs (6.4 μSv/y) is not comparable to the other annual effective dose such as inhalation of radon and its products in cosmic and terrestrial rays in this region. Even though, more epidemiological studies are necessary to confirm the effects of cosmic radiation on biotopes and mammals in this region.

The annual effective dose measured here is much lower than the worldwide mean value of 0.45 mSv which is reported by UNSCEAR, 2000 and is also low enough and below the proposed limits in other countries (Table 2).

Overall, with the satisfactory low levels of ^{226}Ra and ^{222}Rn concentrations in drinking water from the Dimeh springs this is reason why this resources of water may be considered as a safe drinking water in the region.

References

1. Alirezazadeh N (2005) Radon concentrations in public water supplies in Teheran and evaluation of radiation dose. Iranian J Radiat Res 3;2:79–83
2. Al-Kazwini AT, Hasan MA (2003) Radon concentration in Jordanian drinking water and hot springs. J Radiol Prot 23:439–448
3. Bronzovic M, Marovic C (2005) Age-dependent dose assessment of ^{226}Ra from bottled water intake. Health Phys 88;5:480–485
4. Cevik U, Damla N, Karahan G, Celebi N, Kobya AI (2006) Natural radioactivity in tap waters of Eastern Black Sea region of Turkey. Radiat Prot Dosim 118;1:88–92
5. Chereji I (1992) ^{222}Rn (^{226}Ra) determination in water by scintillation metod. J Radioanal Nucl Chem Lett 165:263–267
6. De Oliveira J, Mazzilli B, Sampa MH, Silva B (1998) Seasonal variations of ^{226}Ra and ^{222}Rn in mineral spring waters of Aguas de Prata, Brazil. Appl Radiat Isot 49;4:423–427
7. Fatima I, Zaidi JH, Arif M, Tahir SN (2007) Measurement of natural radioactivity in bottled drinking water in Pakistan and consequent dose estimate. Radiat Prot Dosim 123;2:234–240
8. Folger PF, Nyberg P, Wanty RB, Poeter E (1994) Relationship between ^{222}Rn dissolved in groundwater supplies and indoor ^{222}Rn concentration in some Colorado front range houses. Health Phys 67:244–252
9. Kendal GM, Smith TJ (2002) Dose to organs and tissues from radon and its decay product. J Radiol Prot 22:389–406
10. Kitto ME, Kim MS (2005) Naturally occurring radionuclides in community water supplies of New York state. Health Phys 88;3:253–260
11. Kralik C, Friedrich M, Vojir F (2003) Natural radionuclides in bottled water in Austria. J Environ Radioact 65;2:233–241
12. Kusyk M, Mamont-Cieśla K (2002) Radon levels in household waters in southern Poland. Nukleonika 47:65–68

13. Savidou A, Sideris G, Zouridakis N (2001) Radon in public water supplies in Migedonia Basin, central Macedonia, northern Grece. Health Phys 80:170–174

14. Shahbazi-Gahrouei D (2003) Natural background radiation dosimetry in the highest altitude region of Iran. J Radiat Res 44;3:285–287

15. Shahbazi-Gahrouei D (2003) Possible effect of background radiation on cancer incidence in Chaharmahal and Bakhtiari Province. Iranian J Radiat Res 1;3:171–174

16. Stein L (1987) Chemical properties of radon. In: Hopke PK (ed) Radon and its decay products: occurence, properties and health effects. American Chemical Society, Washington, DC, pp 240–251

17. UNSCEAR (2000) Sources and effects of ionizing radiation. Report to the General Assembly, with scientific annexes. United Nations Scientific Committee on Effects of Atomic Radiation, New York