Dose assessment and measurement of radon concentration in water supplies of Borujerd County in Iran

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▶ ***Short Report***

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ABSTRACT

Background: Radon as a potential risk of radiation exposure is a natural radioactive element that can emit from rocks and soils. Due to solubility in water, it can be inhaled or consumed by the public. The purpose of this study was carrying out measurement and evaluation of radon concentration in samples of drinking water which are collected from water supplies of Borujerd. ***Materials and Methods***: Dose This research was performed to estimate the annual average effective dose ($mSva^{-1}$) to the public from dissolved ^{222}Rn of 16 drinking water supplies of Borujerd, western part of Iran. The methodology of the study includes utilizing radon monitoring apparatus, RTM 1688-2, to meter the concentrations of ^{222}Rn and ^{220}Rn dissolved in samples. ***Results:*** The measured average of radon concentration was 3.451 *Bq.l*$^{-1}$ which was lower than 11 *Bq.l*$^{-1}$ (the EPA level recommended for drinking water). Total radon annual effective dose, ranged from 5.4×10^{-3} to 72.1×10^{-3} *mSv.a*$^{-1}$ with an average of 34.9×10^{-3} *mSv.a*$^{-1}$ which was insignificant compared to all natural sources, 2.4 *mSv*. ***Conclusion:*** The effective received doses for all age groups were less than the standard limit (0.1 *mSv/y*) therefore there is no need for treatment of water for removal of ^{222}Rn in Borujerd County.

Keywords: *Radon concentration, annual effective dose, RTM 1688-2, Boroujerd.*

INTRODUCTION

The most portion of contributed background radiation dose is due to natural radionuclides such as ^{226}Ra and ^{222}Rn. Radon (^{222}Rn), a member of ^{238}U decay chain; having no odor and color; weightier than air, is the daughter radionuclide of ^{226}Ra. It is a natural radioactive noble gas with a half-life of 3.82 days which can enter the human body through drinking water or by inhalation (1). According to the International Commission on Radiation Protection (ICRP), it is estimated that the inhaled ^{222}Rn is the most contributed factor of natural radiation exposure however the quantity of ^{222}Rn dissolving in water ultimately can reach to risky levels and pose hazards (2). With the knowledge that people spend most of their time indoors, at home or workplace, the hazard of radon increases considerably. Moreover, throughout daily household activities such as taking bath and dishwashing, the dissolved ^{222}Rn in water can be released. Therefore, the short lived radon progenies gradually rise in indoor air and can be building up to hazardous criteria. Consequently the emitted ionizing alpha-radiations (^{218}Po, ^{214}Po, ^{214}Pb) cause lung cancer if they are inhaled during a long-term exposure (3). According to the World Health Organization (WHO), radon can bring about 6-15% of the entire lung cancer cases over the globe [4]. Also, radon and its progenies indoors are recognized as the key sources of natural exposure, nearly 50% of mean annual effective dose [5]. There are several works including measurements of radon in various types of water which are carried out in different location of Iran [6-10]. Except the studies performed in Ramsar, northern part of Iran, the others report no considerable amount of radon to adversely affect the social health life. This study aims to determine the concentration of radon in drinking water supplies of Borujerd County to assess the healthiness of the drinking water supplies.

MATERIALS AND METHODS

Location and appliance

The study was carried out in Borujerd, Lorestan province located in the western part of Iran where drinking water has been supplied from several springs and wells. The RTM 1688-2 equipped with a silicon surface barrier-type detector was used as the radon monitoring system provided simultaneous measurements of ^{222}Rn and ^{220}Rn (figure. 1)[11]. Having stable sensitivity against changes of ambient humidity and temperature is the significant characteristic of RTM 1688-2. These features were inspiring to determine the annually effective dose, D_a ($mSva^{-1}$), to the general public from ^{222}Rn in 16 drinking water sources. D_a is due to the ingestion of radon [12].

Sampling and sample analysis

Sampling the radon-contaminated water and also transferring it to a lab required implementing special instructions because radon decays and escapes simply. Sampling, transport, storage conditions and time and also material types of containers highly affect the measurement results. A brief review on radon measurements specially the methods and necessary conditions and facilities have been reported in Jobbagy *et al.* [13]. In our case, the samples were collected according to the protocol provided by the U.S Environmental Protection Agency (EPA). It is recommended to extract samples 30cm deep from the surface of the water [14]. The containers made of polyethylene and provided to store water samples should have been equipped that well to prevent radon leakage [13]. In order to avoid the underestimation of radon concentration and calculate the decay correction factor for each sample, the spent time between the sampling and lab analysis procedure has to be judiciously measured and applied.

Using the RTM 1688-2, radon concentrations measurements were carried out at overall sixteen different locations that each location measurement included the average of two-sample figures at morning and evening, twice every month of the year 2016 (totally an average of 48 samples per location), from water supplies of Borujerd County, Iran. Figure 1 shows the sampling site.

The Radon-Vision 4 interface which has been provided for RTM 1688-2, calculated the concentration of radon in water samples using equation 1[15].

$$Q_{Rn}\left(\frac{Bq}{l}\right) = Q_{RTM}\left(\frac{Bq}{m^3}\right) \times \frac{V_{tot}(m^3)}{V(Lit)} \times \left[exp\left(\frac{Ln2}{3.8\times 24}\right) \times t\right] \quad (1)$$

Where, Q_{RTM} is the recorded figure by RTM 1688-2, V_{tot} (2.4×10^{-3} m^3) is the volume of the detector, $V(l)$ is the volume of water samples (300 *ml*) and t (*h*) is the time. Furthermore, the annual effective dose (ingestion of water) was calculated as [16]:

$$D_a = C_{Rn} \times C_f \times AC_{H2O} \times 365 \times 1000 \quad (2)$$

Where D_a ($mSv.a^{-1}$) is the annual committed effective dose, C_{Rn} ($Bq.l^{-1}$) is the radon concentration in water, C_f ($mSv.\ Bq^{-1}$) is a conversion factor which alters for different ages; for male and female adults (older than 14), teenagers (4-14) and infants equal to 18×10^{-9} $Sv.\ Bq^{-1}$, 26×10^{-9} $Sv.\ Bq^{-1}$ and 35×10^{-9} $Sv.\ Bq^{-1}$ respectively. AC_{H2O} is the annual water consumption that depends on area and ages (*l/day*).

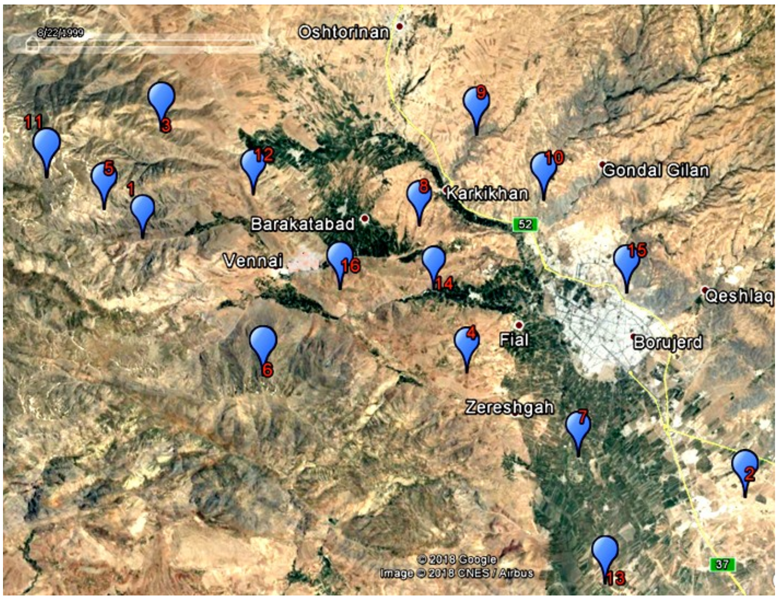

Figure 1. Boroujerd County where the numbers indicate sampling sites (courtesy to Google).

RESULTS AND DISCUSSION

Sampling of radon concentration in drinking water of Borujerd County including 16 different springs and wells are mentioned in table 1. The samplings were performed during the year 2016 where the temperature and humidity recorded between 2-26 ^{o}C and 17-68% of relative humidity. The minimum and maximum level of radon were 1.339 $Bq.l^{-1}$ (sample no.2) and 4.032 $Bq.l^{-1}$ (sample no.6) respectively. Radon concentrations were considered to be lower in springs compared to wells. This is because the radon gas escapes from naturally flowing water or exposing to air. The annual effective dose, D_a, is reported in Figure 2 by using equation (2).

Due to lack of local information of water consumption in Borujerd County, statistics reported by EPA and estimating per capita water in the US, were used. According to the EPA ,the average of global water consumption for an adult is 2 liters per day however, the estimated mean ingestion of total water for different categories are 2.73, 2.129, 0.431 and 0.327(*l/day*) for adult male, female, teenagers and infants respectively (the estimated 95th percentile of empirical distribution of daily average per capita ingestion) [17].

According to the Guidance levels for radionuclides in drinking-water, the recommended reference dose level (RDL) of the committed effective dose equals to 0.1*mSv* from 1 year's consumption of drinking-water which is accepted by most WHO Members and European Commission. If the radon concentration outnumbers 100 *Bq/l*, treatment of the water source should be carried out to decrease the radon levels below 100 *Bq/l* [18]. The results of the current work demonstrated that the activity concentrations of ^{222}Ra in water supplies of Borujerd County ranged from 1.339 to 4.032 *Bq/l* with an overall average of 7.895 *Bq/l* which were lower than the EPA level for drinking water, 11 *Bq/l* [19]. General radon annual effective dose, D_a, is depicted in figure 2. It is ranged from 5.4×10^{-3} to 72.1×10^{-3} $mSv.a^{-1}$ with an average of 34.9×10^{-3} $mSv.a^{-1}$. Also it implies that D_a can be divided in three categories for samples including low (sample series 1st,2nd), medium (14th,16th) and high levels with a same pattern for age-groups of adult men and women, teenagers and infants from majority to minority. Therefore, the adult men and women received higher dose due to the amount of water consumption however, the quantities did not exceed the standard limit of 0.1 *mSv/y*. These doses, compared to average effective dose from all natural sources; 2.4 *mSv* [20], were negligible.

Table 1. Sampling of radon concentration in drinking water of Borujerd County (springs and wells), 2016, Temperature: 2-26oC, Humidity: 17-68%

Sample No.	Sampling Site Name	Average ^{222}Rn Concentration (*Bq/l*)
1	Venaie*	1.768±0.273
2	Zarem*	**1.339±0.421**
3	Kertool	3.802±0.624
4	Zereshkeh	4.019±0.216
5	Sefied	3.948±0.372
6	Panbeh	**4.032±0.153**
7	Jaanizeh	3.848±0.551
8	Haft-Cheshmeh	3.833±0.467
9	Esel	3.858±0.294
10	Darreh-Khooni	3.912±0.712
11	Totia	3.771±0.635
12	Do-Rozaneh	3.780±0.178
13	Roud-Tireh	3.903±0.255
14	Gel-Roud*	2.825±0.383
15	Seh-Raah-e- Nirougah	3.802±0.381
16	Borujerd Azad-University*	2.786±0.734

*spring

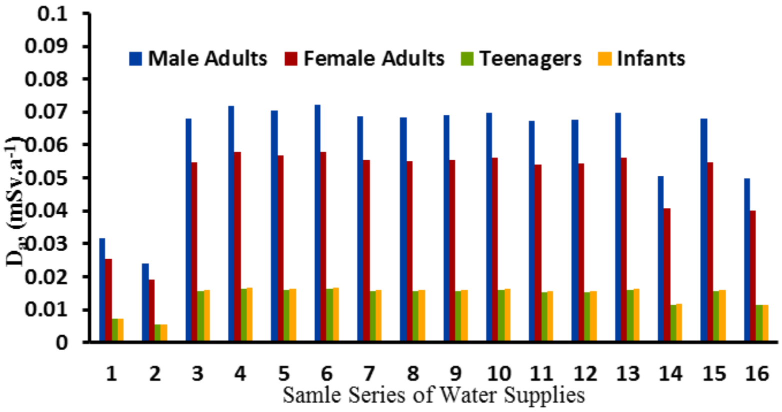

Figure 2. Annual effective dose due to water ingestion.

CONCLUSION

Water extracted from water supplies in Borujerd County was found healthy and radon dosages were not the sources of concern since dose levels were lower compared to the EPA level. Considering C_f, higher uptake of water due to age and gender did not significantly result in higher outcomes. Although the order of the received effective dose in different age groups is adult men, adult women, teenagers and infants from high to low, the effective received dose of all age groups particularly adults, was less than the standard limit (0.1 mSv/y), therefore there is no need for treatment of water for removal of ^{222}Rn in the Borujerd County.

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Conflicts of interest: *Declared none.*

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