Estimation of the effective dose from radon ingestion and inhalation in drinking water sources of Mashhad, Iran

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Background: Radon concentration was measured in 50 drinking water samples in Mashhad - Iran. ***Materials and Methods:*** The tap water used for drinking and other household usages can increase the indoor radon level. Drinking water samples were collected from various places and supplies of public water used in Mashhad. Then radon concentration has been measured by portable radon gas surveyor SILENA (PRASSI) system. ***Results:*** The results showed that about 70% of water samples had radon concentration greater than 11Bq/l the level recommended USA environmental protection agency (EPA). The arithmetic mean of radon concentration for all samples was 16.238 ± 9.322 Bq/l. Also the annual effective dose in stomach and lung per person were estimated in this research, with the mean value of 0.040 mSv and 0.043 mSv per year for these two organs for all samples, respectively. ***Conclusion:*** The results indicate that radon concentrations in public drinking water samples of Mashhad are mostly low enough and below the proposed concentration limits. The mean radon level was 16.238 Bq/l for all samples; which is not much greater than 11Bq/l as EPA advised level. Further, only two samples induced the total annual effective dose greater than 0.1 mSv per year. **Iran. J. Radiat. Res., 2012; 10(1): 37-41**

Keywords: *Radon, effective dose, drinking water, PRASSI system.*

INTRODUCTION

Radon (^{222}Rn) is a naturally occurring, radioactive noble gas with a half-life of 3.82 days, and it is a member of the ^{238}U decay series (1). Radon and its short-lived decay products such as ^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po at indoor places are recognized as the main sources of public exposure by natural radioactivity, contributing to nearly 50% of the global mean effective dose to the public (1, 2). Minkin and Shapovalov discussed the results of 30 years of radon indoor entry and contended that radon transport is still a real problem because many discrepancies between current theories and experimental data still remain (3).

The type of soil, building materials, and water used for drinking and other household usages can make various contributions to the indoor radon level. The available data indicate that the main source of the indoor radon is the soil underlying a building (2). However, certain building materials with high concentrations of radium, and even domestic water with high concentrations of radon can make major contributions to the indoor radon exposure (4, 5). The most important aspect of radon in high concentrations can be health hazard for human, and they are the cause of lung cancer (6, 7). However, a very high level of radon in drinking water can also lead to a significant risk of stomach and gastrointestinal cancer (8, 9). Knowledge of the level of radon in each source, including household water, particularly water from groundwater sources, is necessary to protect the public from consequences of excessive exposure to radiation, the risk of lung cancer in specific.

In Iran, the household water is supplied from various sources. Due to the dry climate condition in most parts of the country, drilled wells have provided the main part of drinking water used by the public (10). In a few places, with high annual rain, surface water is the main source. In Mashhad, both

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groundwater and surface water are the sources of household water. Domestic water of Mashhad is supplied by two dams, namely Torogh and Kardeh, and more than 80 deep wells drilled in and around the city. Mashhad is the second big city of Iran after Tehran, which has more than 2.4 million fixed populations and an annual floating population of 6 million. Depending on raining condition, the contribution of groundwater to the supplied domestic water, may increase particularly in summer. Also, based on geographical situation of a specified region in the city, domestic water may be supplied from groundwater, surface water or a mixture of them. In addition, there are a number of large reservoirs in various parts of Mashhad for the collection and distribution of treated surface water and groundwater in the city.

In this study, the result of radon measurements in 50 water samples, sources and tap water, actually used for drinking and other household in Mashhad are presented.

MATERIALS AND METHODS

Water Sampling

The water samples were collected from various places distributed around Mashhad. The samples were collected from the head ports of active wells, selected for sampling, rivers and surface water reservoirs, as well as from domestic water taps of high consumption rates, using the standard procedure proposed by the USA Environmental Protection Agency, EPA [2, 11]. In this procedure a plastic funnel was connected via a short plastic hose to the water tap. After the water flowed for several minutes, the flow rate was slowed down and the water was allowed to be collected in the funnel. The collected samples were transferred to the laboratory at Mashhad Payam Nour University in Iran for analysis.

Radon Measurement

The PRASSI (Portable Radon Gas Surveyor SILENA) Model 5S was used for radon concentration measurement in the water samples which were, particularly, well suited for the type of measurement which must have been performed in closed loop circuit. The system had a built-in detector suitable for radon measurement based on a broadly-accepted technique. It consisted of a 1830 ml cell coated with zinc-sulphide, activated with silver AnS(Ag) coupled with a low-gain-drift photomultiplier. The cell characteristics provided the detection of very low radon concentration levels in the sampled air. The PRASSI pumping circuit operated with constant flow rate at 3 litters per minute for degassing the water sample properly. The sensitivity of the system in continuous mode was 4 Bq/m^3 during 1 hour integration time. The system was set up of a measurement including bubbler and drier column is shown in figure 1. Moreover, the last recalibration of the system was done by radiation lab of Iranian Atomic Agency in fall 2008.

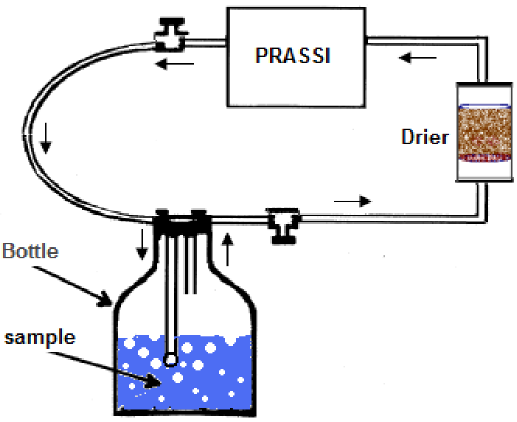

Figure 1. The radon measurement set up.

To measure the content of radon in water, we considered V_{sample}=150 ml of the *water* sample in bubbler and the PRASSI will read a concentration of:

$$Q_{PRASSI}\,[Bq/m^3] = \frac{A_{Rn}[Bq]}{V_{tot}[m^3]} \quad (1)$$

Where V_{tot} is the total volume of system equal to 2.4×10^{-3} m^3 and A_{Rn} is the radon activity. It follows that the concentration of radon in water is:

$$Q_{Ra}[Bq/m^3] = \frac{A_{Rn}[Bq]}{V_{sample}[m^3]} = Q_{PRASSI}\frac{V_{tot}[m^3]}{V_{sample}[m^3]} \quad (2)$$

The average value of three measurements was considered as the radon concentration in the water sample.

RESULTS AND DISCUSSION

Radon measurement result

In the present research, 50 water samples from groundwater of deep wells, surface water of rivers; tap water were collected and analyzed for radon concentrations. The radon concentration in various samples of Mashhads' water is presented in the figure 2, and they are sorted low to high. According to the obtained data, the minimum and maximum radon concentrations in the samples were 0.064 and 46.088 Bq/l, respectively. We have recorded the mean radon measurement data of surface, well and tap water samples with advice and action level of EPA in table 1. The arithmetic mean radon concentration of all samples was 16.24 Bq/l with standard deviation of 9.32. As shown in figure 2, 70% of the samples have the radon concentrations greater than the EPA advised level, 11 Bq/l (11). The main reasons for large differences of radon concentration in the samples seemed to be due to the mixing of surface water with groundwater in proportions mentioned earlier, and storage of the mixed water in large reservoirs before distribution.

Compared to advise contaminant level of 11 Bq/l for radon in public drinking water, suggested by the EPA (11), the radon concentrations in most of the drinkig water samples in Mashhad was not so high, and they were lower than the action level. In addition, the EPA requires that action must be taken to reduce radon levels above an alternative maximum contaminant level of 148 Bq/l (11). A number of investigators have reported much higher radon concentrations in public drinking water (12-15). Kusyk *et al.* (14) have reported the mean value of 74 Bq/l for tap water, and mean value of 207 Bq/l for wells, in southern of Poland.

Estimation of mean annual effective radon dose

The radon concentration of drinking water is an important issue from dosimetry aspect, since more attention is paid to control of public natural radiation exposure (13-16). Regarding radiation dose to public due to waterborne radon, it is believed that waterborne radon may cause higher risks than all other contaminants in water (15, 16). Radon enters human body through ingestion and inhalation as radon is released from water to indoor air. Therefore, radon in

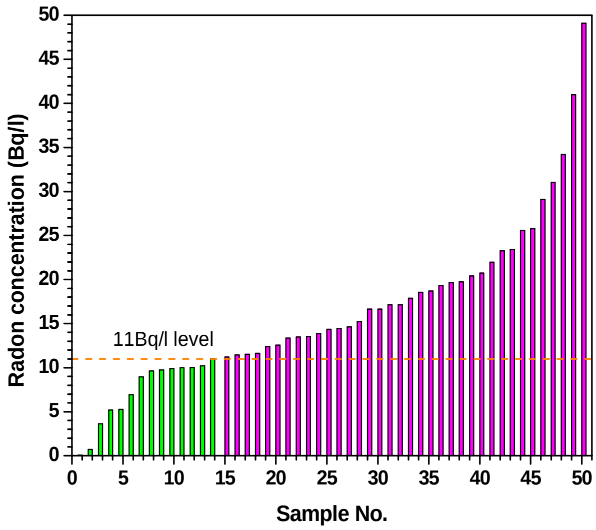

Figure 2. The radon concentration in various samples of Mashhad water (we sorted them increasingly).

Table 1. The mean radon measurement data of different water samples with advice and action level.

Types of sample	Number of Samples	Mean radon concentration (Bq/l)	Standard deviation	EPA advice level (Bq/l)	EPA action level (Bq/l)
Surface water	4	2.15	2.07	11	148
Well water	26	21.77	9.05		
Tap water	21	11.44	4.42		

water is a source of radiation dose to stomach and lungs. The annual effective doses for ingestion and inhalation were calculated according to parameters introduced by UNSCEAR report [2]. For ingestion the following parameters were used:

- The effective dose coefficient from ingestion equals to 3.5 nSv/(Bq l);
- Annual intakes by infants, children, and adults of about 100, 75, and 50 Liters, respectively;
- The annual effective doses due to ingestion corresponding to 1Bq/l would equal to 0.35μSv/y for infants, 0.26μSv/y for children and 0.18μSv/y for adults.

For inhalation the following parameters were used:

- Ratio of radon in air to radon in tap water supply in the range of 4 to 10;
- Average indoor occupancy time per person about 7000 h/y;
- Equilibrium factor between radon and its progeny equal to 0.4,
- Dose conversion factor for radon exposure, 9 nSv/(Bq.h m^3).

The annual effective dose due to inhalation corresponding to the concentration of 1 Bq/l in tap water was 2.5μSv/y. Therefore, waterborne radon concentration of 1 Bq/l caused total effective dose of about 2.68μSv/y for adults. The mean annual effective dose ranges per person for adults caused by different water samples are presented in figure 3 in three groups.

World Health Organization [17] and European Council [18] recommend the determination of reference level of the annual effective dose received from drinking water consumption at 0.1 mSv/y from these three radioisotopes: ^{222}Rn ^{3}H, ^{40}K [1]. So, two samples (No. 49 and 50) induced the total annual effective dose greater than 0.1mSv/y.

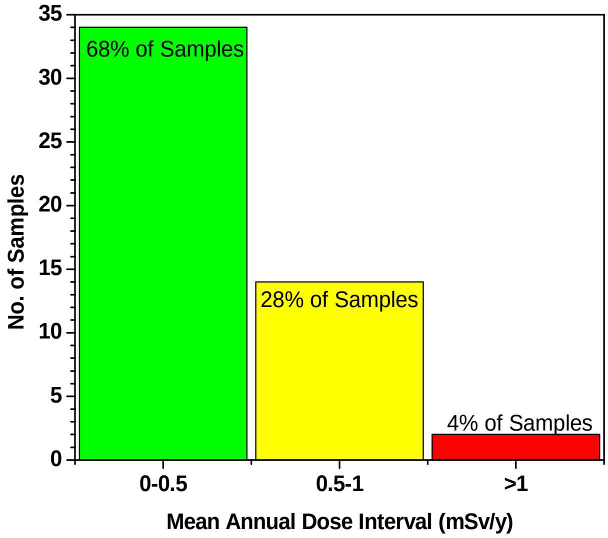

Figure 3. Three groups of radon effective dose histogram of the 50 samples.

CONCLUSION

The results of this study indicated that the radon concentration in public drinking water samples of Mashhad were mostly low enough, and below the proposed concentration limits which the means level 16.238 Bq/l with 9.322 standard deviation for all samples was not much greater than 11Bq/l as EPA advised level. According to the advice of WHO and the EU Council, just the last two samples (No. 49 and 50) induced the total annual effective dose greater than 0.1mSv/y. Therefore, we have suggested reducing their radon level, before public usage, applying methods such as mixing with surface water in large reservoirs or aerate water in order to allow some radon removal from the water.

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