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RESEARCH ARTICLE

MEASURING RADON AND RADIUM CONCENTRATIONS IN 50 SAMPLES OF DRINKING WATER SOURCES OF MASHHAD

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ABSTRACT

Radon and its radioactive progenies in indoor places are recognized as the main sources of public exposure from the natural radioactive sources. The tap water used for drinking and other household uses can increase the indoor radon level. In the present research data on radon concentrations in the water samples of Mashhad city has provided. Water samples were collected from various places and supplies of public water used in Mashhad. Then radon concentration has been measured by PRASSI system tree times for each sample in this research. Result shows about 75% of water samples have radon concentration gather than 10Bq/L which advised EPA as a normal level. According to measurements data, the mean radon concentration of all samples was 16.238 ± 9.322 Bq/L. The annual mean effective dose in stomach and long are 42.674 ± 24.525 and 45.305 ± 26.037 µSv/y, respectively, per person of Mashhad population which is more then 4 millions people. Results show about 75% of water samples have radon concentration gather than 10Bq/L as advised of EPA normal level. The radon and radium concentrations in drinking water samples actually used by people in Mashhad in some regions are not low enough and below the EPA proposed limits. Since a main section of radon come in body is due to drinking and household water, and for improvement of the social health level, we suggest using the low radon level water source, or public water supplies authority reducing the radon in the drinkable water before using by people.

INTRODUCTION

The ^{222}Rn radioisotope with 3.8 days decay half-life is produced from ^{238}U natural series and the ^{220}Rn radioisotope with 55 sec decay half-life from ^{232}Th natural series (UNSCEAR, 1993; 1998).

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Radon can enter to the body via respiring, drinking and eating. The alpha emitted by this radon and other radiation emitted from its decay products increase the absorbed dose in respiratory and digestion systems. Nearly 50% of annually radiation dose absorption of human is due to radon which is one of the main cancers cause at respiratory and digestion systems (UNSCEAR, 1993). Radon in water can enter the human body in tow ways:

1. Radon in drinking water or mineral drinks can enter the human body directly through the gastro-intestinal tract and irradiate whole body which the largest dose being received by the stomach. Assuming an average consumption of 0.5 litters of water per person per day, and stomach dose per Bq of radon is 5 nGy/Bq (UNSCEAR, 1993), with the consider 0.12 for stomach tissue weighting factor and 20 for quality factor of α radiation, the annual equivalent dose per Bq of radon concentration in water is about 2.19×10^{-6} μSv/ (year Bq l) (Tayyeb *et al.,* 1998).

2. Radon can escape from household water and became as an indoor radon source, which then enter the human respiratory tract system to deliver radiation dose. According to the report of UNSCEAR at 1998, the effective dose of the lung due to 1 Bq/l of radon in air with 0.4 equilibrium and 0.8 occupation factors is about 28 mSv/year (Yu *et al.,* 1994). The radon transfer coefficient from water to indoor air is estimated to be 10^{-1} (UNSCEAR, 1993; Mancini *et al.,*1995), so the conversion factor from unite radon concentration at equilibrium situation is 2.8 mSv l/Bq.

Some recent reports of large radon concentration in drinking water in different places (Baykara *et al.,* 2006; Ghosh *et al.,* 2004; Alabdula'aly 1999; Tayyeb *et al.,* 1998; Hakl *et al.,* 1995). Because of these reports, we concern to measure radon concentration in drinkable water sources of Kelardasht region. The present research work is the first ever report of radon and radium measurements in the water sources of the region by PRASSI system.

Radon and Radium Measurement in Water

Water sampling

To measure radon in water, some care must be taken in sampling process. Usually, springs and deep wells water are reach in radon, but after the water has been steered a little, it losses the highest fraction of its content. So, we have taken water sample directly from the sources, about 30 cm under the free surface of water.

PRASSI system and set up of measurement

The PRASSI (Portable Radon Gas Surveyor SILENA) Model 5S has been use for radon concentration measurement in water. This system is particularly well suited for this kind of measurement that must be performed in the closed loop circuit. PRASSI pumping circuit operates with constant fallow rate at 3 litters per minute in order to degassing the water sample properly. Fig. 1 shows the system set up of measurement including bubbler and drier column.

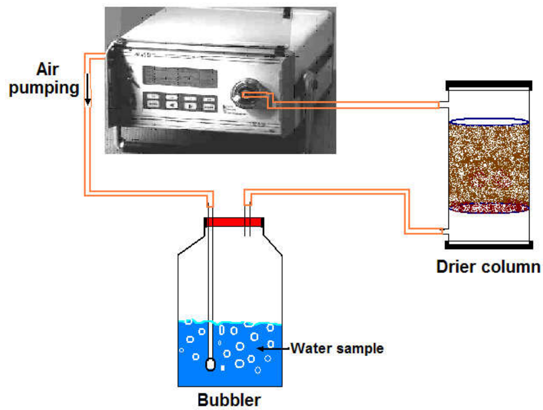

Fig. 1. The PRASSI system set up for radon measuring in the water sample.

To measure the content of radon in water, we put V_{sample} = 0.150 litter of the water sample in bubbler and the PRASSI will read a concentration of:

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

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

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

RESULTS AND DISCUSSION

The USA Environmental Protection Agency (EPA) has proposed a maximum contaminant radon level of 10 Bq/l (EPA, 2006). In this work the water samples were collected in various points distributed in and around the city of Mashhad. Fig. 2 shows the sampling sites. Water sampling has been done from each water supply; including wells, and surface water, as well as from household water. 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 (USEPA, 1991; EPA, 2006). 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. Then, three 150 ml water samples have been collected from each source or region. The collected samples were transferred to the laboratory of Payame Noor University for analysis.

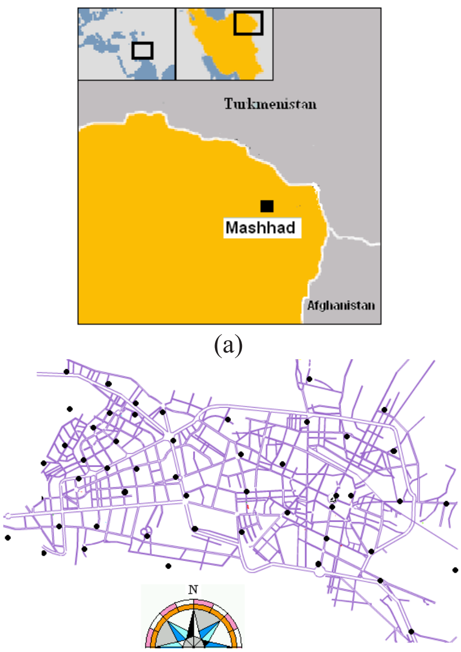

Fig. 2: (a) Mashhad location in Iran, (b) The map of Mashhad city and ● shows the sampling sites.

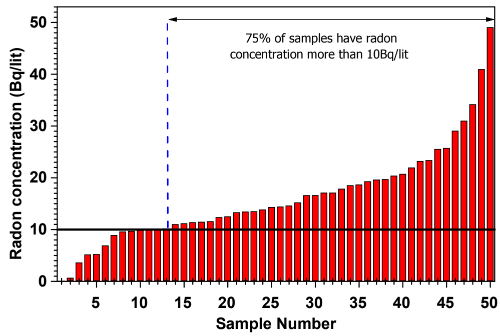

Fig. 3. Radon concentration for various samples of drinking water.

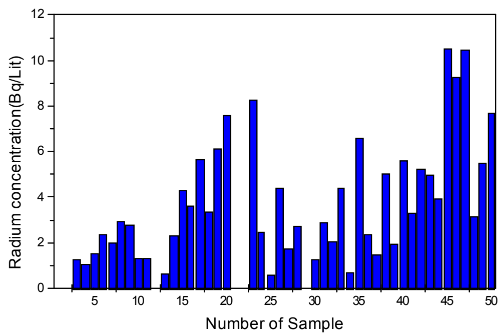

Fig. 4. The histogram of radium concentration in different water samples.

In the present research, a total number of 50 water samples from groundwater of deep wells, surface water of rivers, tap water samples were collected and analyzed for radon concentrations. The third column of Table 1, presents the mean radon concentration in each water samples. According to the data, the minimum and maximum radon concentrations in samples are 0.064 and 46.088 Bq/L, respectively. The arithmetic mean radon concentration of all samples was 16.238 ± 9.322 Bq/L. As the data shown in Fig. 3, the radon concentrations is about 75% for samples used by people in Mashhad which are greater than the EPA advised level, 10 Bq/L (EPA, 2006). We must mention that we sorted the experimental data in ascending order. The main reasons for large differences of radon concentration in sample seems

Table 1. Average radon concentration data and annual effective dose of different water sources per adult person (SW=Surface Water; GW=Ground Water; MW=Mixes of surface and ground Water).

Water Sample	*Source or place of sampling*	*Average Radon level (Bq/L)*	*Annual effective dose of adults(μSv/y)*	
			Stomach	**Lung**
1	Haram Motahar (SW)	0.064± 0.004	0.012	0.160
2	Boiling water of sample 50 (SW)	0.701± 0.004	0.126	1.752
3	Mojtama abi sarzamin mojhaye (SW)	3.641± 0.004	0.655	9.102
4	Anderokh village (SW)	5.195± 0.004	0.935	12.988
5	Qaem hospital (SW)	5.262± 0.004	0.947	13.155
6	Falahi boulevard (GW)	6.942± 0.004	1.250	17.355
7	Manba abe Emamie (MW)	8.942± 0.004	1.610	22.355
8	Qhanat Elahie (SW)	9.632± 0.004	1.734	24.080
9	Koohsangi region (MW)	9.742± 0.004	1.754	24.355
10	Vakilabad river (SW)	9.917± 0.004	1.785	24.793
11	Bande-e Golestan (SW)	9.986± 0.004	1.797	24.965
12	Hashemi boulevard (MW)	10.008± 0.004	1.801	25.020
13	Rahahan region 1 (SW)	10.221± 0.004	1.840	25.553
14	Gaz region (GW)	11.049± 0.004	1.989	27.622
15	Reza shahr (MG)	11.2144± 0.004	2.019	28.036
16	Mokhaberat region (GW)	11.427± 0.004	2.057	28.567
17	Rastgari region (GW)	11.504± 0.004	2.071	28.760
18	Mehregan hospital (GW)	11.614± 0.004	2.091	29.035
19	Gaem square (GW)	12.403± 0.004	2.233	31.008
20	Rahahan region 2 (MW)	12.554± 0.004	2.260	31.385
21	Ferdowsi university of Mashhad (GW)	13.342± 0.004	2.402	33.355
22	Azad university (GW)	13.475± 0.004	2.426	33.688
23	Payame Noor university (GW)	13.542± 0.004	2.438	33.855
24	End of Emamie (GW)	13.875± 0.004	2.498	34.688
25	Manba ab hejab (GW)	14.357± 0.004	2.584	35.892
26	17 Shahrivar square (MW)	14.442± 0.004	2.600	36.105
27	Cheshme Ghasem abad (SW)	14.64± 0.004	2.635	36.600
28	Andishe 19 (GW)	15.241± 0.004	2.743	38.102
29	Toroq river (SW)	16.641± 0.004	2.995	41.602
30	End of Andishe boulevard (MW)	16.656± 0.004	2.998	41.640
31	Melat park (SW)	17.136± 0.004	3.084	42.840
32	Ahmad abad street (MW)	17.136± 0.004	3.084	42.840
33	Ershad boulevard (GW)	17.888± 0.004	3.220	44.720
34	Tabarsi square (GW)	18.562± 0.004	3.341	46.405
35	Ab square (GW)	18.704± 0.004	3.367	46.760
36	Sad metri broad way (GW)	19.328± 0.004	3.479	48.320
37	Seyed Razi boulevard (GW)	19.648± 0.004	3.537	49.120
38	Emdadi hospital (GW)	19.744± 0.004	3.554	49.360
39	Taghato-e Andishe & Hesabi (GW)	20.416± 0.004	3.675	51.040
40	Azadshahr (MW)	20.752± 0.004	3.735	51.880
41	Emam Hosein square (GW)	21.984± 0.004	3.957	54.960
42	Sajad boulevard (GW)	23.248± 0.004	4.185	58.120
43	End of hejab (GW)	23.408± 0.004	4.213	58.520
44	Bustan-e Reja (GW)	25.568± 0.004	4.602	63.920
45	Danesh Amooz boulevard (GW)	25.76± 0.004	4.637	64.400
46	Bargh square (GW)	29.088± 0.004	5.236	72.720
47	Shaahed boulevard (GW)	31.024± 0.004	5.584	77.560
48	Shohada square (GW)	34.208± 0.004	6.157	85.520
49	Abutaleb street (GW)	40.992± 0.004	7.379	102.480
50	Taghato-e Hejab & Hesabi (GW)	49.088± 0.004	8.836	122.720

to be due to mixing of surface water with groundwater in proportions mentioned earlier, and storage of the mixed water in large reservoirs before distribution. Unfortunately up to now, there is no specific national regulation for radioactivity concentrations in drinking water in Iran. Compared to maximum contaminant level of 10 Bq/L for radon in public drinking water, suggested by the EPA (Folger *et al.,* 1994), the radon concentrations in most of the drinkable water samples in Mashhad, is significantly higher. In addition, the EPA requires that action be taken to reduce radon levels above an alternative maximum contaminant level of 150 Bq/L (Zhuo *et al.,* 2001). A number of investigators have reported much higher radon concentrations in public drinking water (Savidou *et al.,*., 2001; Al-Kazwini *et al.,* 2003). Kusyk *et al.,*. has been reported the mean value of 74 Bq/L for tap water, and mean value of 207 Bq/L for wells, in southern of Poland (Kusyk *et al.,* 2002).

For measuring radium in water samples, we have kept 150 ml of the water in the bottle for 2 months to let radon reach the equilibrium with radium. So, by measuring radon of the water sample as described before, we obtain radium concentration. Fig. 4 shows the histogram of radium concentration in different the water samples. The results show samples 45 and 47 have high radium concentration.

Conclusion

The results of this study well indicate that the radon concentrations in public drinking water samples of Mashhad are mostly low enough and below the proposed concentration limits. Measuring radon results show about 75% of samples actually used by people in Mashhad are greater than the EPA advised level, 10 Bq/L. Although, according to the advised of WHO and the EU Council just 2 samples (No. 49 and 50) induced the total annual effective dose greater than 0.1mSv/y. Therefore, there is a radon problem for these two sources and requiring some action to reduce their radon level before public usage, such as mixing with surface water in large reservoirs or aerate water in order to allowing some radon removal from the water. It is evident that if the wells are to be the only water supply for some parts of Mashhad, the required remedial action should be taken to reduce radon concentrations consumed by people.

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