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Radon and Radium Concentrations in 120 Samples of Drinking, Springs and Rivers Water Sources of North West Regions of Mashhad

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Abstract: Radon makes up approximately half of the total dose of radiation were receive naturally. The majority of it comes from the inhalation of progeny of ^{222}Rn and is prominent in a closed atmosphere. The continuous measurement of the levels of ^{222}Rn concentration in different geographical areas is of great importance, particularly in living places. In this study, the concentration of radium and radon in 120 samples of drinking, springs and rivers water sources of north west regions of Mashhad city have been measured. Solid state nuclear track detectors were used for measuring the concentration. The average value of radon and radium concentrations in the studied area is found to be 30.2±5.1 and 18.4±2.2 Bq m^{-3}, respectively. The dose rate due to radon, radium and their progenies received by the population in the studied location between 0.1-0.5 mSv $year^{-1}$. The arithmetic and geometric mean concentrations are 0.2±0.05 and 0.2 mSv $year^{-1}$, respectively. The results show no significant radiological risk for the inhabitants of the studied regions.

Key words: Radon and radium concentrations, water sources, radiation, location, population, Iran

INTRODUCTION

There is much concern these days on the part of the public and government organizations about natural radiation and the environment, particularly for dwellings (Folger *et al*., 1994). Due to relatively higher doses found as a consequence of elevated radon concentrations some countries are now passing legislation to deal with the problem.

This is true particularly in cold climate countries where the energy crisis is a serious problem and where houses were built more hermetically so as to minimize ventilation conditions. Radon contributes most to the effective dose received by a population from natural sources.

It has been estimated that radon and its progeny contribute three-quarters of the annual effective dose received by human beings from natural terrestrial sources and are responsible for about half of the dose from all sources. Radon emanates to a certain degree from all types of soil and rocks (Al-Kazwini and Hasan, 2003).

The presence of ^{222}Rn in the biosphere is due to its semi-disintegration period of 3.8 days which allows it to diffuse from the earth's crust into the atmosphere (Khan, 2000). The radiological importance of radon does not depend on the concentration of radon gas itself but on its short-lived decay progenies such as polonium, bismuth and lead. During breathing, radon is exhaled but the progenies being material particles may deposit on to the lungs, tracks of breathing etc. (Kearfott, 1989). Some factors that influence the diffusion of radon from soil into the air are the existence of uranium and radium in soil and rock, emanation capacity of the ground, porosity of the soil and rock, pressure gradient between the interfaces, soil moisture and water saturation grade of the medium. 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 (Kendal and Smith, 2002). 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 (Li *et al*., 2006). Radon in water can enter the human body in two ways.

Firstly, 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 (Kusyk and Ciesla, 2002).

Assuming an average consumption of 0.5 L of water per person per day and stomach dose per Bq of radon is 5 nGy/Bq 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). Secondly, 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.

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MEASUREMENT METHODS

In this study, radon was measured in the water samples using PRASSI system (Savidou *et al*., 2001). A total of 120 samples including 38 samples of drinking water, 56 river water samples and 26 samples of spring waterwater were tested. Figure 1 shows the sampling sites.

Radium in the water samples were measured keeping the water samples in the bottles for 35 days to let radon reach the equilibrium with radium whereby we obtained radium concentration in the samples.

Figure 2 shows the system set up of measurement including bubbler and drier column. PRASSI pumping circuit operates with constant fallow rate at 3 L min^{-1} in order to degassing the water sample properly. Its detector is a scintillation cell coated with ZnS (Ag) 1830 cm^3 volume. The sensitivity of this system in continuous mode is 4 Bq m^{-3} during the integration time 1 h. Numbers shown by the device is based on Bq m^{-2}. Using relationship Eq. 1, radon gas density is calculated based on Bq/L.

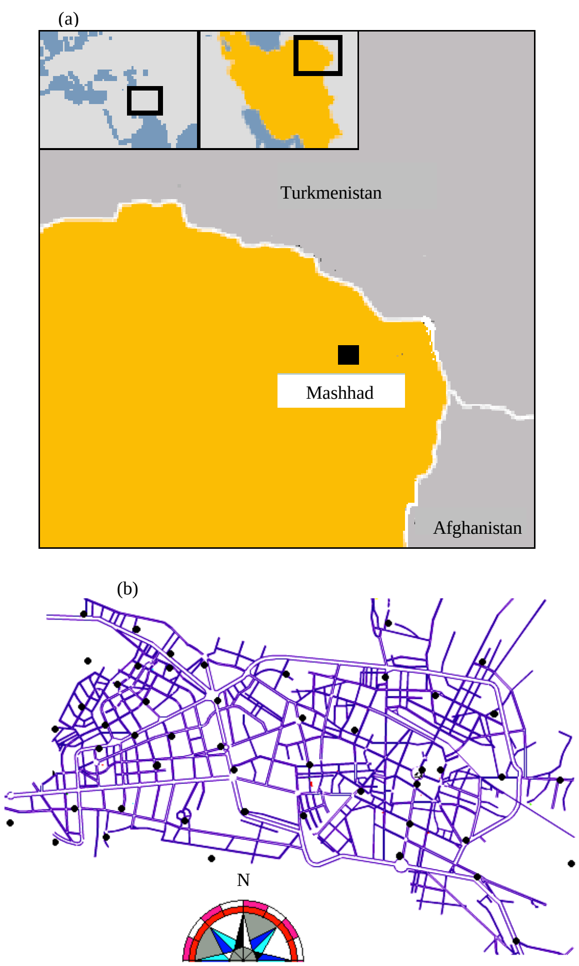

Fig. 1: (a) Mashhad location in Iran; (b) the map of Mashhad city and • shows the sampling sites of Zoshk, Shandiz and Torghabeh

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

Where:

Q_{PRASSI} = Recorded by the device
V_{tot} = The total volume of air connections
V = Volume sample and within the brackets is a correction factor in the delay measurement

Radon in water samples: The third column in Table 1, radon concentration samples that have been ordered from low to high is listed. Also, the radon gas density results are shown in histogram of Fig. 3.

As it can be shown only 81/12% of the samples the last 19 samples in Table 1 have concentrations >11 Bq L^{-1}, particularly the sample number 120 that related to the spring in the village of Zoshk has concentration about 30 Bq L^{-1}.

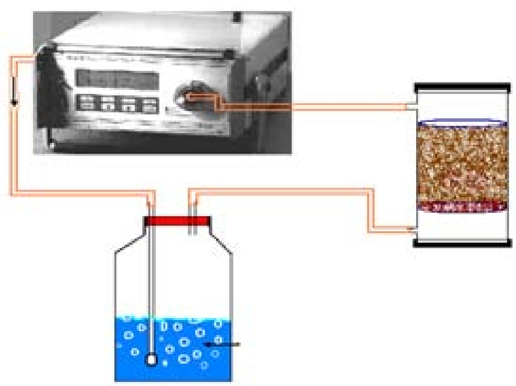

Fig. 2: The PRASSI system set up for radon measuring in the water samples

Table 1: Radon and radium concentration data of different water samples

Water samples	Q_{Rn} (Bq/L)	Q_{Ra} (Bq/L)
Zoshk river	0.000	0.000
River 10 km before Zoshk	0.000	0.230
River 2 km before Zoshk	0.000	0.000
River 8 km before Zoshk	0.000	0.240
River 1 km after Zoshk	0.000	0.150
River 4 km after Zoshk	0.300	0.000
Zoshk spring water	0.330	0.000
Zoshk drinking water (No. 1)	0.320	0.045
River 1.5 km after Zoshk	0.380	0.090
Torghabeh drinking water (No. 1)	0.540	0.000
River of shandiz waterfall (No.1)	0.560	0.680
River 2.3 km after Torghabeh	0.580	0.080
River 2.5 km after Zoshk	0.600	0.050

Table 1: Continue

Water samples	Q_{Rn} (Bq/L)	Q_{Ra} (Bq/L)
River 1.3 km after Zoshk	0.660	0.099
Zoshk drinking water (No. 2)	0.940	0.000
Shandiz waterfall	1.040	0.180
River 2.8 km after Abrdh	1.180	0.170
River 0.8 km after Zoshk	1.299	0.018
River 1.8 km after Zoshk	1.300	0.000
River 2.7 km after Torghabeh	1.350	0.000
Shandiz drinking water (No. 1)	1.400	2.190
River 2.5 km after Zoshk	1.540	0.056
Shandiz drinking water (No. 2)	1.960	0.000
Torghabeh drinking water (No. 2)	1.641	0.163
River 2.3 km after Zoshk	1.763	0.000
Zshk drinking water (No. 3)	1.853	0.130
Upper Torghabeh drinking water (No. 1)	1.937	0.308
River 0.7 km after Zoshk	2.241	0.096
Zshk spring water (No. 1)	2.300	0.036
River 2.7 km after Zoshk	2.352	0.000
Shandiz drinking water (No.3)	2.412	0.492
River 0.8 km after Zoshk spring water	2.435	0.140
Lower Torghabeh drinking water (No. 1)	2.476	0.000
Shandiz drinking water near the mosque	2.476	0.000
Shandiz drinking water (No. 4)	2.630	0.854
Upper Torghabeh drinking water (No. 2)	2.698	0.070
River 5 km after Torghabeh	2.850	0.000
River 1.7 km after Zoshk	2.873	0.208
Lower Torghabeh drinking water (No. 2)	2.870	0.000
Lower Abrdh spring water	3.049	0.240
Shandiz drinking water (No. 5)	3.153	0.660
River of Shandiz waterfall (No. 1)	3.215	0.137
Lower Torghabeh drinking water (No. 3)	3.240	0.491
River 1.3 km after Zoshk	3.269	0.000
River beginning Zoshk	3.418	0.070
River 5.5 km after Torghabeh	3.492	0.000
Shandiz drinking water (No. 6)	3.619	0.787
River at Zoshk	3.760	0.000
River 5.9 km after Torghabeh	4.012	0.013
River 2.4 km after Torghabeh	4.170	0.250
River 0.5 km after Zoshk	4.200	0.133
Shandiz drinking water (No. 7)	4.231	0.000
River 1.5 km after Zoshk	4.237	0.051
Upper Torghabeh drinking water (No. 3)	4.254	0.000
Upper Abrdh drinking water (No. 4)	4.375	0.000
River 2.6 km after Torghabeh	4.729	0.000
River 1.2 km after Zoshk	4.870	0.000
Lower Torghabeh drinking water (No. 4)	4.895	0.300
Shandiz drinking water (No. 8)	4.980	0.000
Lower Torghabeh drinking water (No. 5)	5.051	0.1108
River of shandiz waterfall (No. 2)	5.050	0.316
River 3.5 km after Abrdh	5.081	0.059
Lower Abrdh spring water	5.130	0.244
River 0.1 km after Lower Torghabeh	5.255	0.000
River 1.6 km after Zoshk	5.431	0.057
Upper Torghabeh spring water	5.441	0.044
River 0.2 km after Zshk	5.453	0.290
Torghabeh drinking water (No. 3)	5.482	0.000
River 4 km before Torghabeh	5.579	0.133
River 5 km before Torghabeh	5.675	0.000
River 0.5 km after Torghabeh	5.660	0.094
Zoshk spring water (No. 2)	5.727	0.000
Upper Torghabeh drinking water(No. 5)	6.141	0.087
Lower Torghabeh drinking water (No. 6)	6.574	0.047
Torghabeh drinking water (No. 4)	6.907	0.288
Spring water 1 km after Zoshk	7.020	0.000
Lower Torghabeh drinking water (No.7)	7.150	0.240
River 2.8 km after Zoshk	7.130	0.000
Torghabeh drinking water (No. 5)	7.770	0.240
River 0.2 km after Lower Torghabeh	7.587	0.093

Table 1: Continue

Water samples	Q_{rn} (Bq/L)	Q_{ra} (Bq/L)
Lower Torghabeh spring water (No. 1)	7.631	0.132
River 2.9 km after Zoshk	7.867	0.291
Zoshk spring water (No. 3)	7.895`	0.000
River 4.5 km after Torghabeh	7.969	0.000
Torghabeh drinking water (No. 6)	8.131	0.178
Zoshk drinking water (No. 4)	8.155	0.058
Zoshk drinking water (No. 5)	8.310	0.000
Zoshk spring water (No. 4)	8.327	0.000
River 0.4 km after Zoshk	8.356	0.000
Zoshk drinking water (No. 6)	8.603	0.054
Lower Torghabeh drinking water (No. 8)	8.630	0.437
Zoshk spring water (No. 5)	9.034	0.183
Zoshk spring water (No. 6)	9.056	0.280
River 2.5 km after Torghabeh	9.931	0.0189
River of Shandiz waterfall (No. 3)	10.124	0.000
Qelqeli spring water	10.402	0.083
Zoshk drinking water (No. 7)	10.721	0.0014
Lower Torghabeh drinking water (No. 9)	10.729	0.000
Zoshk drinking water (No. 8)	10.915	0.0052
Lower Torghabeh drinking water (No. 10)	10.992	0.022
Shandiz drinking water (No. 9)	11.199	0.000
Spring water 0.5 km after Zoshk	11.360	0.127
River 1 km before Zoshk	11.434	0.207
Lower Torghabeh Drinking water (No. 11)	11.595	0.096
River 2 km after Zshk	11.778	0.433
Zoshk spring water (No. 7)	13.055	0.133
River 1 km after Zoshk	13.058	0.091
Zshk spring water (No. 8)	13.761	0.0026
Zshk spring water (No. 9)	14.430	0.183
Spring water 0.1 km after Zshk	14.577	0.000
Spring water 2 km after Zshk	14.863	0.207
Zshk drinking water (No. 9)	15.755	0.000
River 0.5 km before Zshk	16.324	0.000
Spring water at Zshk	16.344	0.000
River of Shandiz waterfall (No. 4)	17.363	0.354
Upper Abrdh drinking water (No. 6)	17.879	0.207
Lower Abrdh spring water (No. 2)	18.445	0.047
River 1.5 km after Abrdh	18.578	0.000
Spring water 0.7 km after Zshk	21.495	0.010
Spring water 1.5 km before Zshk	31.881	0.660

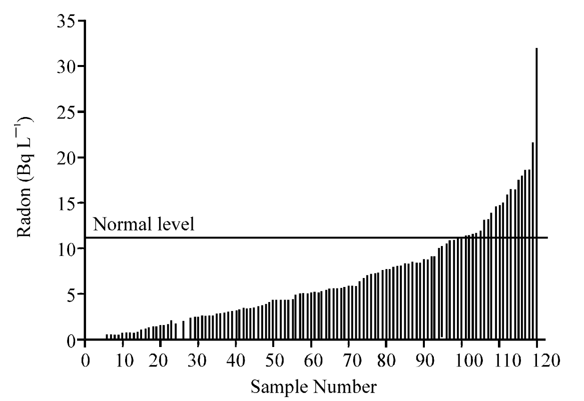

Fig. 3: The histogram of radon gas concentration in 120 water samples of Shandiz, Zoshk and Torghabeh regions

Radium in water samples: Figure 4 shows the histogram of radium concentration in different water samples as well

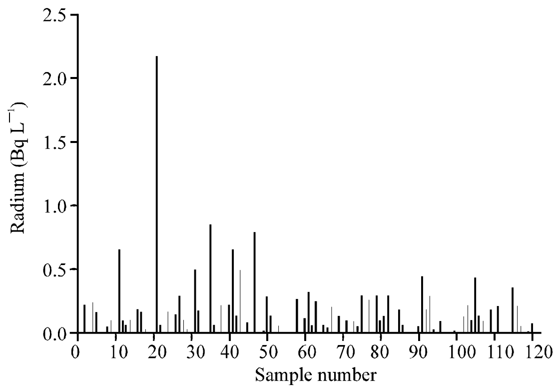

Fig. 4: The histogram of radium concentration in different water samples

as the data shown in 4th column of Table 1. The radium concentration of samples were <1 Bq L^{-1} except sample number 21, drinking water of Shandiz region is about 1.87 Bq L^{-1}.

CONCLUSION

Results of radon concentration in the water samples showed that only 14.67% sample concentrations were higher than the normal 11 Bq L^{-1}, set by United States Environmental Protection Agency (USEPA). About 148 Bq L^{-1} is limit amount of action or reaction that radon should be reduced. Radium concentration of all samples except sample number 21, drinking water of Shandiz were small and <1 Bq L^{-1}. Therefore, radon and radium concentration in the water of the regions were not high and these were appropriate.

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