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Full Length Research Paper

Radon and radium concentrations in 120 samples of drinking springs and rivers water sources of northwest regions of Mashhad

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Radon makes up approximately half of the total dose of radiation were received 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 northwest 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 y^{-1}. The arithmetic and geometric mean concentrations are 0.2±0.05 and 0.2 mSv y^{-1}, respectively. The results show no significant radiological risk for the inhabitants of the studied regions.

Key words: Radon and radium concentrations, water sources.

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 et al., 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 et al., 2002). Nearly 50% of annually radiation dose absorption

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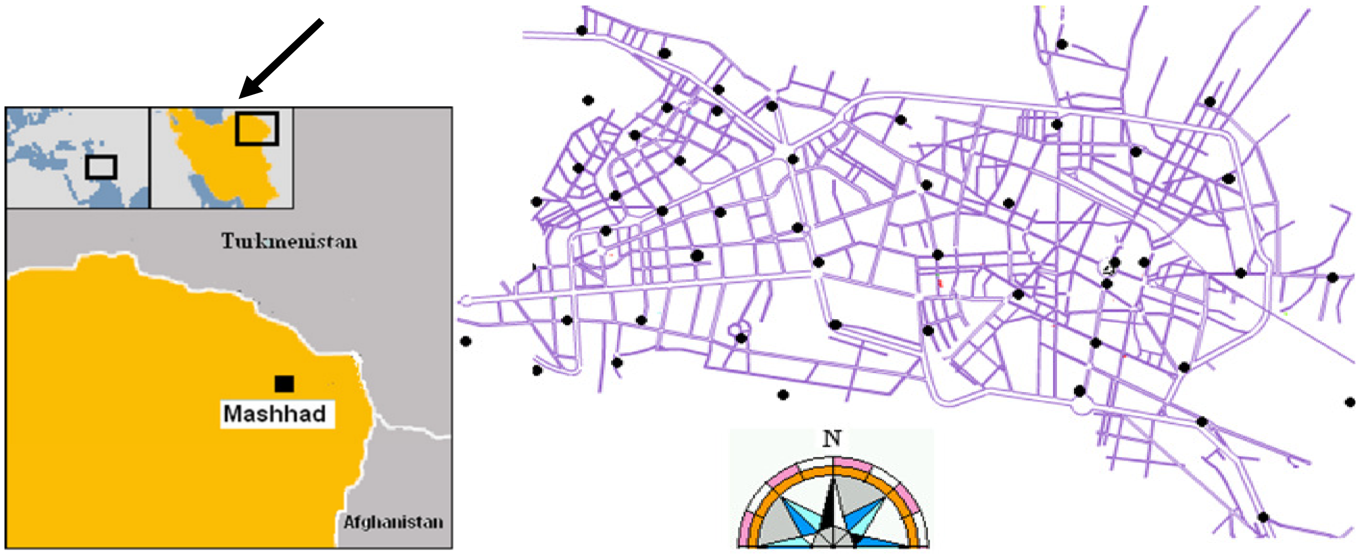

(a) (b)

Figure 1. (a) Mashhad location in Iran. (b) The map of Mashhad city and ● shows the sampling sites of Zoshk, Shandiz and Torghabeh.

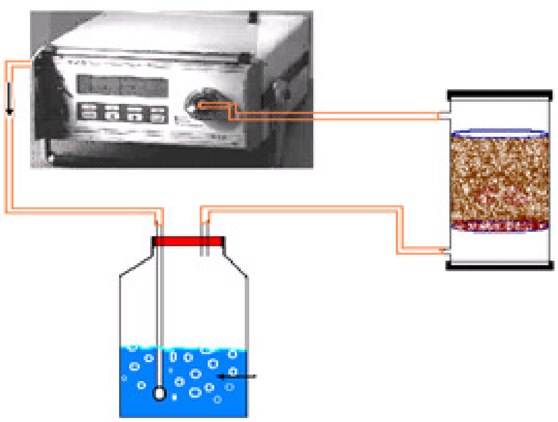

Figure 2. The PRASSI system set up for radon measuring in the water samples

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 et al., 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 an indoor radon source, which then enter the human respiratory tract system to deliver radiation dose.

MEASUREMENT METHOD

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 water 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 follow rate at 3 liters per minute 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 Equation 1, radon gas density is calculated based on $\frac{Bq}{l}$.

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

Where Q_{PRASSI} value recorded by the device, V_{tot} is the total volume of air connections, V is 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

Table 1. Radon and radium concentration data of different water samples**.**

Sample No.	Water sample	$Q_{Rn}(\frac{Bq}{l})$	$Q_{Ra}(\frac{Bq}{l})$
1	Zoshk River	0	0
2	River 10 km before Zoshk	0	0.23
3	River 2 km before Zoshk	0	0
4	River 8 km before Zoshk	0	0.24
5	River 1 km after Zoshk	0	0.15
6	River 4 km after Zoshk	0.30	0
7	Zoshk spring water	0.33	0
8	Zoshk drinking water (No. 1)	0.32	0.045
9	River 1.5 km after Zoshk	0.38	0.09
10	Torghabeh drinking water (No. 1)	0.54	0
11	River of Shandiz waterfall (No.1)	0.56	0.68
12	River 2.3 km after Torghabeh	0.58	0.08
13	River 2.5 km after Zoshk	0.6	0.05
14	River 1.3 km after Zoshk	0.66	0.099
15	Zoshk drinking water (No. 2)	0.94	0
16	Shandiz waterfall	1.04	0.18
17	River 2.8 km after Abrdh	1.180	0.17
18	River 0.8 km after Zoshk	1.299	0.018
19	River 1.8 km after Zoshk	1.3	0
20	River 2.7 km after Torghabeh	1.35	0
21	Shandiz drinking water (No.1)	1.4	2.19
22	River 2.5 km after Zoshk	1.54	0.056
23	Shandiz drinking water (No. 2)	1.96	0
24	Torghabeh drinking water (No. 2)	1.641	0.163
25	River 2.3 km after Zoshk	1.763	0
26	Zshk drinking water (No. 3)	1.853	0.13
27	Upper Torghabeh drinking water (N0.1)	1.937	0.308
28	River 0.7 km after Zoshk	2.241	0.096
29	Zshk spring water (No. 1)	2.3	0.036
30	River 2.7 km after Zoshk	2.352	0
31	Shandiz drinking water (No.3)	2.412	0.492
32	River 0.8 km after Zoshk spring water	2.435	0.14
33	Lower Torghabeh drinking water (No.1)	2.476	0
34	Shandiz drinking water near the Mosque	2.476	0
35	Shandiz drinking water (No. 4)	2.63	0.854
36	Upper Torghabeh drinking water (No. 2)	2.698	0.07
37	River 5 km after Torghabeh	2.85	0
38	River 1.7 km after Zoshk	2.873	0.208
39	Lower Torghabeh drinking water (No. 2)	2.87	0
40	Lower Abrdh spring water	3.049	0.24
41	Shandiz drinking water (No. 5)	3.153	0.66
42	River of Shandiz waterfall (No.1)	3.215	0137
43	Lower Torghabeh drinking water (No. 3)	3.24	0.491
44	River 1.3 km after Zoshk	3.269	0
45	River beginning Zoshk	3.418	0.07
46	River 5.5 km after Torghabeh	3.492	0
47	Shandiz drinking water (No. 6)	3.619	0.787
48	River at Zoshk	3.76	0
49	River 5.9 km after Torghabeh	4.012	0.013
50	River 2.4 km after Torghabeh	4.17	0.25

Table 1. Cont.

51	River 0.5 km after Zoshk	4.2	0.133
52	Shandiz Drinking Water (No.7)	4.231	0
53	River 1.5 km after Zoshk	4.237	0.051
54	Upper Torghabeh drinking water (N0. 3)	4.254	0
55	Upper Abrdh drinking water (N0. 4)	4.375	0
56	River 2.6 km after Torghabeh	4.729	0
57	River 1.2 km after Zoshk	4.87	0
58	Lower Torghabeh drinking water (N0. 4)	4.895	0.3
59	Shandiz drinking water (No. 8)	4.98	0
60	Lower Torghabeh drinking water (N0. 5)	5.051	0.1108
61	River of Shandiz waterfall (No. 2)	5.05	0.316
62	River 3.5 km after Abrdh	5.081	0.059
63	Lower Abrdh spring water	5.130	0.244
64	River 0.1 km after lower Torghabeh	5.255	0
65	River 1.6 km after Zoshk	5.431	0.057
66	Upper Torghabeh spring water	5.441	0.044
67	River 0.2 km after Zshk	5.453	0.29
68	Torghabeh Drinking Water (N0. 3)	5.482	0
69	River 4 km before Torghabeh	5.579	0.133
70	River 5 km before Torghabeh	5.675	0
71	River 0.5 km after Torghabeh	5.66	0.094
72	Zoshk spring water (No. 2)	5.727	0
73	Upper Torghabeh drinking water (No. 5)	6.141	0.087
74	Lower Torghabeh drinking water (N0. 6)	6.574	0.047
75	Torghabeh drinking water (N0. 4)	6.907	0.288
76	Spring water 1 km after Zoshk	7.02	0
77	Lower Torghabeh drinking water (N0.7)	7.15	0.24
78	River 2.8 km after Zoshk	7.13	0
79	Torghabeh drinking water (No. 5)	7.77	0.24
80	River 0.2 km after lower Torghabeh	7.587	0.093
81	Lower Torghabeh spring water (No. 1)	7.631	0.132
82	River 2.9 km after Zoshk	7.867	0.291
83	Zoshk Spring Water (No. 3)	7.895`	0
84	River 4.5 km after Torghabeh	7.969	0
85	Torghabeh drinking water (No. 6)	8.131	0.178
86	Zoshk drinking water (No. 4)	8.155	0.058
87	Zoshk drinking water (No. 5)	8.310	0
88	Zoshk spring water (No. 4)	8.327	0
89	River 0.4 km after Zoshk	8.356	0
90	Zoshk drinking water (No. 6)	8.603	0.054
91	Lower Torghabeh drinking water (No. 8)	8.630	0.437
92	Zoshk spring water (No. 5)	9.034	0.183
93	Zoshk spring water (No. 6)	9.056	0.280
94	River 2.5 km after Torghabeh	9.931	0.0189
95	River of Shandiz waterfall (No. 3)	10.124	0
96	Qelqeli spring water	10.402	0.083
97	Zoshk drinking water (No. 7)	10.721	0.0014
98	Lower Torghabeh drinking water (No. 9)	10.729	0
99	Zoshk Drinking Water (No. 8)	10.915	0.0052
100	Lower Torghabeh drinking water (No. 10)	10.992	0.022
101	Shandiz drinking water (No. 9)	11.199	0
102	Spring Water 0.5 km after Zoshk	11.360	0.127

Table 1. Cont.

103	River 1 km before Zoshk	11.434	0.207
104	Lower Torghabeh drinking water (N0. 11)	11.595	0.096
105	River 2 km after Zshk	11.778	0.433
106	Zoshk spring water (No. 7)	13.055	0.133
107	River 1 km after Zoshk	13.058	0.091
108	Zshk spring water (No. 8)	13.761	0.0026
109	Zshk spring water (No. 9)	14.43	0.183
110	Spring water 0.1 km after Zshk	14.577	0
111	Spring water 2 km after Zshk	14.863	0.207
112	Zshk drinking water (No. 9)	15.755	0
113	River 0.5km before Zshk	16.324	0
114	Spring water at Zshk	16.344	0
115	River of Shandiz waterfall (No. 4)	17.363	0.354
116	Upper Abrdh drinking water (No. 6)	17.879	0.207
117	Lower Abrdh spring water (No. 2)	18.445	0.047
118	River 1.5 km after Abrdh	18.578	0
119	Spring water 0.7 km after Zshk	21.495	0.01
120	Spring water 1.5 km before Zshk	31.881	0.66

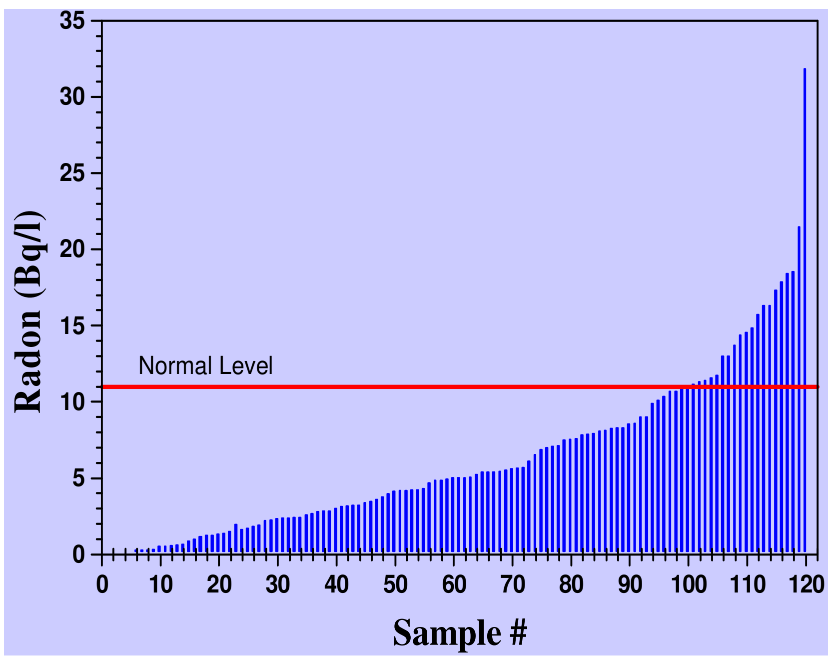

Figure 3. The histogram of radon gas concentration in 120 water samples of Shandiz, Zoshk and Torghabeh regions.

that have been ordered from low to high, is listed. Also, the radon gas density results are shown in histogram of Figure 3. As it can be seen, only 81/12% of the samples, the last 19 samples in Table 1 have concentrations higher than 11 Bq/l, particularly the sample number 120 that related to the spring in the village of Zoshk has concentration about 30 Bq/l.

Radium in water samples

Figure 4 shows the histogram of radium concentration in different water samples as well as the data listed in fourth column of Table 1. The radium concentration of samples were less than 1 Bq/l, except sample number 21, drinking water of Shandiz region is about 1.87 Bq/l.

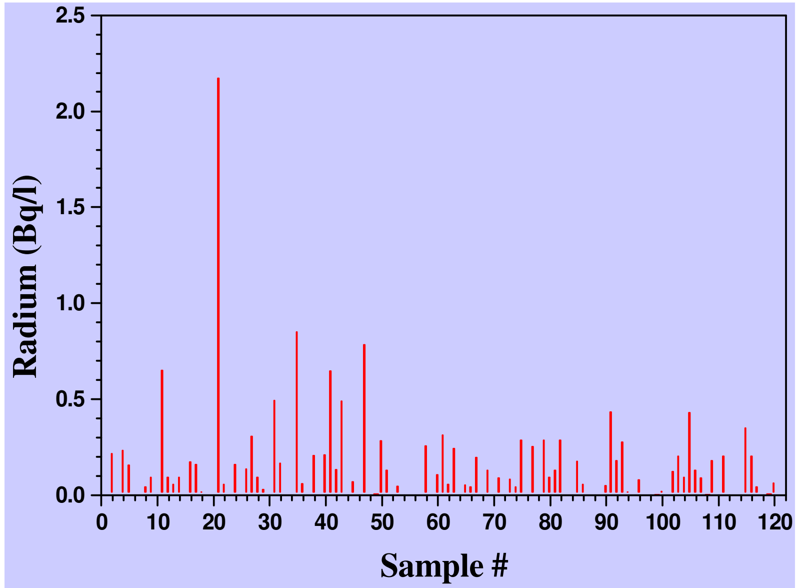

Figure 4. The histogram of radium concentration in different water samples.

Conclusion

Results of radon concentration in the water samples showed that only 14.67% sample concentrations were higher than the normal 11 Bq/l, set by United States Environmental Protection Agency (USEPA). 148 Bq/l 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 less than 1 Bq/l. Therefore, radon and radium concentration in the water of the regions were not high and these were appropriate.

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