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Measuring Radon and Radium Concentrations in 120 Samples of Drinking Water Sources, Springs and Rivers of Shandiz, Zoshk and Abrdeh Regions

[1]A. Binesh, [2]S. Mohammadi, [3]A.A. Mowlavi and [2]P. Parvaresh
[1]Department of Physics, Payam Nour University, Fariman, Iran
[2]Department of Physics, Payam Nour University, Mashhad, Iran
[3]Department of Physics, Sabzevar Tarbiat Moallem University, Sabzevar, Iran

Abstract: Radioactive element radium produces radon gas with the alpha decay. Radon is a colorless gas without smell, weak, ineffective and over 50% radiation of the annual dose human body is involved. The two heavy radioactive elements in the natural decay chain from uranium and thorium is produced. Radon through breathing, eating and drinking enters the body. Alpha emission from gas and other radiations emitted from daughter nuclei of its short life makes serious damage to the respiratory system and into the human digestive, therefore after smoking this radiation is the second risk factor of lung cancer. In this study, the concentration of radium and radon in water sources, springs and rivers of Shandiz, Zoshk and Abrdeh regions (Mashhad-Iran) and using light and portable PRASSI system is measured. Total 120 samples including 38 samples of drinking water, 56 river water samples and 26 samples of spring water has been tested. A total of 19 samples had concentrations >11 (Bq L^{-1}), the reference level set by the U.S. Environmental Protection Agency. Radium concentration of all samples was <1, only sample No. 21 related to drinking water of Shandiz city is about 2.2 (Bq L^{-1}).

Key words: Measuring radon, radium, drinking water, Shandiz, Zoshk and Abrdeh regions, PRASSI system, agency

INTRODUCTION

^{222}Rn radioisotope with half-life 3.8 days from the ^{238}U decay series and ^{220}Rn with half-life 55 sec from ^{232}Th decay series are produced. Radon gas is alpha emitter and enters the body with breathing, eating and drinking. In addition to radon exposure, its daughter nuclei which are very short lived as sediment in the inner membrane respiratory or digestive body remain and increase the body absorption dose (United States Environmental Protection Agency, 1991; UNSCEAR, 1998; ICRP, 1993; IARC, 1988; Mowlavi *et al*., 2009; Baykara and Dogru, 2006). Natural exposure of people is about 50% of radon gas that many people in the annual risk of cancers of the respiratory and gastrointestinal die. Thus, measurement of radon in water and air is very important and many studies have been done in this area (IARC, 1988; Mowlavi *et al*., 2009; Baykara and Dogru, 2006; Vogiannis *et al*., 2004; Field *et al*., 2001; Tayyeb *et al*., 1998; Yu *et al*., 1994; Mancini and Giannelli, 1995; Alabdulaaly, 1999; Schmitz and Nickels, 2001; Mortazavi, 2000). This study is the first report measuring radon and radium in drinking water and springs in the region.

MATERIALS AND METHODS

In this study, to measure radon in water samples PRASSI system has been used. This system is lightweight and portable device that has the ability to measure radon concentration in water, soil and air.

Figure 1 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^{-1}).

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

Corresponding Author: A. Binesh, Department of Physics, Payam Nour University, Fariman, Iran

Where:

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

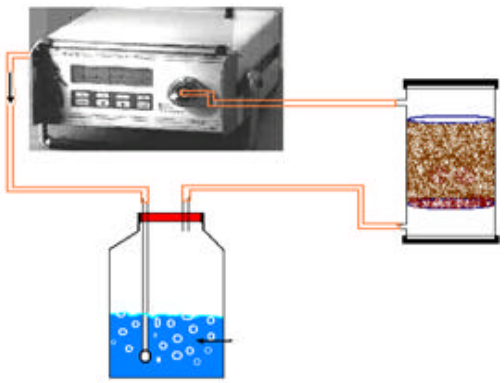

Fig. 1: View from the device to measure radon in water

RESULTS AND DISCUSSION

Measuring radon in water samples: In this study, 120 samples of radon concentration of water including drinking water, rivers and springs of Shandiz, Zoshk and Abrdeh regions and adjacent villages (Mashhad-Iran) have been measured. The third column in Table 1, radon concentration samples that have been ordered from low to high. Also, the radon gas density results are shown in histogram of Fig. 2 and 3. Seen that only 83/15% 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 32 (Bq L^{-1}).

Measuring radium in water samples: For measuring radium in water samples, the water samples have kept in the bottles for 35 days to let radon reach the equilibrium with radium. So, by measuring, we obtain radium concentration in the samples. Figure 4 shows the

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

Sample number	Water sample	Q_{Rn} (Bq L^{-1})	Q_{Ra} (Bq L^{-1})
1	Zoshk river	0.000	0.000
2	River 14 km before Abrdeh	0.000	0.221
3	River 1 km before Zoshk	0.000	0.000
4	River 10 km before Zoshk	0.000	0.237
5	River 2 km after Zoshk	0.000	0.159
6	River 6 km after Abrdeh	0.302	0.000
7	Abrdeh spring water	0.327	0.000
8	Zoshk drinking water (No. 1)	0.331	0.047
9	River 1.5 km after Zoshk	0.379	0.097
10	Abrdeh drinking water (No. 1)	0.545	0.000
11	River of shandiz waterfall (No.1)	0.555	0.654
12	River 2.3 km after Abrdeh	0.590	0.095
13	River 2.5 km after Zoshk	0.636	0.059
14	River 1.3 km after Zoshk	0.695	0.097
15	Zoshk drinking water (No. 2)	0.922	0.000
16	Shandiz waterfall	1.041	0.177
17	River 2.8 km after Abrdeh	1.180	0.163
18	River 0.8 km after Zoshk	1.299	0.018
19	River 1.8 km after Zoshk	1.305	0.000
20	River 2.7 km after Abrdeh	1.345	0.000
21	Shandiz drinking water (No.1)	1.412	2.176
22	River 2.5 km after Zoshk	1.525	0.059
23	Shandiz drinking water (No.2)	1.994	0.000
24	Abrdeh drinking water (No. 2)	1.641	0.163
25	River 2.3 km after Zoshk	1.763	0.000
26	Zoshk drinking water (No. 3)	1.853	0.141
27	Upper Abrdeh drinking water (N0.1)	1.936	0.308
28	River 0.7 km after Zoshk	2.241	0.096
29	Zoshk spring water (No. 1)	2.307	0.034
30	River 2.7 km after Zoshk	2.352	0.000
31	Shandiz drinking water (No.3)	2.416	0.498
32	River 0.8 km after Zoshk spring water	2.433	0.170
33	Lower Abrdeh drinking water (No.1)	2.476	0.000
34	Shandiz drinking water near the mosque	2.476	0.000
35	Shandiz drinking water (No.4)	2.629	0.854
36	Upper Abrdeh drinking water (N0.2)	2.698	0.062
37	River 5 km after Abrdeh	2.833	0.000
38	River 1.7 km after Zoshk	2.873	0.208
39	Lower Abrdeh drinking water (N0.2)	2.876	0.000
40	Lower Abrdeh spring water	3.049	0.215
41	Shandiz drinking water (No.5)	3.153	0.652
42	River of shandiz waterfall (No.1)	3.215	0.137

Table 1: Continued

Sample number	Water sample	Q_{Rn} (Bq L^{-1})	Q_{Ra} (Bq L^{-1})
43	Lower Abrdeh drinking water (N0.3)	3.227	0.4910
44	River 1.3 km after Zoshk	3.269	0.0000
45	River beginning Zoshk	3.418	0.0740
46	River 5.5 km after Abrdeh	3.492	0.0000
47	Shandiz drinking water (No.6)	3.619	0.7870
48	River at Zoshk	3.796	0.0000
49	River 5.9 km after Abrdeh	4.012	0.0130
50	River 2.4 km after Abrdeh	4.172	0.2850
51	River 0.5 km after Zoshk	4.230	0.1330
52	Shandiz drinking water (No.7)	4.231	0.0000
53	River 1.5 km after Zoshk	4.237	0.0510
54	Upper Abrdeh drinking water (N0. 3)	4.254	0.0000
55	Upper Abrdeh drinking water (N0. 4)	4.375	0.0000
56	River 2.6 km after Abrdeh	4.729	0.0000
57	River 1.2 km after Zoshk	4.883	0.0000
58	Lower Abrdeh drinking water (N0. 4)	4.895	0.2610
59	Shandiz drinking water (No.8)	4.967	0.0000
60	Lower Abrdeh drinking water (N0.5)	5.051	0.1108
61	River of shandiz waterfall (No. 2)	5.058	0.3170
62	River 3.5 km after Abrdeh	5.081	0.0590
63	Lower Abrdeh spring water	5.130	0.2440
64	River 0.1 km after lower Abrdeh	5.255	0.0000
65	River 1.6 km after Zoshk	5.431	0.0570
66	Upper Abrdeh spring water	5.441	0.0440
67	River 0.2 km after Zoshk	5.453	0.1990
68	Abrdeh drinking water (N0. 3)	5.482	0.0000
69	River 4 km before Abrdeh	5.579	0.1330
70	River 5 km before Abrdeh	5.675	0.0000
71	River 0.5 km after Abrdeh	5.692	0.0940
72	Zoshk spring water (No. 2)	5.727	0.0000
73	Upper Abrdeh drinking water (No. 5)	6.141	0.0870
74	Lower Abrdeh drinking water (N0. 6)	6.574	0.0470
75	Abrdeh drinking water (N0. 4)	6.907	0.2880
76	Spring water 1 km after Zoshk	7.020	0.0000
77	Lower Abrdeh drinking water (N0. 7)	7.111	0.2570
78	River 2.8 km after Zoshk	7.150	0.0000
79	Abrdeh drinking water (N0. 5)	7.530	0.2880
80	River 0.2 km after lower Abrdeh	7.591	0.0960
81	Lower Abrdeh spring water (No. 1)	7.631	0.1320
82	River 2.9 km after Zoshk	7.867	0.2910
83	Zoshk spring water (No. 3)	7.895`	0.0000
84	River 4.5 km after Abrdeh	7.969	0.0000
85	Abrdeh drinking water (N0. 6)	8.131	0.1780
86	Zoshk drinking water (No. 4)	8.155	0.0580
87	Zoshk drinking water (No. 5)	8.310	0.0000
88	Zoshk spring water (No. 4)	8.327	0.0000
89	River 0.4 km after Zoshk	8.356	0.0000
90	Zoshk drinking water (No. 6)	8.603	0.0540
91	Lower Abrdeh drinking water (N0. 8)	8.630	0.4370
92	Zoshk spring water (No. 5)	9.034	0.1830
93	Zoshk spring water (No. 6)	9.056	0.2800
94	River 2.5 km after Abrdeh	9.931	0.0189
95	River of shandiz waterfall (No. 3)	10.124	0.0000
96	Qelqeli spring water	10.402	0.0830
97	Zoshk drinking water (No. 7)	10.721	0.0014
98	Lower Abrdeh drinking water (N0. 9)	10.729	0.0000
99	Zoshk drinking water (No. 8)	10.915	0.0052
100	Lower Abrdeh drinking water (N0. 10)	10.992	0.0220
101	Shandiz drinking water (No. 9)	11.199	0.0000
102	Spring water 0.5 km after Zoshk	11.360	0.1270
103	River 1 km before Zoshk	11.434	0.2070
104	Lower Abrdeh drinking water (N0. 11)	11.595	0.0960
105	River 2 km after Zoshk	11.778	0.4330
106	Zoshk spring water (No. 7)	13.055	0.1330
107	River 1 km after Zoshk	13.058	0.0910
108	Zoshk spring water (No. 8)	13.761	0.0026
109	Zoshk spring water (No. 9)	14.43	0.1830
110	Spring water 0.1 km after Zoshk	14.577	0.0000
111	Spring water 2 km after Zoshk	14.863	0.2070
112	Zoshk drinking water (No. 9)	15.755	0.0000
113	River 0.5km before Zoshk	16.324	0.0000

Table 1: Continued

Sample number	Water sample	Q_{Rn} (Bq L^{-1})	Q_{Ra} (Bq L^{-1})
114	Spring water at Zoshk	16.344	0.0000
115	River of shandiz waterfall (No. 4)	17.363	0.3540
116	Upper Abrdeh drinking water (No. 6)	17.879	0.2070
117	Lower Abrdeh spring water (No. 2)	18.445	0.0470
118	River 1.5 km after Abrdeh	18.578	0.0000
119	Spring water 0.7 km after Zoshk	21.495	0.0100
120	Spring water 1.5 km before Zoshk	31.881	0.6600

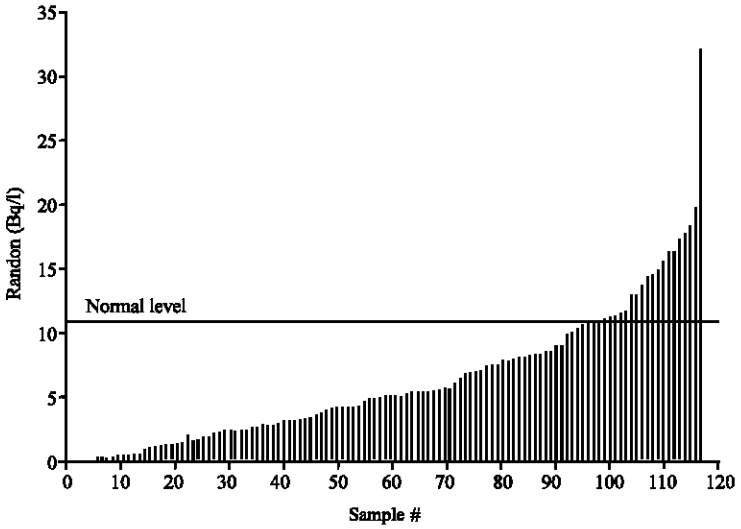

Fig. 2: The histogram of radon gas concentration in 120 water samples of Shandiz, Zoshk and Abrdeh regions

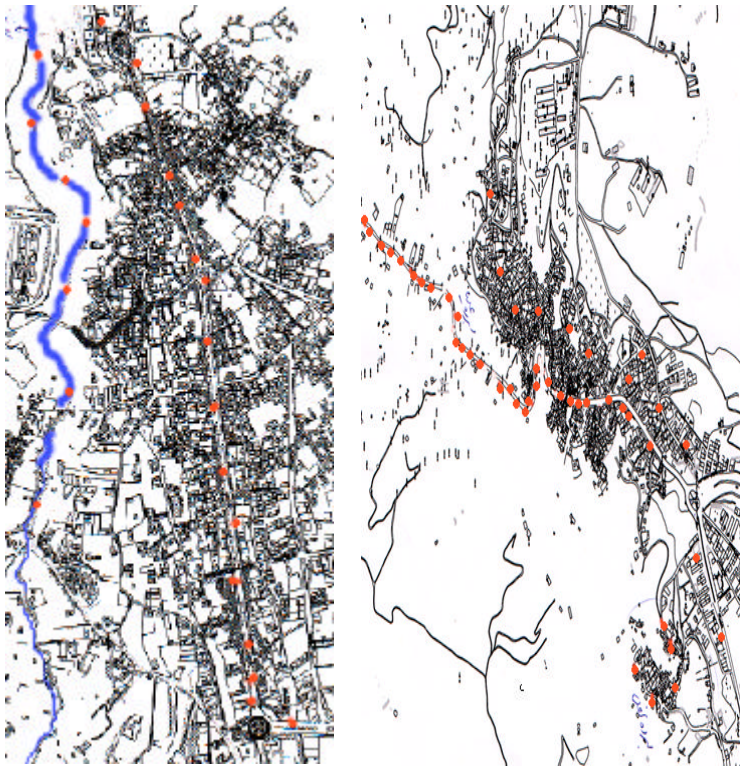

Fig. 3: Locations of sampling in Shandiz, Zoshk and Abrdeh regions

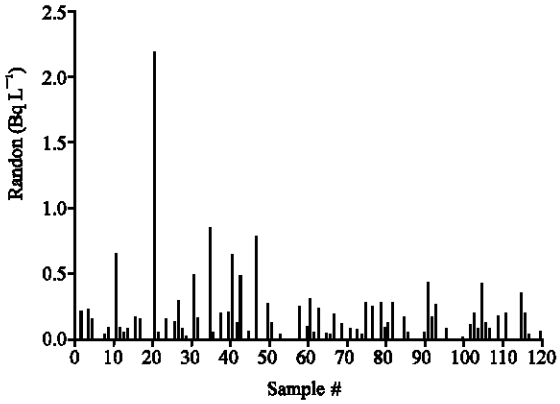

Fig. 4: The histogram of radium concentration in different water samples

histogram of radium concentration in different water samples as well as the data are listed in fourth column of Table 1. It is notice that all the radium concentration of samples was <1 (Bq L^{-1}), except sample number 21, drinking water of Shandiz region is about 2.2 (Bq L^{-1}).

CONCLUSION

Measurement results of radon concentration in the water samples shows that only 15.83% sample concentrations are higher than the normal 11 (Bq L^{-1}). This limit by United States Environmental Protection Agency (EPA) as normal is defined and 148 (Bq L^{-1}) is limit the amount of action or reaction that radon should be reduced (Mowlavi *et al*., 2009). Any sample has not this amount of concentration but most amount of radon concentration with 32 (Bq L^{-1}) is related to spring in Zoshk that is almost one-fifth of the reaction too. Radium concentration of all samples, except sample number 21, drinking water of Shandiz is small and <1 (Bq L^{-1}). Therefore, radon and radium concentration in the water of the regions is not high and this is appropriate.

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