International Archive of Applied Sciences and Technology, Vol 2 [1] June 2011: 32 -36

ISSN 0976- 4828
http:// www.soeagra.com

RESEARCH ARTICLE

Determination of Radon and Radium in springs, Wells, Rivers and Drinking Water Samples of Ramsar in Iran

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ABSTRACT
The largest fraction of the natural radiation exposure we receive comes from a radioactive gas, radon and its decay products (nearly 50%). The radon gas can enter to the body via respiring, drinking and eating and caused damage to respiratory and digestion systems. Also radium-226 is widely distributed in the environment. When a person ingests radium, this element deposits in bones and cause to bone cancer. In this study radon and radium concentrations of the 77 water samples of Ramsar city in Iran have been measured by PRASSI system. 7 samples have radon concentration higher than 11 Bq/l as normal level. Also, ^{226}Ra alone, in 5 samples have concentration higher than 0.555 Bq/l as normal level for gross alpha. For improvement of the social health level, it is essential that to reduce the radon and radium concentrations in the drinking water before using by people.
KEY WORDS: *Radon, Radium, drinking water, PRASSI system, Ramsar city.*

INTRODUCTION

Radon, a progeny of ^{238}U formed from the radioactive decay of radium, is a colourless, odourless, electrically uncharged noble but hazardous gas which is radioactive and emits alpha radiation has been found to be a ubiquitous air pollutant to which all persons are exposed [1]. Radon isotope 222 has a half-life of 3.8 days, long enough to diffuse into the atmosphere through the solid rock or soil in which it is formed [2]. Radon alpha particles, can initiate a series of molecular and cellular events that culminates in the development of lung and other cancers [3]. About radon in drinking water, the highest organ dose from ingested radon is to the stomach, which receives >90% of the total effective dose [4], that can be a factor in the induction and progression of stomach cancer.
^{226}Ra in the environment is widely distributed, being present in various concentrations in waters, soils, sediments and rocks [5]. When radium is ingested, the majority of material is rapidly excreted. However, since the chemical behavior of radium is similar to that of calcium, radium absorbed to blood from the GI-tract or lungs follows the behavior of calcium and is primarily deposited in bone [6].
So, presence These radioactive contaminants in water is dangerous and many studies specially about radon have been done in this area [7, 8, 9, 10, 11, 12, 13]. These reasons and because Some areas of Ramsar, a city in northern Iran, have among the highest known background radiation levels in the world [14] caused we measured radon and radium concentration in water sources of Ramsar region.
In the present research results of radon measurement in 77 water samples, sources and tap water are actually used for drinking and other household uses in Ramsar. Radon of water samples that have been measured using PRASSI system includes a ZnS (Ag) scintillation detector.

MATERIALS AND METHODS

Water sampling

The water samples were collected in various points distributed in and around the city of Ramsar; however, Figure 1 shows the sampling sites. Water sampling has been done from each water supply, including wells and rivers and springs, as well as from household water. The samples were collected from the active wells selected for sampling, rivers and surface water reservoirs, springs as well as from domestic water taps of high consumption rates, 150 ml water samples were collected from each source or region. The collected samples were then transferred to the laboratory of Payam Nour University for analysis.

Radon measurement

The PRASSI (Portable Radon Gas Surveyor SILENA) Model 5S has been used for radon concentration measurement in the water samples, which is particularly well suited for this type of measurement that

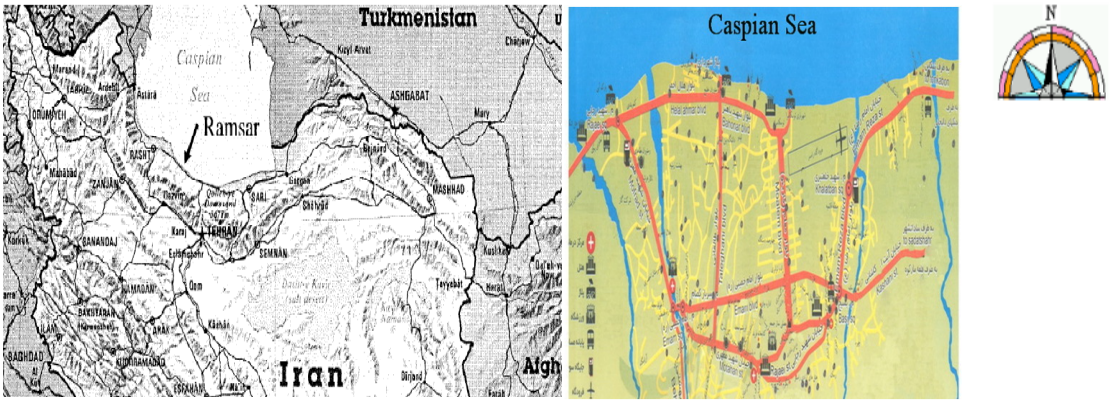

Fig. 1: (a) Ramsar location in Iran, (b) The map of Ramsar city and ● shows the sampling sites.

must be performed in the closed loop circuit. Figure 2 shows the system set up of measurement including bubbler and drier column. PRASSI pumping circuit operates with a constant flow rate at 3 liters per minute in order to degas the water sample properly. The sensitivity of this system in a continuous mode is 4 Bq/m^3 during the integration time of 1 h.

Numbers shown by the device is based on Bq/m^3. Using relationship Eq. 1, radon gas density is calculated based on (Bq/L):

$$Q_{Rn}\left(\frac{Bq}{L}\right) = Q_{PRASSI} \times \frac{V_{tot}(m^3)}{V(lit)} \times \left[\left[exp\left(\frac{Ln2}{3.824\times24}\Delta t\right)\right]\right] \qquad (1)$$

Where:

Q_{PRASSI} = The value recorded by the device

Vtot = The total volume of air connections

V = The volume sample and within the brackets is a correction factor in the delay measurement

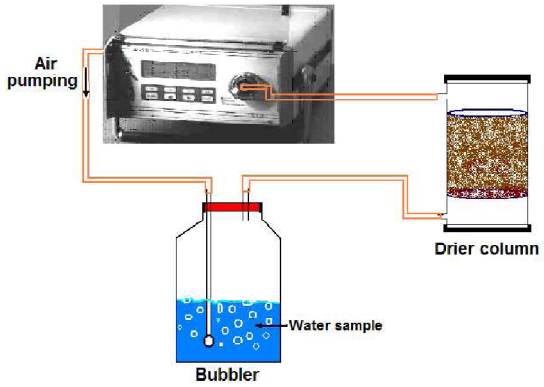

Fig. 2: The PRASSI system set up for radon measuring in the water sample.

Radium measurement

For measuring radium in water samples, we have kept 150 ml of the water samples in the bottles for 35 days to let radon reach the equilibrium with radium. So, by measuring radon of the water sample as described before, we obtain radium concentration.

RESULTS AND DISCUSSION

In the present research, a total number of 77 water samples including 7 spring water, 13 surface water of rivers, 11 wells and 46 tap water samples were collected and analyzed for radon and radium concentrations. The third column of Table 1, presents the concentration of radon in water samples. Also, the radon gas density results are shown in histogram of Fig. 3. According to the data, the minimum and maximum radon concentrations in samples are 0.000 and 40.946 Bq/L, respectively. The mean radon concentration for springs sampled was 25.323 Bq/L. The mean ^{222}Rn concentration

in surface water samples was 1.450 Bq/L. The mean ^{222}Rn concentration in well water samples was 5.322 Bq/L. The mean ^{222}Rn concentration in tap water samples was 3.005 Bq/L.

There is no specific national regulation for radioactivity concentrations in drinking water in Iran. When this is compared to the maximum contaminant level of 11Bq/L for radon in public drinking water, suggested by the EPA [15], sample No. 67 related to drinking water of Azadi hotel is 15.108 Bq/L, this site very adjacent many springs. Also, about wells, N0.10 that is used by people for drinking is 20.208 Bq/L, that indicate this 2 sample are higher than normal level.

As the data indicate, the ^{222}Rn concentrations in most of spring water sampled are high and in rivers are low. Groundwater may contain high amounts of natural radioactivity mainly associated with uranium and thorium-rich soils and rocks, while surface water usually contains lower amounts of ^{222}Rn than groundwater [16].

Figure 4 shows the histogram of radium concentration in different water samples as well as the data are listed in fourth column of Table 1. The minimum and maximum radium concentrations in samples are 0.000 and 0.934 Bq/L, respectively and mean ^{226}Ra concentration of all samples is 0.207 Bq/L. Specific drinking water standards have not been established for radium 226 or other alpha emitters, but in 5 samples of total samples, ^{226}Ra concentration even higher than MCL for gross alpha is 15 pCi/L(0.555Bq/L) that determined by U.S Environmental Protection Agency [16].

Table 1: Radon and radium concentration data of different water samples (T W=Tap Water)

Sample number	Source or place of water sampling	Q_{Rn}(Bq/L)	Q_{Ra}(Bq/L)
1	Hot spring water near Azadi hotel (No.1)	40.946	**0.934**
2	Pahlavi hot spring	39.790	**0.283**
3	Springhead Ab siahe ramak spring	36.591	**0.734**
4	Ab siahe ramak, 6 km after sample 3	4.839	**0.546**
5	Spring near Dalkhani forest	2.416	**0.000**
6	Hot spring water near Azadi hotel (No.2)	31.421	**0.523**
7	Spring near hotel(cold water)	21.260	**0.508**
8	Nesarood river	3.691	**0.234**
9	Sorkhanrood river	1.863	**0.036**
10	Safarood river	3.370	**0.000**
11	Torkrood river	1.027	**0.103**
12	Torkrood, 4Km after bridge	0.000	**0.391**
13	River near Narenjbon region	2.051	**0.428**
14	River of Chaparsar region	0.000	**0.415**
15	River near Kakhe mooze	4.117	**0.228**
16	River of Bagh region	1.658	**0.379**
17	Safarood river, 2Km after bridge	0.000	**0.149**
18	Chalakrood river	0.215	**0.009**
19	Shirood river	0.853	**0.000**
20	Shirood river, suburb of Ramsar	0.000	**0.007**
21	Well water near Lidoo camp	0.845	**0.000**
22	Well water of Behesht zeynabiye (No.1)	2.609	**0.208**
23	Well water of Behesht zeynabiye (No.2)	2.549	**0.482**
24	Well water of Caspian camp	5.902	**0.046**
25	Well water of Behesht zeynabiye (No.3)	2.706	**0.352**
26	Well water of Behesht zeynabiye (No.4)	5.232	**0.047**
27	Well water of Behesht zeynabiye (No.5)	4.867	**0.000**
28	Well water of Behesht zeynabiye (No.6)	3.051	**0.207**
29	Well water of Behesht zeynabiye (No.7)	4.595	**0.379**
30	Well water of Behesht zeynabiye (No.8)	20.208	**0.079**
31	Well water of Behesht zeynabiye (No.9)	5.973	**0.083**
32	Near of Farid library (T W)	3.017	**0.000**
33	Tea office (T W)	1.176	**0.000**
34	Emam sajad hospital (T W)	1.712	**0.223**
35	Negin restaurant (T W)	2.549	**0.205**
36	Esmat academy (T W)	7.728	**0.219**

37	400 dastgah region, Golestan alley (T W)	3.500	**0.000**
38	Confectionery shop, near municipality (T W)	2.894	**0.184**
39	Baradaran restaurant (T W)	3.317	**0.055**
40	Cheshmandaz steeple (T W)	3.565	**0.010**
41	Honarmandan hotel (T W)	0.000	**0.226**
42	Toosasan region (T W)	5.352	**0.086**
43	Narenjbon region (T W)	2.301	**0.060**
44	Moallem boulevard(No.1) (T W)	1.844	**0.170**
45	Tooskasara region (T W)	7.880	**0.000**
46	Beginning of Ramak region (T W)	0.000	**0.251**
47	Beginning of Ghaemiye region (T W)	1.328	**0.310**
48	Shahid alamouti alley (T W)	2.578	**0.204**
49	Ghaemiye region, Goharrostami alley (T W)	1.712	**0.000**
50	Taleghani boulevard(No.1) (T W)	0.430	**0.000**
51	Taleghani boulevard (No.2) (T W)	1.790	**0.747**
52	Airport street (T W)	3.142	**0.170**
53	Airport street, gasoline station (T W)	2.653	**0.306**
54	Airport street, Beyhaghi school (T W)	0.000	**0.421**
55	Airport street, gas company (T W)	2.923	**0.000**
56	End of 400 dastgah (T W)	3.348	**0.139**
57	Sakhtsar hotel (T W)	2.630	**0.096**
58	End of Moallem boulevard (T W)	6.713	**0.105**
59	Lamtar region (T W)	1.694	**0.000**
60	Shirloo camp (T W)	0.994	**0.198**
61	Rajaei square (T W)	1.704	**0.167**
62	Mofrad region(No.1) (T W)	1.449	**0.000**
63	Helal ahmar boulevard (T W)	2.605	**0.190**
64	square Sarbaz gomnam(T W)	1.945	**0.170**
65	Mofrad region(No.2) (T W)	8.019	**0.149**
66	Toosasan region (T W)	6.101	**0.090**
67	Azadi hotel (T W)	15.108	**0.363**
68	Mofrad region (No.3) (T W)	2.741	**0.260**
69	Mofrad region (No.4) (T W)	2.417	**0.009**
70	Mofrad region (No.5) (T W)	1.289	**0.000**
71	Moallem boulevard (No.2) (T W)	2.465	**0.000**
72	Farhangian region (No.1) (T W)	3.836	**0.856**
73	After Melli garden (T W)	1.970	**0.797**
74	Farhangian region(No.2) (T W)	1.917	**0.330**
75	Caspian camp(T W)	1.744	**0.098**
76	2Km after Caspian camp (T W)	0.916	**0.207**
77	Near Shahrdari camp (T W)	3.241	**0.090**

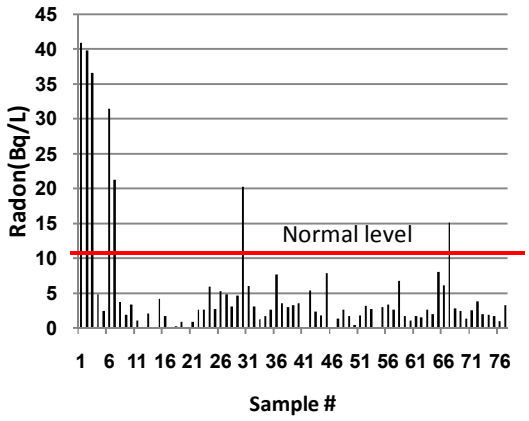

Fig. 3: The histogram of radon gas concentration

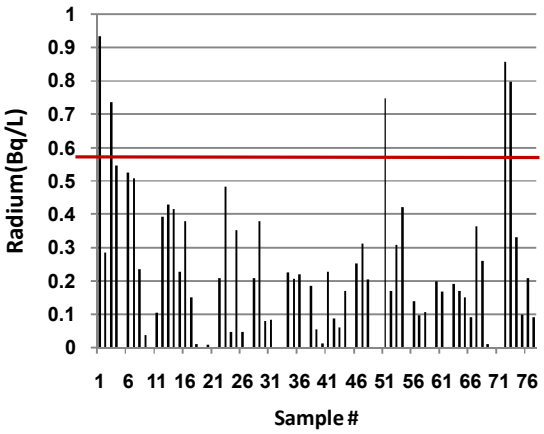

Fig.4: The histogram of radium concentration

CONCLUSION

Measuring radon results show that about 9.09% of samples are greater than the EPA advised level, 11 Bq/L. The U.S Environmental Protection Agency requires that action be taken to reduce radon levels above an Alternative Maximum Contaminant Level (AMCL) of 150 Bq/L. Any sample has not this amount of concentration but most amount of radon concentration with 40.946 Bq/L is related to Hot spring water near Azadi hotel one fourth of the reaction too. The results of radium concentration show that about 6.5% of total samples are greater than 0.555Bq/L. For improvement of the social health level, it would be better to reduce the radon in the drinking water before using by people.

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