Environmental Research Journal 5 (4): 170-172, 2011
ISSN: 1994-5396

Evaluation of the Radiation Dose from Radon Ingestion and Inhalation in Water Supplies of Sadatshahr and Javaherdeh in Iran

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Abstract: Radon is an odorless, radioactive gas formed from the breakdown of uranium and thorium. Chronic exposure to elevated radon (^{222}Rn) decay product concentrations is recognized as health risk. The water used for drinking and other household uses can increase the indoor radon level because dissolved radon escapes from the water and gets into household air in the course of dishwashing showering and other water-using activities. Also, ingesting water with elevated levels of radon can present a risk for developing internal organ cancers. In this study radon concentrations of the 43 water samples have been measured by PRASSI system. The 4 samples have radon concentration higher than 11 Bq L^{-1} as normal level. Similarly, the annual effective dose in stomach and lung per person has been evaluated in this research. According to the advised of WHO and the EU council none of the samples induced the total annual effective dose >0.1 mSv $year^{-1}$.

Key words: Radon, effective dose, drinking water, PRASSI system, Sadatshahr and Javaherdeh regions, Iran

INTRODUCTION

Radon is a colorless, odorless, tasteless, naturally occurring radioactive gas produced from the decay of the element radium which occurs naturally in rocks and soil worldwide. The radon readily escapes from the soil or rock where it is generated and enters surrounding water or air. This colorless, odorless and chemically inactive gas is 7.6 times heavier than air; it readily dissolves in water particularly if water is slightly acidic and not rich in minerals and in alcohol and fatty acids (Zdrojewicz and Strzelczyk, 2006). High radon concentration in indoor air coupled with the prolonged exposure periods related to indoor habitation make indoor radon a potential hazard (Mohamed *et al.*, 2008). Radon and its daughters emit alpha, beta and gamma radiations as they decay. Internally deposited alpha radiations are the most damaging as their relative biological effectiveness is about 20 times that of beta radiations (Virk and Sharma, 2000). These inhaled solid radon decay products deliver the radiologically significant dose to the lung tissues (Field, 2001) that can hurt lung tissue lead to lung cancer.

Radon in water can follow two different paths to enter the human body. Firstly, radon can escape from household water and become a source for indoor radon which can then enter the human body through the respiratory tract to deliver the radiation dose. Secondly, radon in drinking water or mineral drinks can enter the human body directly through the Gastro-Intestinal (GI) tract and deliver a whole body radiation dose, the largest dose being received by the stomach (Tayyeb *et al.*, 1998).

MATERIALS AND METHODS

The water samples were collected in various points distributed in and around the Sadatshahr and Javaherdeh regions. 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 Payame Noor University for analysis. Radon of water samples that have been measured using PRASSI system includes a ZnS (Ag) scintillation detector.

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 L min^{-1} in order to degassing the water sample properly. Figure 1 shows the system set up of measurement including bubbler and drier column.

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

$$Q_m\,(Bq/L) = Q_{PRASSI} \times V_{tot}\,(m^3)/V\,(lit) \times [\exp\,(Ln2/3.824 \times 24)\,\Delta t] \quad (1)$$

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

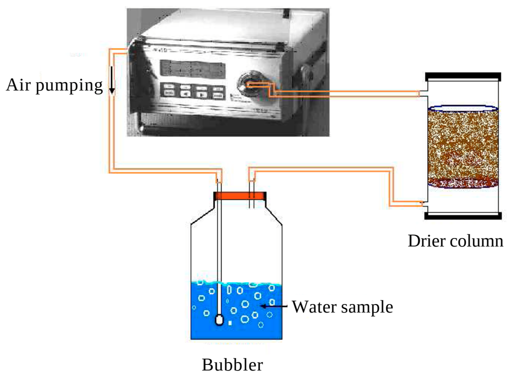

Fig. 1: The PRASSI system set up for radon measuring in the water sample

RESULTS AND DISCUSSION

In this study radon concentration in the 43 water sources of Sadatshahr and Javaherdeh regions has been measured. US EPA proposed regulations on radon concentration in drinking water: a Maximum Contaminant Level (MCL: 11 Bq L^{-1}) and an alternative maximum contaminant level (AMCL: 148 Bq L^{-1}) (Ishikawa *et al.*, 2005). The third column of Table 1 shows the concentration of radon in water samples. The results in this study show 4 samples (No. 4, 8, 13, 30) have radon concentration higher than normal level. According to the data, the minimum and maximum radon concentrations in samples are 0.000 and 21.291 Bq L^{-1}, respectively. The mean radon concentration for samples is 4.183 Bq L^{-1}. It is believed that waterborne radon may cause higher risk than all other contaminants combined appearing in water (Savidou *et al.*, 2001). This element enters human body through ingestion and through inhalation as radon is released from water to indoor air. Therefore, radon in water is a source of radiation dose to stomach and lungs. The annual effective doses for ingestion and inhalation were calculated according to parameters introduced by UNSCEAR report. For ingestion, the following parameters were used:

Table 1: Average radon concentration data and annual effective dose of different water sources of Sadatshahr and Javaherdeh

			Annual effective dose of adults (µSv $year^{-1}$)	
Water samples	Source or place of sampling	Average radon level (Bq L^{-1})	Stomach	Lung
1	Spring near Nesarood river	2.594	0.467	6.4850
2	Bamsi spring	1.489	0.268	3.7230
3	Safarood spring	2.610	0.470	6.5250
4	Abmadan spring	19.573	3.523	48.9330
5	Javaherdeh spring	1.810	0.326	4.5250
6	Latmahale spring	0.000	0.000	0.0000
7	Sadatshahr hot spring (No. 1)	5.490	0.988	13.7250
8	Sadatshahr hot spring (No. 2)	14.751	2.655	36.8780
9	Sangbone hot spring	4.991	0.898	12.4780
10	Katolom hot spring	5.266	0.948	13.1650
11	Markooh hot spring	4.751	0.855	11.8780
12	Bamsi river	1.333	0.240	3.3330
13	Abmadan river (Javaherdeh)	21.291	3.832	53.2280
14	Javaherdeh river	7.125	1.283	17.8130
15	Dashtejalami river	2.958	0.532	7.3950
16	Katalom river	1.973	0.355	4.9330
17	Markooh river (No. 1)	1.015	0.183	2.5380
18	Markooh (No. 2) environs of Ramsar city	1.230	0.221	3.0750
19	Chalakrood river	2.457	0.442	6.1430
20	Nesarood river	1.298	0.234	3.2450
21	Javaherdeh drinking water (No. 1)	0.000	0.000	0.0000
22	Javaherdeh drinking water (No. 2)	3.179	0.572	7.9480
23	Javaherdeh drinking water (No. 3)	3.725	0.671	9.3130
24	Javaherdeh drinking water (No. 4)	1.263	0.227	3.1580
25	Javaherdeh drinking water (No. 5)	6.153	1.108	15.3830
26	Javaherdeh drinking water (No. 6)	3.248	0.585	8.1200
27	Javaherdeh drinking water (No. 7)	5.285	0.951	13.2130
28	Javaherdeh drinking water (No. 8)	3.494	0.629	8.7350

Table 1: Continue

Water samples	Source or place of sampling	Average radon level (Bq L^{-1})	Annual effective dose of adults (μSv $year^{-1}$)	
			Stomach	Lung
29	Javaherdeh drinking water (No. 9)	2.831	0.510	7.0780
30	Javaherdeh drinking water (No. 10)	11.403	2.053	28.508
31	Javaherdeh drinking water (No. 11)	2.381	0.429	5.9530
32	Javaherdeh drinking water (No. 12)	2.789	0.502	6.9730
33	Payame noor university (Sadatshahr)	0.000	0.000	0.0000
34	Kashani street (Sadatshahr)	0.000	0.000	0.0000
35	Bibisekine region (Sadatshahr)	3.383	0.609	8.4580
36	End of Kashani street (Sadatshahr)	1.471	0.265	3.6780
37	15 Hkordad street (No. 1) (Sadatshahr)	4.665	0.840	11.663
38	15 Hkordad street (No. 2) (Sadatshahr)	2.292	0.413	5.7300
39	Shahid dastgheyb street (Sadatshahr)	9.189	1.654	22.973
40	Shahid dastgheyb street, yas alley (Sadatshahr)	1.413	0.254	3.5330
41	End of Shahid dastgheyb street (Sadatshahr)	2.576	0.464	6.4400
42	15 Khordad street, golsar alley (Sadatshahr)	1.916	0.345	4.7900
43	End of 15 khordad street (Sadatshahr)	3.225	0.581	8.0630

- The effective dose coefficient from ingestion equals 3.5 nSv Bq L^{-1}
- Annual intakes by infants, children and adults are found to be about 100, 75 and 50 L, respectively
- The annual effective doses due to ingestion corresponding to 1 Bq L^{-1} would equal 0.35 μSv $year^{-1}$ for infants, 0.26 μSv $year^{-1}$ for children and 0.18 μSv $year^{-1}$ for adults

For inhalation, the following parameters were used:

- Ratio of radon in air to radon in tap water supply is in the range of 10^{-4}
- Average indoor occupancy time per person is about 7000 h $year^{-1}$
- Equilibrium factor between radon and its progeny is equal to 0.4
- Dose conversion factor for radon exposure is 9 nSv/(Bq.h m^3)

The annual effective dose due to inhalation corresponding to the concentration of 1 Bq L^{-1} in tap water is 2.5 μSv $year^{-1}$. Therefore, waterborne radon concentration of 1 Bq L^{-1} causes total effective dose of about 2.68 μSv $year^{-1}$ for adults. The mean annual effective dose per person for adults caused by different water samples are shown in Table 1. According to the advised of WHO and the EU council none of the samples induced the total annual effective dose >0.1 mSv $year^{-1}$.

CONCLUSION

In this study the results show 4 samples have radon concentration >11 kBq L^{-1} as normal level. Therefore, radon and concentration in the water of the regions is not high and this is appropriate. None of the samples induced the total annual effective dose >0.1 mSv $year^{-1}$ that advised by WHO and the EU council.

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