International Journal of the Physical Sciences Vol. 6(35), pp. 7969 - 7977, 23 December, 2011
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS11.1308
ISSN 1992 - 1950 ©2011 Academic Journals

Full Length Research Paper

Radioactivity and dose assessment of heavy radioactive pollution, radon and radium from water sources of 3 northern regions in Iran

A. Binesh, H. Arabshahi and Z. Pourhabib*

Department of Physics, Payame Noor University of Fariman, Fariman, Iran.

Accepted 15 November, 2011

Knowledge of natural radioactivity in man and his environment is important since naturally occurring radionuclides are the major source of radiation exposure to man. One of the main sources of public exposure from natural radioactivity is radium and radon and its short lived decay products. This radio nuclides are produced from the decay of uranium. Drinking water containing ^{226}Ra, fifth member of the ^{238}U series, is dangerous for people health, because this element deposits in bones and caused to bone cancer. Also, radon the decay product of ^{226}Ra can enter to the body via respiring, drinking and eating. Radon and its decay products emit alpha particles that lead to increase the absorbed dose in respiratory and digestion systems, which may cause cancers. The aim of this study is focused on determining the concentration of mentioned radionuclides in the water resources of the Ramsar, Sadatshar and Javaherdeh regions, in north Iran .In this study radon and radium concentrations of the 120 water samples of this regions have been measured by PRASSI system. 11 samples have radon concentration higher than 11 Bq/L as normal level. Also, ^{226}Ra in 53 samples have concentration higher than 0.185 Bq/L as normal level for radium-226. Similarly, the annual effective dose in stomach and lung per person has been evaluated in this research. According to the advice of WHO and EU Council, radon induced the total annual effective dose greater than 0.1 mSv/y in 2 sample and in 12 samples the annual effective dose is induced by radium greater than 0.1 mSv/y.

Key words: Radon, radium, effective dose, drinking water, PRASSI system, Ramsar, Sadatshahr and Javaherdeh regions.

INTRODUCTION

Radiation plays an important role in our life. All living organisms are continually exposed to ionizing radiation, which has always existed naturally. The sources of exposure are cosmic rays, terrestrial radionuclides in the Earth's crust, their presence in building materials and in the air, water and foods, and those present in the human body itself. In addition, exposure may arise from man-made radionuclides released into the terrestrial and marine environment (Nikolov et al., 2011). The largest contributor of ionizing radiation to the population is natural radioactivity. The presence of natural radiation is due to the distribution of radionuclides on earth and causes exposure to all living organisms. There are three primordial radioactive decay chains in the earth's crust: the thorium chain starting with ^{232}Th, the uranium chain starting with 238U, and the actinium chain starting with ^{235}U (McKittrick et al., 2003). The radium isotope ^{226}Ra and its decay product ^{222}Rn are investigated here, produced from decay chain of ^{238}U. ^{222}Rn emits alpha particles as it spontaneously decays to a series of short-lived radioactive decay products, which are followed by a longer-lived series headed by ^{210}Pb (half-life, 22.3 y), as shown in Figure 1 (Uchida and Tagami, 2009).

The discovery of radium [^{226}Ra] by a Polish lady scientist M. Sklodowska-Curie and her husband, French professor P. Curie followed. Only two years later, in 1900, a daughter product of radium, radon [^{222}Rn] was discovered by a German chemist F.E. Dorn who called it

*Corresponding author. E-mail: fm_sarlak@yahoo.com.

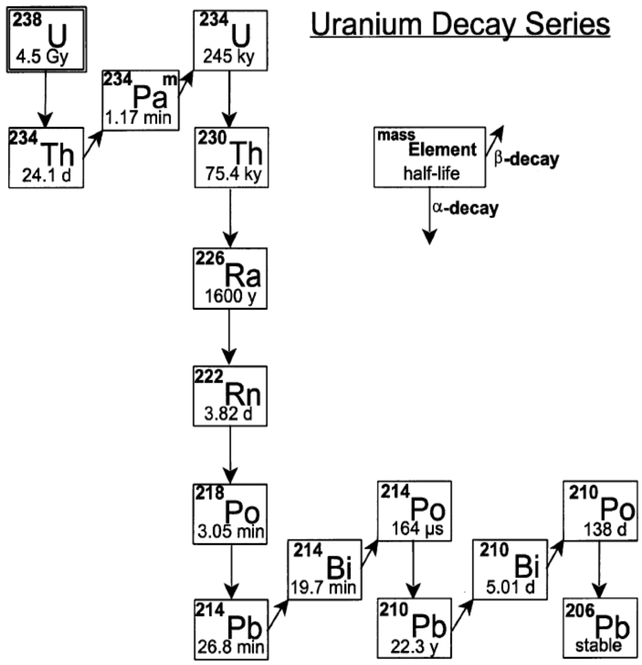

Figure 1. Decay scheme for natural occurring ^{238}U chain.

"radium emanation" (Zubair et al., 2011). In the very early years following the discovery of radium, most studies about uses of radium in radium therapy took place in Europe. Radium was an early radiation source for cancer treatment, but this use has largely been replaced by other radioactive materials or methods. Radium-226 has also been used in medical equipment, gauges, and calibrators, and in lightening rods. Alpha emitters such as radium and plutonium can be used as components of a neutron generator. Because of the health hazards from radium many uses of this radionuclide such as luminous paint, hair tonic, toothpaste, ointments, and elixirs was discontinued (Kiliari et al., 2010). Of the four isotopes, ^{226}Ra causes the most concern due to a combination of its long half-life (1600 years) and radiological effects. It is among the most toxic long-lived □-emitters present in environmental samples, as well as one of the most widespread (López et al., 2002). High solubility of this element compared with uranium causing penetration through fractures into bedrock and can leak out into groundwater. Radium-226 is a bone seeker element and can cause bone marrow cancer (Kearfott, 1989).

The greatest health risk from radium is from exposure to its radioactive decay product, radon. Radon is a major cause, second only to cigarette smoking, of lung cancer deaths. Radon has also been classified as a Group 1 carcinogen by the World Health Organization (Kendal and Smith, 2002). Despite the warnings of agencies, thousands of people annually expose themselves to radon for therapeutic purposes in facilities ranging from rustic old mines to upscale spas and clinics. Reports issued more than a decade ago by the United Nations Scientific Committee on the Effect of Atomic Radiation suggested adaptive responses to radiation by cells and organisms. Waters with radon appear to have analgesic, anti-inflammatory properties and provide neuro-vegetative balance. About this matter we must notice that the radiation doses to cells and tissues from environmental radon activity-concentrations must also be assessed by the exposure, exposure rate and time length of exposure usually by models. Low level irradiations might be beneficial through stimulating cellular and tissue reactions (Khan, 2002).

The worldwide average annual effective dose from natural radiation sources is estimated to be 2.4 mSv, of which 1.3 mSv is from exposure to radon and its decay products. Table 1 shows typical average annual effective doses in adults from the principal natural sources. Some researchers reported that the average effective dose from inhalation of radon and its decay products is even higher (Kusyk and Ciesla, 2002).

Ramsar town and some of the villages around of it in the Caspian Sea strip in Iran have high dose natural ionizing radiation. Radioactivity of the high background radiation areas (HBRAs) of Ramsar is due to ^{226}Ra and its decay products, which have been brought up to earth surface by the water of warm springs. When the groundwater reaches the surface at hot spring locations, travertine, a calcium carbonate mineral, precipitates out of solution with dissolved radium substituting for calcium in the mineral. A secondary cause of high local radiation levels is travertine deposits with a high thorium concentration. The radioactivity in local soils and the food grown in them is also high because soils are derived from the weathering of local bedrock. Due to extraordinary levels of natural radiation in these areas that in some cases is 55-200 times higher than normal background areas. Over 2000 people are exposed to radiation doses ranging from 1 to 26 rem per year. There are more than 9 hot springs with different concentrations of radium in this city. The visitors as well as residents usually use these springs as spas. Some experts suggested that dwellings having such high levels of natural radiation need urgent remedial actions. However, the inhabitants still live in their unaltered paternal dwellings. Findings clearly show that high levels of natural radiation may induce radio adaptive response (Li et al., 2006).

Review of physical properties

Uranium (^{238}U) an ultimate progenitor of ^{222}Rn is a heavy, silvery-white, ductile and slightly paramagnetic metal, which is pyrophoric when finely divided. It is easily oxidizes in air, and becomes coated with a layer of oxide. Thus, uranium mainly occurs in oxidized form in nature. The Uranium concentration in groundwater depends on lithology, geomorphology and other geological conditions of the region. In groundwater uranium is present both in

Table 1. Annual effective doses to adults from natural sources.

Source of exposure	Annual effective dose (mSv)
Cosmic rays	0.39
Terrestrial gamma rays	0.46
Radionuclides in the body (except radon)	0.23
Radon and its decay products	1.3
Total (rounded)	2.4

dissolved and particulate form due to minerals such as Uranitie, Pitchblende and Cornalite or as secondary mineral in the form of complex oxides of silicates phosphates, vanadates, lignite and monazite sands (Binesh and Arabshahi, 2011).

Uranium is present in the earth's crust, principally in the hexavalent form. It is used primarily as a fuel in nuclear energy plants and is introduced into water supplies as a result of leaching from natural sources, from mill tailings, from emissions of the nuclear industry, from the combustion of coal and other fuels, and from phosphate fertilizers. Although available information on concentrations in food and drinking-water is limited, it is likely that food is the principal source of intake of uranium in most areas.

The decay products of uranium pass over 10 elements, all with very different chemical properties. The ^{226}Ra is an alpha emitter, whose half-life is relatively long (1602 years), and it is the fifth member of the ^{238}U series.

The chemical properties of radium are similar to other alkaline earth elements, particularly barium and calcium. Radium exists in only the +2 oxidation state in solution and does not easily complex in water. Freshly prepared radium metal has a brilliant white metallic luster but rapidly becomes black on exposure to air supposedly because of the formation of a nitride Radium-226 is of special interest because it is an important radionuclide for the assessment of radioactive waste disposal. Radium is one million times more radioactive than the same mass of uranium. Its decay occurs in at least seven stages, the following main products were called radium emanation recognized as radon.

The radon readily escapes from the soil or rock where it is generated and enters surrounding water or air. Radon, a noble gas, is essentially chemically inert. Unlike the other noble gases, radon has no known stable isotope. Rather it has 36 radioactive isotopes and isomers, which range in mass number from 198 to 228. ^{222}Rn emits alpha particles as it spontaneously decays to a series of short-lived radioactive decay products. 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. 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. Alpha radiation with 5.49 MeV energy emitted by radon operates on short distance with penetration ability of about 41.1 μm in water and about 20 μm in tissue. High radon concentration in indoor air coupled with the prolonged exposure periods related to indoor habitation make indoor radon a potential hazard.

Routes of exposure and health effect

Radium can reach humans through several transfer paths in the environment. Ra is taken into the human body by ingestion of food and water or inhalation. Radium is a naturally occurring solid radioactive element in the earth's surface and it is absorbed from soil by plants and passed up the food chain to humans.

The uptake of ^{226}Ra from soil by plant roots is influenced by soil type, as well as by factors such as soil pH, content of other alkaline-earth elements in the soil, clay content, exchangeable calcium and potassium, plant species, and chemical form of ^{226}Ra in soil.

Surface water is usually low in radium but groundwater can contain high levels of radium depending on local geology. Groundwater moves very slowly, allowing substances in the rocks and soil around it to dissolve into the water over time. Then Water consumed by livestock and used for irrigating purposes can be a source of this radionuclide.

Radium-226 is a known bone-seeker due to its metabolic similarity to calcium; the greatest body burden of an animal ingesting ^{226}Ra would be in the skeleton. Thus, the human populations potentially exposed to the highest concentrations in animal tissue would be those who ingest significant quantities of bone meal.

Great amount of ^{226}Ra, above 70%, is excreted (by feces and urine) from the body on the first day after the ingestion while the rest of ^{226}Ra follows the metabolic path of calcium. Radium deposits in bone within those areas where new bone mineral is being formed and also on all bone surfaces.

Radium remains in those areas of new bone formation, but the radium deposits on bone surfaces eventually move into the depths of compact bone as new bone matrix is deposited on top of them.

Long-lived radium-226 remains in the skeleton indefinitely. The United States Environmental Protection Agency (USEPA) stated that radium is a human carcinogen and that exposure to higher levels of radium over a long period of time may result in harmful effects including anemia, cataracts, fractured teeth, cancer (especially bone cancer), and death. As ^{226}Ra decays, its gaseous daughter product ^{222}Rn diffuses into the pore water of rock formation, once in contact with ground water; it may migrate over some distances, which are limited by its relatively short half-life.

The story of radon as a cause of lung cancer is a long one with historical accounts documenting a fatal lung disease, centuries ago in miners working in the Erz Mountains of Eastern Europe. Over a century ago, the miners were found to have thoracic malignancy, later identified as primary lung cancer. In the early 20th century, the levels of radon in the mines in this region were measured and found to be quite high; the hypothesis was soon advanced that radon was the cause of the unusually high rates of lung cancer. Although not uniformly accepted initially, as the findings of epidemiologic studies of underground miners were reported from the 1950s on, there was substantial evidence showing that radon was a cause of occupational lung cancer. Radon can enter a home via at least three common pathways:

1. Migration (up from the soil) into the basement through cracks and/or other openings in the foundation.
2. Release of dissolved radon gas from the household on-site water supply.
3. Some of the radon dissolved in tap water will escape to indoor air through common household activities such as showering, bathing, clothes washing, dish washing, and cooking. The proportion lost in this way will depend on circumstances. However, UNSCEAR has suggested that, as a general rule, radon in tap water gives rise to radon in room air at a concentration 10^{-4} lower than that in the water.
4. Release from building materials such as a granite block foundation, some fireplace materials, and floor or wall tiles.

When radon decays to form its progeny (^{218}Po and ^{214}Po), they can collect electrostatically on tiny dust particles, water vapours, oxygen, trace gases in indoor air and other solid surfaces. These dust particles (aerosols) can easily be inhaled and attach to the bronchial epithelium, producing a high local radiation dose. Radon alpha particles, can initiate a series of molecular and cellular events that culminates in the development of lung and other cancers.

In the ingestion of radon in drinking water, the highest organ dose from ingested radon is the stomach, which receives >90% of the total effective dose, that can be a factor in the induction and progression of stomach cancer. In summary, scientific studies have clearly demonstrated that this radionuclide increases the risk of cancer. But there are some methods to minimize the presence radon and radium in water.

Mitigation

The two commonly accepted practices for removing radon from water are aeration and the use of activated carbon filters. Aeration techniques simply allow the radon to volatilize from the water and exhaust it outdoors, where it can be dispersed harmlessly. There are basically four types of aeration processes that can be used for residential water treatment; spray aeration, packed columns, diffused aeration and a new process called horizontally extended shallow aeration. Aeration can achieve over 99% percent removal of radon gas from water. Adsorption methods; collect the radon on activated carbon and allow it to decay in place. Activated carbon is generally not recommended for radon removal, since radioactivity will build up on the carbon. In some cases, this could make the carbon in the treatment container too radioactive to be near (in the basement or floor above) and would result in very expensive disposal. Granular activated carbon filters should only be used for water with radon levels less than 10,000 pCi/L. Several methods are available to remove radium from well water: oxidation and filtration, reverse osmosis, sodium cation exchange, and lime-soda ash softening are particularly effective and generally remove 50 to 90% of the ^{226} Ra present in untreated waters.

Measurement procedure

In this study, radon was measured in the water samplers using PRASSI system. To measure radon in water, some care must be taken in sampling process. Usually, springs and deep wells water are reach in radon, but after the water has been steered a little, it losses the highest fraction of its content. So, we have taken water sample directly from the sources, about 30 cm under the free surface of water. The water samples were collected in various points distributed in and around the cities of Ramsar, Sadatshahr and Javaherdeh; however, Figure 2 shows the sampling sites. In the present research, a total number of 120 water samples were collected and analyzed for radon and radium concentrations. 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.

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

Figure 3 shows the system set up of measurement including bubbler and drier column. PRASSI pumping circuit operates with constant fallow rate at 3 L/min 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

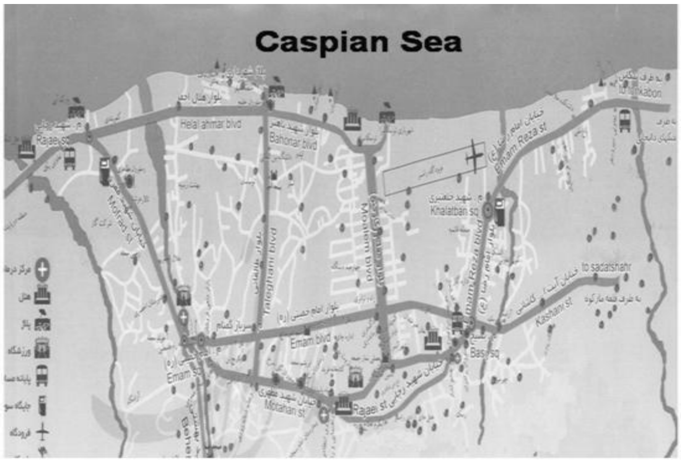

Figure 2. The sampling sites of Ramsar, Sadatshahr, Javaherdeh.

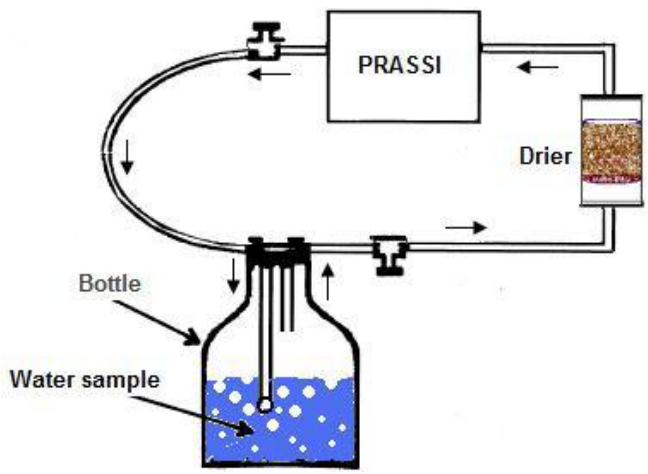

Figure 3. The PRASSI system set up for radon measuring in the water sample.

shown by the device is based on Bq/m^3. Using Equation 1, radon gas density is calculated based on (Bq/l):

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

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.

Radon determination

A total of 120 samples including 18 samples of spring water, 11 samples of well water, 22 river water samples and 69 samples of drinking water were tested. The third column of Table 2, presents the concentration of radon in water samples. Also, the the radon gas density results are shown in Figure 3. It can be showed that 9.17% of the samples, the last 11 samples in Table 2 have concentrations > 11 Bq/L, that is, maximum contaminant level for radon in public drinking water, suggested by the EPA. Also Environmental Protection Agency proposed an alternative maximum contaminated level (AMCL) 148 Bq/l for radon in drinking water. The AMCL is set at a level that would result in a contribution of radon from drinking water to radon levels in indoor air equivalent to the national average concentration of radon in outdoor air. The average value of radon concentration for all samples is found to be 4.773 Bq/L. According to the data, the minimum and maximum radon concentrations in samples are 0.000 and 40.946 Bq/L, respectively.

Radium determination

Specific drinking water standards have not been established for radium 226. The fourth column of Table 2 and Figures 4 and 5 shows radium concentration in different water samples. The radium concentration in the studied location is between 0-0.934 Bq/L. The average radium concentration for all samples is 0.204 Bq/L. In 53 samples of total samples, ^{226}Ra concentration even higher than the MCL for radium-226 is 5 pCi/L (0.185Bq/L) as determined by U.S Environmental Protection Agency.

Evaluation of mean annual radon dose

Radon enters the 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:

1. The effective dose coefficient from ingestion equals 3.5 nSv/(Bq/L).
2. Annual intakes by infants, children and adults are found to be about 100, 75 and 50 L, respectively.
3. The annual effective doses, due to ingestion corresponding to 1 Bq/l, would equal 0.35 μSv/y for infants, 0.26 μSv/y for children and 0.18 μSv/y for adults.

For inhalation, the following parameters were used:

i. Ratio of radon in air to radon in tap water supply is in the range of 10^{-4}.
ii. Average indoor occupancy time per person is about 7000 h/y;
iii. Equilibrium factor between radon and its progeny is equal to 0.4.

Table 2. Radon and radium concentration data and annual effective dose of different water sources of Ramsar, Sadatshahr and Javaherdeh (T W=Tap Water).

S/N	Source or place of water sampling	Q_{Rn} (Bq/L)	Q_{Ra} (Bq/L)	Annual effective dose of adults (μSv/y) from radon		Annual effective dose (mSv/year) from radium
				Lung	Stomach	
1	Hot spring water near Azadi hotel (No.1)	40.946	0.934	7.370	102.365	0.191
2	Pahlavi hot spring	39.790	0.283	7.162	99.475	0.058
3	Springhead Ab siahe ramak spring	36.591	0.734	6.586	91.478	0.150
4	Ab siahe ramak, 6 km after sample 3	4.839	0.546	0.871	12.098	0.112
5	Spring near Dalkhani forest	2.416	0.000	0.435	6.040	0.000
6	Hot spring water near Azadi hotel (No.2)	31.421	0.523	5.656	78.553	0.107
7	Spring near hotel (cold water)	21.260	0.508	3.827	53.150	0.104
8	Nesarood river	3.691	0.234	0.664	9.228	0.048
9	Sorkhanrood river	1.863	0.036	0.335	4.658	0.007
10	Safarood river	3.370	0.000	0.607	8.425	0.000
11	Torkrood river	1.027	0.103	0.185	2.568	0.021
12	Torkrood, 4 km after bridge	0.000	0.391	0.000	0.000	0.080
13	River near Narenjbon region	2.051	0.428	0.369	5.128	0.087
14	River of Chaparsar region	0.000	0.415	0.000	0.000	0.085
15	River near Kakhe mooze	4.117	0.228	0.741	10.293	0.047
16	River of Bagh region	1.658	0.379	0.298	4.145	0.077
17	Safarood river, 2 km after bridge	0.000	0.149	0.000	0.000	0.030
18	Chalakrood river	0.215	0.009	0.039	0.538	0.002
19	Shirood river	0.853	0.000	0.154	2.133	0.000
20	Shirood river, suburb of Ramsar	0.000	0.007	0.000	0.000	0.001
21	Well water near Lidoo camp	0.845	0.000	0.152	2.113	0.000
22	Well water of Behesht zeynabiye (No.1)	2.609	0.208	0.470	6.523	0.043
23	Well water of Behesht zeynabiye (No.2)	2.549	0.482	0.459	6.373	0.099
24	Well water of Caspian camp	5.902	0.046	1.062	14.755	0.009
25	Well water of Behesht zeynabiye (No.3)	2.706	0.352	0.487	6.765	0.072
26	Well water of Behesht zeynabiye (No.4)	5.232	0.047	0.942	13.080	0.010
27	Well water of Behesht zeynabiye (No.5)	4.867	0.000	0.876	12.168	0.000
28	Well water of Behesht zeynabiye (No.6)	3.051	0.207	0.549	7.628	0.042
29	Well water of Behesht zeynabiye (No.7)	4.595	0.379	0.827	11.488	0.077
30	Well water of Behesht zeynabiye (No.8)	20.208	0.079	3.637	50.520	0.016
31	Well water of Behesht zeynabiye (No.9)	5.973	0.083	1.075	14.933	0.017
32	Near of Farid library (T W)	3.017	0.000	0.543	7.543	0.000
33	Tea office (T W)	1.176	0.000	0.212	2.940	0.000
34	Emam sajad hospital (T W)	1.712	0.223	0.308	4.280	0.046
35	Negin restaurant (T W)	2.549	0.205	0.459	6.373	0.042
36	Esmat academy (T W)	7.728	0.219	1.391	19.320	0.045
37	400 dastgah region, Golestan alley (T W)	3.500	0.000	0.630	8.750	0.000
38	Confectionery shop, near municipality(TW)	2.894	0.184	0.521	7.235	0.038
39	Baradaran restaurant (T W)	3.317	0.055	0.597	8.293	0.011
40	Cheshmandaz steeple (T W)	3.565	0.010	0.642	8.913	0.002
41	Honarmandan hotel (T W)	0.000	0.226	0.000	0.000	0.046
42	Toosasan region (T W)	5.352	0.086	0.963	13.380	0.018

Table 2. Contd

43	Narenjbon region (T W)	2.301	0.060	0.414	5.753	0.012
44	Moallem boulevard(No.1) (T W)	1.844	0.170	0.332	4.610	0.035
45	Tooskasara region (T W)	7.880	0.000	1.418	19.700	0.000
46	Beginning of Ramak region (T W)	0.000	0.251	0.000	0.000	0.051
47	Beginning of Ghaemiye region (T W)	1.328	0.310	0.239	3.320	0.063
48	Shahid alamouti alley (T W)	2.578	0.204	0.464	6.445	0.042
49	Ghaemiye region, Goharrostami alley (TW)	1.712	0.000	0.308	4.280	0.000
50	Taleghani boulevard (No.1) (T W)	0.430	0.000	0.077	1.075	0.000
51	Taleghani boulevard (No.2) (T W)	1.790	0.747	0.322	4.475	0.153
52	Airport street (T W)	3.142	0.170	0.566	7.855	0.035
53	Airport street, gasoline station (T W)	2.653	0.306	0.478	6.633	0.063
54	Airport street, Beyhaghi school (T W)	0.000	0.421	0.000	0.000	0.086
55	Airport street, gas company (T W)	2.923	0.000	0.526	7.308	0.000
56	End of 400 dastgah (T W)	3.348	0.139	0.603	8.370	0.028
57	Sakhtsar hotel (T W)	2.630	0.096	0.473	6.575	0.020
58	End of Moallem boulevard (T W)	6.713	0.105	1.208	16.783	0.021
59	Lamtar region (T W)	1.694	0.000	0.305	4.235	0.000
60	Shirloo camp (T W)	0.994	0.198	0.179	2.485	0.040
61	Rajaei square (T W)	1.704	0.167	0.307	4.260	0.034
62	Mofrad region(No.1) (T W)	1.449	0.000	0.261	3.623	0.000
63	Helal ahmar boulevard (T W)	2.605	0.190	0.469	6.513	0.039
64	square Sarbaz gomnam (T W)	1.945	0.170	0.350	4.863	0.035
65	Mofrad region(No.2) (T W)	8.019	0.149	1.443	20.048	0.030
66	Toosasan region (T W)	6.101	0.090	1.098	15.253	0.018
67	Azadi hotel (T W)	15.108	0.363	2.719	37.770	0.074
68	Mofrad region (No.3) (T W)	2.741	0.260	0.493	6.853	0.053
69	Mofrad region (No.4) (T W)	2.417	0.009	0.435	6.043	0.002
70	Mofrad region (No.5) (T W)	1.289	0.000	0.232	3.223	0.000
71	Moallem boulevard (No.2) (T W)	2.465	0.000	0.444	6.163	0.000
72	Farhangian region (No.1) (T W)	3.836	0.856	0.690	9.590	0.175
73	After Melli garden (T W)	1.970	0.797	0.355	4.925	0.163
74	Farhangian region(No.2) (T W)	1.917	0.330	0.345	4.793	0.067
75	Caspian camp (T W)	1.744	0.098	0.314	4.360	0.020
76	2Km after Caspian camp (T W)	0.916	0.207	0.165	2.290	0.042
77	Near Shahrdari camp (T W)	3.241	0.090	0.583	8.103	0.018
78	Spring near Nesarood river	2.594	0.000	0.467	6.485	0.000
79	Bamsi spring	1.489	0.066	0.268	3.723	0.013
80	Safarood spring	2.610	0.308	0.470	6.525	0.063
81	Abmadan spring	19.573	0.000	3.523	48.933	0.000
82	Javaherdeh spring	1.810	0.510	0.326	4.525	0.104
83	Latmahale spring	0.000	0.112	0.000	0.000	0.023
84	Sadatshahr hot spring (No.1)	5.490	0.276	0.988	13.725	0.056
85	Sadatshahr hot spring (No.2)	14.751	0.377	2.655	36.878	0.077
86	Sangbone hot spring	4.991	0.317	0.898	12.478	0.065
87	Katolom hot spring	5.266	0.339	0.948	13.165	0.069

Table 2. Contd.

88	Markooh hot spring	4.751	0.490	0.855	11.878	0.100
89	Bamsi river	1.333	0.334	0.240	3.333	0.068
90	Abmadan river (Javaherdeh)	21.291	0.441	3.832	53.228	0.090
91	Javaherdeh river	7.125	0.214	1.283	17.813	0.044
92	Dashtejalami river	2.958	0.089	0.532	7.395	0.018
93	Katalom river	1.973	0.338	0.355	4.933	0.069
94	Markooh river (No.1)	1.015	0.000	0.183	2.538	0.000
95	Markooh (No.2) environs of Ramsar city	1.230	0.000	0.221	3.075	0.000
96	Chalakrood river	2.457	0.000	0.442	6.143	0.000
97	Nesarood river	1.298	0.465	0.234	3.245	0.095
98	Javaherdeh drinking water (No.1)	0.000	0.000	0.000	0.000	0.000
99	Javaherdeh drinking water (No.2)	3.179	0.085	0.572	7.948	0.017
100	Javaherdeh drinking water (No.3)	3.725	0.398	0.671	9.313	0.081
101	Javaherdeh drinking water (No.4)	1.263	0.000	0.227	3.158	0.000
102	Javaherdeh drinking water (No.5)	6.153	0.329	1.108	15.383	0.067
103	Javaherdeh drinking water (No.6)	3.248	0.165	0.585	8.120	0.034
104	Javaherdeh drinking water (No.7)	5.285	0.342	0.951	13.213	0.070
105	Javaherdeh drinking water (No.8)	3.494	0.775	0.629	8.735	0.158
106	Javaherdeh drinking water (No.9)	2.831	0.524	0.510	7.078	0.107
107	Javaherdeh drinking water (No.10)	11.403	0.110	2.053	28.508	0.022
108	Javaherdeh drinking water (No.11)	2.381	0.012	0.429	5.953	0.002
109	Javaherdeh drinking water (No.12)	2.789	0.005	0.502	6.973	0.001
110	Payam nour university (Sadatshahr)	0.000	0.891	0.000	0.000	0.182
111	Kashani street (Sadatshahr)	0.000	0.000	0.000	0.000	0.000
112	Bibisekine region (Sadatshahr)	3.383	0.000	0.609	8.458	0.000
113	End of kashani street (Sadatshahr)	1.471	0.000	0.265	3.678	0.000
114	15 hkordad street (No.1) (Sadatshahr)	4.665	0.000	0.840	11.663	0.000
115	15 hkordad street (No.2) (Sadatshahr)	2.292	0.117	0.413	5.730	0.024
116	Shahid dastgheyb street (Sadatshahr)	9.189	0.046	1.654	22.973	0.009
117	Shahid dastgheyb street, yas alley (Sadatshahr)	1.413	0.000	0.254	3.533	0.000
118	End of shahid dastgheyb street (Sadatshahr)	2.576	0.000	0.464	6.440	0.000
119	15 khordad street, golsar alley (Sadatshahr)	1.916	0.002	0.345	4.790	0.000
120	End of 15 khordad street (Sadatshahr)	3.225	0.000	0.581	8.063	0.000

iv. 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 in tap water is 2.5 μSv/y. Therefore, waterborne radon concentration of 1 Bq/L, causes a total effective dose of about 2.68 μSv/y for adults. The mean annual effective dose per person for adults caused by different water samples are reported in Table 2. The dose rate due to radon concentration by the population in the studied location is between 0.000-110 mSv/y. According to the advised of WHO and the EU Council, just 2 samples (No. 1 and 2) induced the annual effective dose greater than 0.1 mSv/y.

Evaluation of mean annual radium dose

Annual effective dose of ^{226}Ra in drinking water is

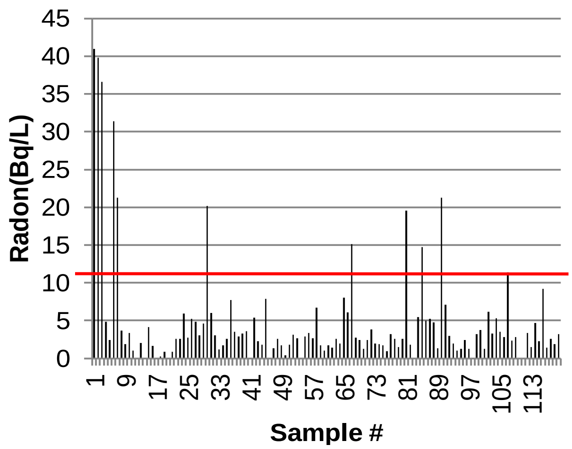

Figure 4. The histogram of radon gas concentration.

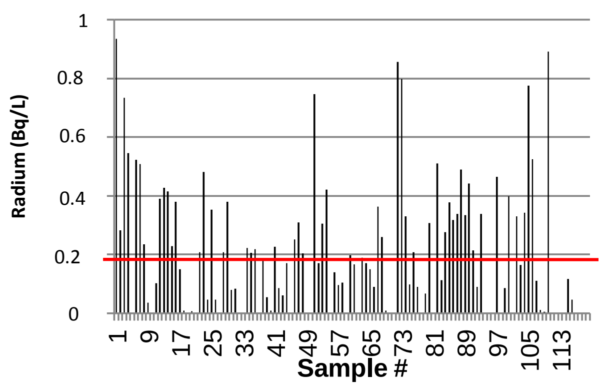

Figure 5. The histogram of radium concentration.

calculated by using $D = C_{Ra} \times U_a \times D_f$, where C is the measured radionuclide concentration in potable water in Bq/l, U is the annual water consumption in L/year (wich for 2 L/day is equivalent to 730 l/year) and D_f is the dose conversion factor in mSv/Bq (for ^{226}Ra is 2.8×10^{-7} Sv/Bq).

The results are presented in Table 2. Table 2 shows that 12 samples induced the annual effective dose greater than 0.1 mSv/y and 1 sample is equal to 0.1 mSv/y.

DISCUSSION

Results of radon concentration in water samples showed that 9.17% of samples were higher than the normal level 11 Bq/L, set by EPA. As the data indicate, the ^{222}Rn concentrations in most of spring water sampled are high and low in rivers. Particularly, the sample number 1 that related Hot spring water near Azadi hotel has a concentration of about 40.946 Bq/L. 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.

No sample has a concentration of 146 Bq/L of 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. The results of radium concentration show that about 44.17% of total samples are greater than 0.185 Bq/l. According to the advice of WHO and EU Council, radon induced the total annual effective dose greater than 0.1 mSv/y. In 2 samples and in 12 samples the annual effective dose is induced by radium greater than 0.1 mSv/y.

Therefore, there is a radon and radium problem for these sources. Nearly, half of this samples that have annual effective dose greater than 0.1 mSv/y belong to springs, and remained samples from tap waters. Tap waters produce problems certainly. Springs water can also cause diseases, because although people do not use spring water for drinking, but area residents and visitors use spring water to treat skin diseases without any medical supervision, leading to inhaling air containing radon that can be a risk factor. For improvement of the social health level, it is essential that to reduce the radon and radium concentrations in the drinking water before usage.

REFERENCES

Binesh A, Arabshahi H (2011). Radon and radium concentrations in 120 samples of drinking springs and rivers water sources of northwest regions of Mashhad. Int. J. Water Resour. Environ. Eng., 3(2): 46-51.

Kiliari T, Tsiaili A, Pashalidis I (2010), Lithological and seasonal variations in radon concentrations in Cypriot ground waters. J. Radioanal. Nucl. Chem., 284: 553-556.

López RN, Segovia N, Cisniega MG, Lṗez MBE, Armienta MA, Seidel JL, Peȁ P, Godيnez L, Tamez E (2002), Determination of radon, major and trace elements in water samples from springs and wells of northern Mexico State, Mexico. Geofيsica Int., 41(4): 407-414.

Kearfott KJ (1989). Preliminary experiences with 222Rn gas Arizona homes. Health Phys., 56: 169-179.

Kendal GM, Smith TJ (2002). Dose to organs and tissues from radon and its decay products. J. Radiol. Prot., 22: 389-406.

Khan AJ (2000). A study of indoor radon levels in Indian dwellings, influencing factors andlung cancer risks. Radiation Measure, 32: 87-92.

Kusyk M, Ciesla KM (2002). Radon levels in household waters in southern Poland. NUKLEONIKA, 47(2): 65-68.

Li X, Zheng B, Wang Y, Wang X (2006). A study of daily and seasonal variations of radon concentrations in underground buildings. J. Environ. Radioactivity, 87: 101-106.

Lόpez RN, Segovia N, Cisniega MG, Lṗez MBE., Armienta MA, Seidel JL, Peȁ P, Godيnez L, Tamez E (2002). Determination of radon, major and trace elements in water samples from springs and wells of northern Mexico State, Mexico. Geofيsica. Int., 41(4): 407-414.

McKittrick L, Sequeira S, Ryan T, Colgan T (2003). Radon in Drinking Water in County Wicklow – A PILOT STUDY. Diffuse Pollution Conference Dublin.

Nikolov J, Todorovic N, Forkapic S, Bikit I, Mrdja D (2011). Radon in Drinking Water in Novi Sad. World Academy Sci. Eng. Technol., 76: 307-310.

Uchida S, Tagami K (2009). Transfer of Radium-226 from Soil to Rice: A Comparison of Sampling Area Differences. J. Nuclear Sci. Technol., 46(1): 49-54.

Zubair M, Shakir-Khan M, Verma D (2011). Radium Studies in Sand Samples Collected from Sea Coast of Tirur, Kerala, India Using LR-115 Plastic Track Detectors. Int. J. Appl. Sci. Eng., 9(1): 43-47.