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The Environmental Impact of Radon Emitted from Hot Springs of Sarein (A Touristic City Northwestern Iran)

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Abstract: Radon is one the most important radioactive elements which is created from decomposition of uranium and radium existing in the earth and might be found naturally in soil, air and water. Radon concentration in the spring waters is directly proportional to their geothermal origin. Dissolved in the mineral waters, radon poses a threat to human health, although having some benefits. The objective of present study is to measure radon concentration in hot springs of Sarein (a touristic city northwestern Iran) as well as in the closed spaces of the city to evaluated the environmental impacts of the gas in the region studied. The results obtained from analysis of 9 mineral springs in Sarein indicate that the concentration of radon dissolved in the waters of the springs is between 9.7-139.8 bq/l this is lower than the standard limit, while its concentration in closed spaces of 25 selected residential locations, especially near to the hot springs, is higher than the standard limit.

Key words: Radon · Sarein · Hot spring · Iran

INTRODUCTION

Radon is a natural radioactive element which lacks any color and odor; it is produced by fission of uranium, radium and thorium which are naturally found in the ground. The most stable isotope of radon is Rn^{222} which is created as U^{238} is broken up and it has a half-life of about 3.8 days; Rn^{222} is also used in radiotherapy [1]. The radioactive element radon is found naturally either in the air or in the water; and since it has a great solubility under ambient pressure and temperature, it is found in all the water sources on the earth, such as rivers, lakes, seas, oceans, underground waters, springs and even atmospheric falls [2]. Previous research has indicated that mineral waters, due to passing through rocks and sediments of different compositions, contain different salts of radium and thorium (in dissolved state) which are decomposed to radon and thorium. However, because of the short half-life of thorium, radon constitutes the major part of the radioactive gases present in mineral waters [3].

Although presence of radon in waters assisted the humanity greatly in identification and prediction of earthquake occurrence, volcanic activities, fault dislocation, as well as in hydrological research, it has led to fatal happenings. As easily as it dissolves in the water, it is released from water to the surrounding area and, therefore, water resources, especially mineral waters, are the second main sources of radon release to the environment after the soil [4].

Sarein (Ardebil province) is a center of mineral water springs in northwestern Iran; and considering the number of hot and cold springs as well as their therapeutic effects, it is of great renown. Because of the volcanic source of the springs and occurrence of radioactive elements in their waters and since the city is located on younger geological sediments with a bed of volcanic rocks [5] which potentially contain radioactive elements such as uranium and thorium and considering the great tendency of people to use these waters for curing some diseases, we collected water samples from preselected hot and cold springs as well as from the inside of the buildings around the springs and analyzed the waters and determined concentration of radon in them to assess the environmental impact of the gas in Sarein region.

Study Area: Being a touristic city with the area of more than 1280000 m^2, Sarein is located on the hillsides of Sabalan Mountain 25 km from Ardebil [6];

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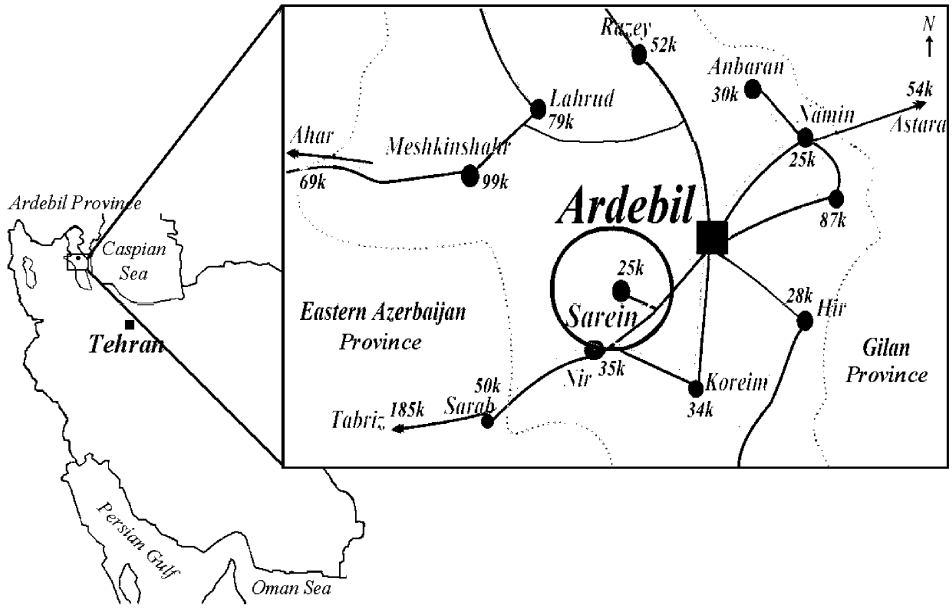

Fig. 1: Location map showing location of the touristic city Sarein, Iran

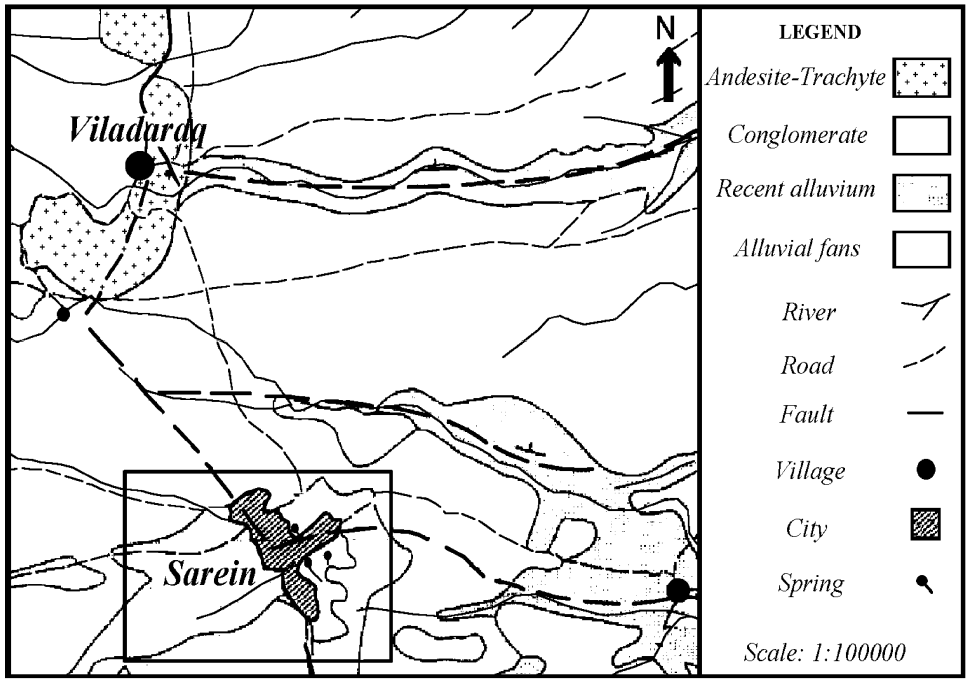

Fig. 2: The geological map of Sarein region

the city has been established in a bowl-shaped 1650-meter-high valley generated from the slight slopes of Sabalan hillsides and its geographical coordinates are as follows: N 38° 9′, E 48° 9′ [7]. The slopes are slighter in the western part and they are opened, like a valley, toward southeast (Figure 1).

From a geological viewpoint, the region is located on alluvial fans composed of pyric cobbles with the diameter of more than 1 m in matrix of sand, silt and clay which stretches toward north (around Viladaraq village) to acidic rocks such as andesite, trachyandesite and basalt together with lava and toward southeast to intensely folded deposits made of sandstone and gypsiferous red marl with the thickness of more than 300m [8] (Figure 2).

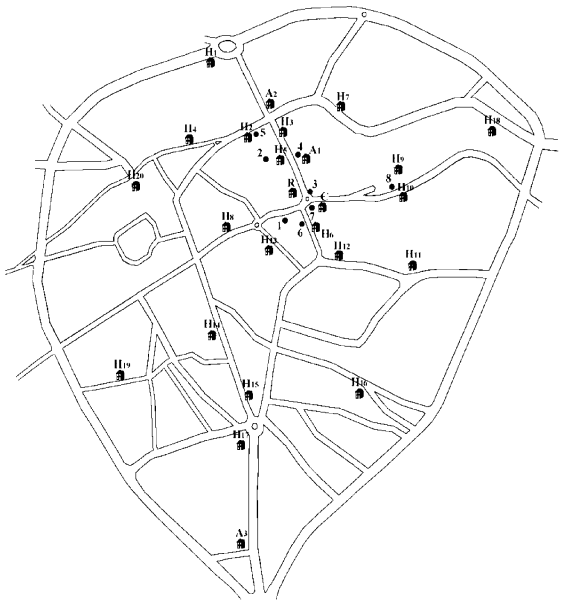

Fig. 3: Selected springs and locations in the Sarein city

Method of Study: In Sarein, there are more than 12 hot springs and one cold spring. For the purpose of this study, in addition to measuring pH and Ec (using the radon extraction method), samples were collected in late February from 9 hot springs with the temperature of higher than 40°C and one cold spring with the temperature of 15.5°C. The water sample was collected in an organic cocktail with trimethylbenze solution (Ready Organic cocktail) and shipped to the laboratory for determining radon gas concentration in the water. Simultaneously, from the height of 1 m above the ground in 25 selected locations in the city (20 hotels (H_{1-20}), 3 houses (A_{1-3}), 1 restaurant (R) and 1 coffeehouse (C)) a specified volume of air was taken (Figure 3); and then counting was done using Thomas method (three counts) in periods of 2-5 min, 6-20 min and 21-30 min, [9] and radon concentration rate (bq/l) was determined.

RESULTS AND DISCUSSION

Because of their volcanic origin, the mineral springs of Sarein are mostly hot springs which contain salts of radioactive elements in dissolved state. With these compounds, the springs are among the radioactive waters which are usually used for curing some diseases. Bathing in radioactive waters increases the tissue activity and acts as a sedative for rheumatic, nervous pains as well as the pains in body joints; it is also helpful in treating skin diseases such as itching eczema. Results of research on radon therapy indicate that radon dissolved in water together with heat can increase activities of superoxidants, e.g. Superoxide Dismutase (*SOD*) which prevents production of cholesterol and peroxide in body [10].

Table 1: Concentration of radon in mineral springs of Sarein

Spring	Concentration(bq/l)	T (°C)	Ec(mho/cm)	pH
1	18.70	42.50	1320	7.30
2	18.70	41.00	1390	6.28
3	23.20	43.50	1520	6.07
4	16.50	43.00	1330	7.13
5	12.40	46.00	1320	7.34
6	9.70	43.00	1390	5.98
7	17.20	46.00	1370	6.15
8	42.00	42.00	850	5.83
9	139.80	15.50	496	5.18
Standard	150.00	-	-	-

The results of water analysis on selected mineral springs in Sarein (Table 1) show that the concentration of radon in the water of the springs varies between 9.7-139.8 bq/l which is lower than the permitted limit by the standard of EPA (150 bq/l) [11]. Since radon concentration in the springs is negatively correlated with temperature and electrical conductivity (Ec) of the waters and based on the results obtained by Valcanberg *et al*. (1985), there is a direct negative relationship between gas solubility in the water of the mineral springs and water temperature, in a way that an increase in water temperature results in both a lower surface absorption and, consequently, a lower radon release [12], thus, high concentration of radon in the water of Viladaraq spring (9) can be explained. Drinking such water, albeit for a short time, causes excretion of uric acid by the urine and relieves joint paints.

Concentration of radon in underground waters and springs depends on the type and the age of the rocks of hydroferous bed and the geological structure of the hydroferous bed rocks are of two main groups:

- Hydroferous beds composed of igneous and metamorphic rocks; radon concentration in the springs and underground aquifers of this type of beds depends on uranium concentration in the bed rocks and radon transfer efficiency from solid phase to liquid phase [13]. With its over-saturation potential, water can easily expand radon gas, especially when there is sufficient disturbance. Said in other way, when underground waters pass through the hydroferous beds rich in uranium, radon production and transfer occurs in solid, liquid and gas phases.

- Hydroferous beds of a sedimentary geological structure (layered, carbonate) in which gas transfer by decomposition of radioactive elements is dependent on porosity percentage and the number of holes in those beds; porocity itself is under the effect of thickness and age of the sediments [14].

Since Sarein hot springs are located on young alluvial fans which are made up of a high percentage of caly and therefore a low porosity, the rate of radon production and spread in the springs is lower than the standard limit.

About 50% of the effective absorbed doze of gas enters human body through inhaling, drinking water and, more important than others, bathing. High concentration of radon in the air around the springs accelerates gas entry to the lungs through inhaling. Due to the fact that radon, in comparison to inhaling time, is of longer half-life, it remains in the lungs and it then decomposes to its solid daughters with a half-life shorter than 0.5; the daughters can absorb á-particles and consequently damage the lungs and creates a risk to human health [15]. Considering the risk of radon inhaling, most hot springs in Sarein are in the form of open pools from which radon easily exits and becomes dispersed in the windy environment of the city. Therefore, no special side effect can be related to radon inhaling in the open pools. In the two covered pools, radon concentration in the closed space of the pools is low and radon is discharged from these pools through suitable ventilation.

Natural radioactive sources are the main factors in exposure of human and other living beings; such sources continuously affect the dose received by the human and, depending on concentration of natural radioactive nuclei and the exposure mode, they pose different harms. Radon accumulation in closed locations, especially houses and work places and its biological consequences is one the main issues explored continuously by the developed countries [16].

In regions with colder climates in which doors and windows are often kept close, radon accumulates faster in the buildings. The gas exits through soil, rocks placed in building foundations and the fissures in the walls and the building floors. Moreover, the space around the pipes and connections set on the walls and the floors can act as a passage for radon to enter the houses [17, 18]. One of the main issues in Sarein region is radon emission from the soil and the rocks around the springs and its accumulation in the houses and covered areas of this overcrowded region. Wind blow and high temperature of the inside of the buildings are two factors creating a pressure difference. A higher temperature increases the pressure inside the buildings and, through the process of stack effect, results in air suction from the fissures in the walls and the floors and increases radon concentration. In addition, wind blow transfers radon inside by creating a pressure difference between inside and outside of the building.

Table (2) presents the results obtained from measurement of radon accumulated in 25 selected closed spaces around the hot springs. In all the buildings, radon accumulation rate is higher than the permitted limit for the closed areas (30- 40 bq/l). The lowest radon concentration (39.90 bq/l) was obtained for a restaurant which has suitable ventilation and the highest radon concentration (486.10 bq/l) was recorded in a coffeehouse 12m from one of the hot springs; since the coffeehouse lacked appropriate floor covering, there was a possibility of radon emission from the floor soil and its accumulation in the closed space of the coffeehouse.

Table 2: Radon accumulation rate in the selected locations around Sarein hot springs

location	Concentration of radon(bq/l)	location	Concentration of radon(bq/l)
A_1	144.70	H_8	127.20
A_2	117.00	H_9	130.60
A_3	129.00	H_{10}	118.00
H_1	46.90	H_{11}	122.00
C	486.10	H_{12}	167.00
H_2	107.90	H_{13}	51.00
H_3	81.90	H_{14}	114.08
R	39.90	H_{15}	146.30
H_4	50.90	H_{16}	48.80
H_5	58.90	H_{17}	123.00
H_6	274.50	H_{18}	130.00
H_7	117.00	H_{19}	80.98
Standard	143.00	H_{20}	131.00

Radioactive materials such as radon can often enter human body through three ways of inhaling, swallowing and absorption through skin; then inside the body, they are systematically assimilated. Accordingly, if not discharged from the closed spaces around Sarein hot springs by suitable ventilation, the accumulated radon can result in belated side effects of gas radiation in Sarein population.

The belated side effects of radon radiation are developed from a single over-exposure; i.e, the radioactive isotope enters the body and become assimilated through reacting with the tissue proteins and because of the chemical resemblance between the isotope and the typical products of the body metabolism absorbed regularly in some tissues and organs, it becomes deposited in the tissues and radiates for a long time [19]. Examples of the belated effects of radon radiation might be gene mutation, a pause in cell division, genetic alteration, chromosome break (which leads to abnormal cells and, consequently, cancer in lung, bone and blood) and cataract which all together lead to a shorter lifetime [20].

CONCLUSION

As a radioactive element with great solubility, radon is found in almost all the water sources, especially mineral springs. Having a volcanic origin and being mostly hot springs, the mineral water springs of Sarein are among the radioactive waters which are often used for sedating rheumatic, nervous and joint pains. The measured radon concentration in 9 hot and cold springs of Sarein is lower than the standard limit. In addition, the accumulation rate of radon emitted from the springs is not posing a risk to human health, considering the fact that most of the pools are of open type. Comparing the concentration of the accumulated radon in closed spaces of 25 selected locations around Sarein mineral springs with the standard limit indicates that radon is concentrated near the hot springs and, if inhaled for a long time, might result in cancer and a short lifetime.

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