Iran. J. Radiat. Res., 2008; 6 (1): 13-18

Staff exposure rate in Mahallat hot spring region

M.B. Tavakoli*, G.H. Fallah Mohammadi, Z. Shahi, Z. Shaneh

Department of Medical Physics and Medical Engineering, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran

Background: High level radiation areas have been recognized on various parts of the earth. Mahallat hot spring region is one of these areas. Study of exposure in these areas can be helpful in investigating the effects of ionizing radiation. Internal and external exposure to the staff was studied. ***Materials and Methods:*** Used materials and instruments include: RSS-112 ionizing chamber for environmental gamma rays measurement, pure germanium detector for measuring radioactive elements in the ground, liquid scintillation counter for measuring ^{222}Rn gas concentration in water samples, Bubbler chamber and Locus cells for ^{226}Ra concentration measurements as emanation method and Alfa guard detector for ^{222}Rn concentration measurements. ***Results:*** Considering stay period of the studied groups in indoor and outdoor environment, calculated annual external effective dose for staff has been 514.8 ± 22.7 μSv. Annual internal effective doses for staff in outdoor and indoor environment has been 21.1 mSv. Annual internal effective dose for staff due to drinking water has been 32 μSv. ***Conclusion:*** Measurements showed that more than 90% of the received dose in the studied groups was due to inhalation of Radon gas. External and internal effective dose for the staff was 21.6 mSv. Considering these results Mahallat hot spring region is a high level natural radiation area (HLNRA). **Iran. J. Radiat. Res., 2008; 6 (1): 13-18**

Keywords: *Effective dose, background dose, Radon, high level natural radiation area.*

INTRODUCTION

A significant amount of the effective dose received by the world population is due to the natural ionizing radiations; therefore, estimation of the dose of these radiations in the individuals is of great importance (1, 2). Based on the latest data of United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR), mean individual annual effective dose from natural radiating sources is estimated to be 2.4 mSv per year. While mean effective dose from all nuclear activities, including doses due to atomic explosions, nuclear events, normal functioning of atomic factories and also medical exposure (diagnosis and treatment) is 0.8 mSv annually (3). Major natural radiation sources consist of long-lived primary radioactive materials and their products and also cosmic rays. Main important natural radioactive sources are: ^{40}K (half life: 1.28×10^{9} y), ^{232}Th (half-life: 1.41×10^{10} y), ^{238}U (half life: 4.47×10^{9} y), Rb (half life: 4.7×10^{10} y) and ^{235}U (half life: 7.04×10^{8} y).

Usually dose rate per unit concentration is calculated. Dose coefficients are expressed in $nGyh^{-1}/BqKg^{-1}$. When this coefficient is multiplied by the concentration of radioactive sources in the ground, the mean dose rate can be obtained (4, 5).

Population dose rate in different parts of the world has been reported (6, 7). In open air condition reported mean external dose rate is 57 $nGyh^{-1}$ and in closed environmental condition it is 80 $nGyh^{-1}$. Suggested mean external annual effective dose is 0.46 mSv which is somehow more than the determined amount from cosmic rays (0.38 mSv). The differences can be accounted for the radiations from radioactive materials present in the ground elements (1).

Radium enters body via drinking water and food. In the body a small amount is absorbed in the bone and the remainder is excreted through urine and feces. As the skin prevents alpha particles from entering body,

***Corresponding author:**
Dr. Mohammad Bagher Tavakoli, Department of Medical Physics and Medical Engineering, School of Medicine, Isfahan University of Medical Sciences. Isfahan, Iran.
Fax: *+98 311 7922412*
E-mail: *mbtavakoli@mui.ac.ir*

external radiation from radium due to bathing, washing or other uses of water - containing radium is negligible (8).

The major radiation pathway in closed environment is inhaling short half-lived decay products of main radon isotope, i.e. ^{222}Rn. Although doses to the lungs are mostly due to radon decay products rather than radon itself, it is radon that is frequently measured, because of two reasons: 1) Measurement of radon is much easier and less expensive; 2) It has relatively constant equilibrium factors. Based on UNSCAER report (3) using equilibrium equivalent concentration (EEC) of radon gas, which is related to radon decay products, can be calculated by knowing equilibrium coefficient or equilibrium factor. The EEC in closed environment is 0.4, and in open environment it is 0.8. Reported mean annual effective dose due to inhalation of radon gas, is 0.13 mSv and 0.1 mSv in open and closed environment, respectively.

Some drinking water wells have high radon concentrations. Minerals in spring water, monazite stones and other mineral sediments are of main sources of high radiation factors in the world. It has been recognized from past that many mineral water springs contain relatively high concentrations of radium and dissolved radon. Many of these springs are utilized for their therapeutic properties (6). Tourists are not only encouraged in drinking and bathing in these springs, but also sit in these places and inhale deeply the gas existing in significant amounts in the air. Mahallat hot spring water, a region in the north-east of Mahallat, a town in central part of Iran, is of high background radiations because of these mineral water springs. The main permanent springs are: Shafa, Soleimani, Dombe, Sauda, and Romatism. High mean temperature of 46 ± 1°C in these springs helps spread of radiation in an area as wide as several square meters. These springs absorb large numbers of tourists to visit the area. Measurement of the rate of exposure of individuals from natural radiating sources is the subject of this study.

MATERIALS AND METHODS

The instruments used in this study were consisted of:

1. A high pressure environmental exposure meter model Ruter stokes RSS-112 made in USA for measuring exposure rate (in μRh^{-1}) in air. It had eight liters sensitive volume filled with pure argon gas under 25 atmosphere pressures. Each measurement at each point took ten minutes and it was repeated in eight directions for each hot-spring (9). The instrument was calibrated with a 3.7×10^{7} Bq ^{60}Co radioactive source.

2. An Ultra-Pure Germanium detector (HPGe). The detector was used for measuring terrestrial radioactive elements. Similar to measuring environmental gamma rays, soil samples were collected from eight directions around each of the hot springs to measure the concentration of terrestrial radioactive elements.

Samples were dried primarily, and then riddled completely with 0.63mm pore diameter. Soil samples were placed in special columnar containers made of polyethylene (the container is also used for calibration of apparatus). The sample weights were kept 300gm for all of the measurements. The samples are kept for a minimum of three weeks for the chain of radiating soil elements to equilibrate, and then placed directly in HPGe apparatus for pre-selected 60,000 counting (10). The detector was used for gamma spectroscopy. The resulted spectrums for the samples were used to calculate concentration of each radioactive element. The calculations were performed using GC 4020 Canberra multichannel analyzer software.

3. Liquid scintillation counter model Quantalus 122 Perkin-Elmer was used for measuring ^{222}Rn gas concentration in water samples collected from the hot springs. Measurements were performed according to method describing Prichard and Gesell (11). Determination of ^{222}Rn activity was made after counting. Background correction, decay correction for the duration between sample collection, measurements and application of

conversion factor to obtain activity in pCi/10 ml were also applied (11).

4. Bubbler chambers and lucas cells, were used to determine ^{226}Ra (Emanation method) concentration in water. To apply the emanation method, the radium was collected from a 2 liter water sample. After purification, radium and barium sulphate were dissolved in alkaline EDTA reagent and were placed in a 20 ml bubbler. The bubbler was then purged by about 100 ml of nitrogen gas with a purity of 99.99 % to remove any exiting ^{222}Rn before the ingrowths. The bubbler was then connected to an evacuated radon emanation system, having ascarite and magnesium per chlorate $[Mg(ClO_2)_2]$ for removing the moisture and CO_2. To transfer the radon gas into a 100 ml scintillation cell, the babbler was purged again with 100 ml nitrogen gas. After a waiting time of 3 h to reach the equilibrium between ^{222}Rn and its progeny, the cells were counted for 50min using an Eberline scintillation counter Model SAC-R5.

5. Alpha Guard Genitron model PQ 2000 dosimeter made in Germany was used for determining ^{222}Rn gas concentration in air. It was a portable dosimeter that measures radon gas concentration and its products. Continuous measurements of radon were performed for 1hour in each location. Radon decay products concentrations are calculated by multiplied by EEC in radon concentration.

Assuming radioactive nuclei are distributed homogeneously on the ground surface, the dose rate one meter above the ground level is calculated by the following equation (12):

$$D^{\circ}(nGyh^{-1}) = C_R(Bq/kg) \times CF(nGyh^{-1} \text{ per } Bq/kg) \quad (1)$$

Where D^{o} is absorbed dose rate in air in $nGyh^{-1}$; C_R, is radioactive concentration in Bq/kg and CF is conversion factor in $nGyh^{-1}$ per Bq/kg. For calculating gamma exposure rate one meter above the ground level from water springs distributed on the earth, conversion factors (dose rate in the air per

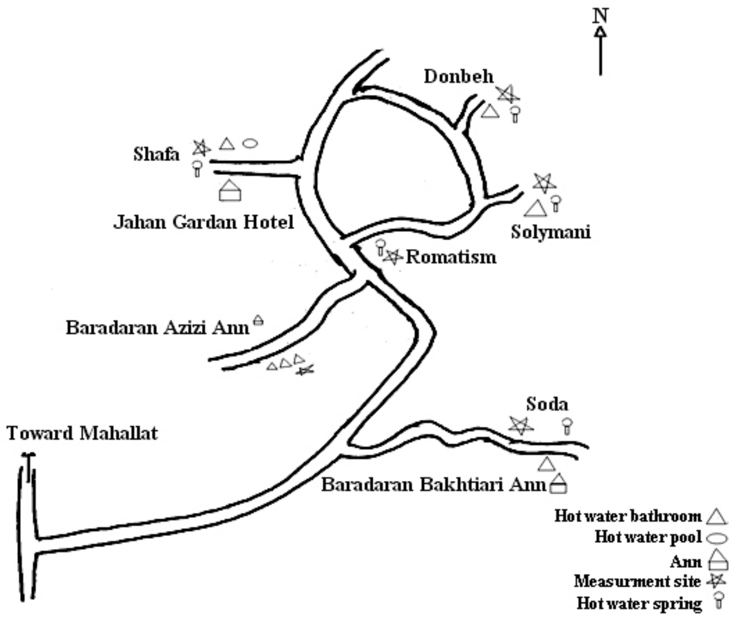

Figure 1. A drawing map of Mahhallat hot spring region.

unit activity and unit ground mass, $nGyh^{-1}$) should be used. Considering dose rate in the air and stay time for individuals in open environment, annual effective dose rate is calculated from the following equation.

$$\begin{aligned} E_{eff}(mSvy^{-1}) = {} & D^{\circ}(nGyh^{-1}) \times 24\,h/d \times 365.25\,d/y \times \\ & [0.8(\text{for indoor}) \text{ and} \times 0.2(\text{for outdoor})] \\ & \times 0.7\,SvGy^{-1} \times 10^{-6} \end{aligned} \quad (2)$$

Where E_{eff} is annual effective dose in mSv and D^{o} is absorbed dose rate in air in $nGyh^{-1}$. A residence time factor of 0.8 was used for staying indoors and 0.2 for outdoors. For the conversion of the absorbed dose rate in air to effective dose equivalent rate in the tissue, conversion factor of 0.7 Sv/Gy was used. This was a general relation and was used for effective dose calculation in outdoor and indoor environment. In this research, stay time of individuals in open and closed environment were estimated and then used for calculating annual effective dose for each of the staff. External exposure from all environmental ionizing radiations was measured by RSS-112 apparatus, including cosmic rays, as well. On the other hand the absorbed dose rate in the air, due to terrestrial radioactive elements had been measured with the HPGe instrument. Exposure rate from cosmic rays was obtained by subtracting these two values.

Annual effective dose of individuals from drinking water can be calculated using the following formula [3]:

$$D = C_{226Ra}(BqL^{-1}).\ U(Ly^{-1}).\ D_f(SvBq^{-1}) \quad (3)$$

Where C_{226Ra} is ^{226}Ra concentration in drinking water in Bq/lit, U is annual consumption of drinking water in liter per year (Ly^{-1}), Df is radiation conversion factor to dose, (in $SvBq^{-1}$).

The following relation showed mean annual effective dose due to inhalation of radon products in open and closed environment:

$$\text{Annual effective dose (mSv)} = EEC \times 9nSvh^{-1}/Bqm^{-3}(EEC) \times \text{hours of stay per day} \times 365dy^{-1} \quad (4)$$

To calculate effective dose from radon gas inhalation in the study groups, stay time of the individuals were estimated and then effective dose was calculated using equation 4.

In this study the number of staff was 35 persons. They work in different hotels throughout the year in the region. In table 1 the staff stay time in open and closed environment is shown.

Table 1. Stay time of Mahallat hot-spring region staff in open and closed environment (hour per year).

Groups	Open environment.	Closed environment (rooms)	Closed environment (bathrooms)
Staff Stay time	1074	4380	104

Open environments were near the hot spring water, parks and any other parts without ceiling. Staffs stay indoor for cleaning hotel rooms and resting in this part, as well as hotels' reception staff in hotel and garcons. Staying in bathroom was for swimming and cleaning.

RESULTS

External dose rate

Mean external dose rate in outdoor condition in Mahallat hot spring region was 264.5 ± 16.3 $nGyh^{-1}$ which included dose rate form radionuclide in soil and cosmic ray, in indoor environment condition of bathrooms was 181.8±13.5$nGyh^{-1}$, and in hotels' rooms was 93.8 ± 9.7 $nGyh^{-1}$ which was gamma ray dose rate from building material. Terrestrial dose rate in the air at one meter above the ground level of Mahallat hot spring region due to radionuclide in soil was 217.6 ± 14.8 $nGyh^{-1}$; hence, effective dose rate due to cosmic ray in open air condition was 46.9 $nGyh^{-1}$. Table 2 shows external indoor, outdoor and total effective dose.

The ratio of staff external exposure from terrestrial elements, cosmic rays, bathrooms and hotels room are shown in figure 2.

Table 2. Annual outdoor, indoor and total effective dose of Mahallat hot spring workers.

	Radiation	Dose rate ($nGyh^{-1}$)	Conversion factor (Sv/Gy)	Stay time (h/y)	Annual effective dose (µSv)
Outdoor	Terrestrial	217.6±14.8	0.7	1074	163.6±12.8
	Cosmic	46.9	1	1074	50.4
Indoor	Bathrooms	181.8±13.5	0.7	104	13.2±3
	Hotel rooms	93.8 ±9.7	0.7	4380	287.6
			Total annual effective dose		514.8±22.7

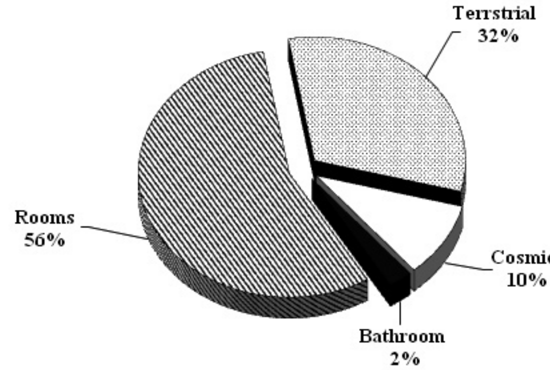

Figure 2. Comparison of annual external effective dose of staff in different environments of Mahallat hot spring region.

Internal Exposure

Radon gas inhalation

Mean measured radioactivity of radon gas and its disintegration products concentration in the air, in open environment was 287.2 ± 16.9 Bqm^{-3}, in closed environment of bathrooms it was 776.2 ± 27.9 Bqm^{-3} and in hotel rooms 1182.3 ± 34.4 Bqm^{-3}. Considering stay time of staff in open and closed environment, total annual effective dose due to inhalation of radon gas is shown in table 3.

Table 3. Total annual effective dose due to inhalation of radon gas and its disintegration products in open and closed environment (in mSv).

Studied	Open	Closed	Closed environment,	Total annual
Group	environment	environment	hotel rooms	effective dose
		bathrooms		
Staff	2.2 ± 0.05	0.3 ± 0.02	18.6 ± 4.3	21.1±4.6

Drinking water

Drinking water of the region was provided from Mahallat town water. Drinking water consumption per head for staff that came from Mahallat Township has been taken the same amount reported in UNSCEAR 2000 for different ages. The amount was 150, 350, and 500 liter per year (L/y) for children, adolescents and adults, respectively. The staff included only adults (children and adolescents are not present in this group). If drinking water consumption per capita was converted to daily consumption for age group adults consume 0.4, 0.96 and 1.37 liters per day drinking water, respectively, therefore annual consumption of drinking water in Mahallat hot spring region should be 46.58 liters for this group during their stay time.

Radiation conversion factor for the mentioned age group in Sv/Bq was 0.28. Annual effective dose of staff due to consumption of drinking water was 0.32 µSv.

Total annual effective dose of staff including dose from external dose from indoor and outdoor condition, internal effective dose due to radon inhalation and drinking water was 22.6 mSv/y.

DISCUSSION

On the average the staffs spend 0.8 of their total attendance hours in the closed environment, so the maximum received dose of staff has been due to their stay in closed environment (55%).

Table 4 shows annual effective dose of studied group in the hot spring region from different paths of indoor and outdoor condition.

Table 4. Annual effective dose of the staff from different paths (µSv).

Radiation pathway	terrestrial	Cosmic ray	bathrooms	Hotel rooms	Radon inhalation	Water intake
Annual effective dose	163.6±12.8	50.4	13.2±3	287.6±	2110±46	0.00032

Absorbed dose rate due to cosmic rays in Mahallat hot spring region was 46.9 $nGyh^{-1}$. Cosmic rays at sea level in Ramsar area had been reported to be 32 $nGyh^{-1}$ [13, 14]. The difference in calculations might be due to altitude difference of two areas. UNSCEAR 2000 [3], has reported ^{222}Rn gas concentration in indoor and outdoor environment 40 and 10 Bq/m^3, respectively. Annual effective dose due to Radon gas inhalation in closed and open environment was 0.1 and 0.13 mSv, respectively. This has been the exposure rate for those who attend in the area permanently and spend 0.8 of a year (7008 h) in closed environment and 0.2 a year (1752 h) in open environment. Mahallat hot spring staff effective dose due to inhalation of Radon gas and its products, with a stay time of 4380 hours in closed environment and 1074 hours in open environment were 18.9 mSv and 2.2 mSv, respectively. Exposure from drinking water is of less importance in comparison to other paths of exposure. More than 90% of the received dose of the study group was due to inhalation of radon gas. In this study, measurement and calculations have shown total annual effective internal and external dose of 21.6 mSv for staff. The staffs were considered as individuals, who had the longest stay time in the area, considering annual effective dose of 21.6 mSv for this group. Therefore, it can be concluded that Mahallat hot spring region is one of the high level natural radiation areas as reported previously [1, 6].

REFERENCES

1. Ghiasi Nejad M, Baitolahy M, Fallahyan NA (2001) Exposure from Natural radiation sources. *Iranian Atomic Energy Agency; Chapters **1-3**: 1-70.*

2. Ghiasi Nejad M and Katozy M (2001) Radioecology, *Iranian Atomic Energy Agency; Chapter* ***10****: 153.*
3. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000 Report to the General Assembly, with Scientific Annexes. *Sources and Effects of Ionizing Radiation.* 2000 New York.
4. Petoussi N, Zanke M, Saito K (1989) Organ dose to adults and children from environmental gamma rays. *The Radioecology of Natural and Artificial Radionuclide, 372-377.*
5. Saito K, Ptooussi K, Zankl M (1990) Calculation of organ doses from environmental gamma rays using human phantoms and Monte Carlo methods. *Part 1. Monoenergetic Sources of Natural Radionuclides in Ground GSF-B2/90.*
6. Sohrabi M, Beitollahi M, Lasemi Y, Sobhani EA (1997) Origin of a New high level natural radiation area in the hot spring region on Mahalat, central Iran. Proc. of an International Conference on High Levels of Natural Radiation (1996). Elsevier Science BV.
7. Sohrabi M (1998) The State of the Art on World Studies in some Environments with Elevated Naturaly Occuring Radioactive Materials (NORM). *Int J Appl Radiat Isot,* ***49****: 169-188.*
8. Department of water affairs and forestry institute for water quality studies (2002) Radioactivity dose calculation and water quality evaluation guideline for domestic water use. March 20-26 ***(http://www.dwaf.gov.za/iwqs/)***.
9. Reuter-stokes Operational Manual. Version 1. *Reuter112 PIC Environmental Radiation Monitoring Station. 1991 Reuter-stokes, OH, USA.*
10. Sohrabi M and Esmaili AR (1997) Assessment of radiation from Natural radiation sources in Babolsar; M.Sc thesis, 84.
11. Parsa B (1986) Measurement of Radon-222 in water. N.J. Dept. of Environmental Laboratories, January 1986.
12. Fujitaka K and Abe S (1986) Effect of partition Walls and neighouring buildings on indoor exposure rate due to cosmic ray. *Health Physics,* ***51****: 47-659.*
13. Sohrabi M and Esmaili AR (2002) New public dose assessment of elevated natural radiation areas of Ramsar (Iran) for epidemiological studies. *International Congress Series,* ***1225****: 15-24.*
14. Sohrabi M (1996) The radiation paradigm regarding health risk from exposures to low dose radiation. Proc Int Conf on High Levels Natural Radiation, Beijing, China, 21-25 Oct. 1996, L. Wei, T. Sugahara and Z. Tao. 1997 p: 331-340. Elsevier, Tokyo.