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Measurement of Natural Radioactivity in Soil Samples of Sarein

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Abstract: The activity concentration of radionuclides in soil from around of Sarein (Ardabil), IRAN was investigated with aim of evaluating the environmental radioactivity and radiological health hazard. Concentration of radionuclides in Samples was determined by gamma ray spectrometer, using a high-purity germanium (HPGe) detector. The activity concentrations were ranged from 321 to 774 (Bq/kg) for ^{40}K, 19.1 to 134(Bq/kg) for ^{226}Ra and 29.2 to 83.7 (Bq/kg) for ^{232}Th . The mean radium equivalent activity, the terrestrial absorbed dose rate and external hazard index for the area under study were calculated 156.21 (Bq/kg), 72.46(nGy/h) and 0.4 respectively. The annual effective dose to the public was found to be 0.09 mSv. The present result was compared with the data obtained from different countries and world average values. The results show that the area under investigation has a normal level of natural background and radiation hazard is low for human health.

Key words: Natural radioactivity · Activity concentration · High-purity germanium (HPGe) detector · Gamma-ray spectrometry

INTRODUCTION

Natural radioactivity is widely exists in the air, water, plants and the soil of earth's environment. The natural radioactivity in soil comes mainly from the U and Th series and natural K. Radiations come from soil have a significant portion of background radiation exposure of the population. Determination of external absorbed dose rate in the air at 1m above the ground level and the annual effective dose, are commonly used to estimate of the external exposure to population.

Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions and appear at different levels in the soils of each region in the world. Gamma radiation emitted from terrestrial materials is known as the major external source that affects the human body. The interaction of radiation with human body leads to various biological effects which may later show up many diseases. Information of radioactive level of an environment leads to control and preventing of diseases. Therefore monitoring natural radioactivity in the environment is an important parameter for public health studies and assessing possible changes in the environment radioactivity. [1]

In the present work soil samples were collected from Sarein region nearby Ardabil to determine the values of concentration of radionuclides ^{226}Ra, ^{232}Th and ^{40}K.
Sarein town is located in 28km west of Ardabil, with more than 1280000 square meters area and approximate height from sea level of 1650 meters.

The population is about 8000 and it increases to more than 20000 in the summer because of some tourism attractions like charming climate and hot springs. Nearby Sarein town, there are two tourist regions; a small village called Villadarag is located in the north of Sarein and Alvars village that is located in the west of Sarein as winter sports center.

The geological formations in the study area are formed from volcano-sedimentary rocks (except of Viladarag region).

MATERIALS AND METHODS

Twenty soil samples were collected from four main directions and central region of Sarein and surrounded areas as shown in figure 1. From each location, three subsamples were collected from uncultivated fields. The samples were grinded and homogenized after collection and air-dried for several days.

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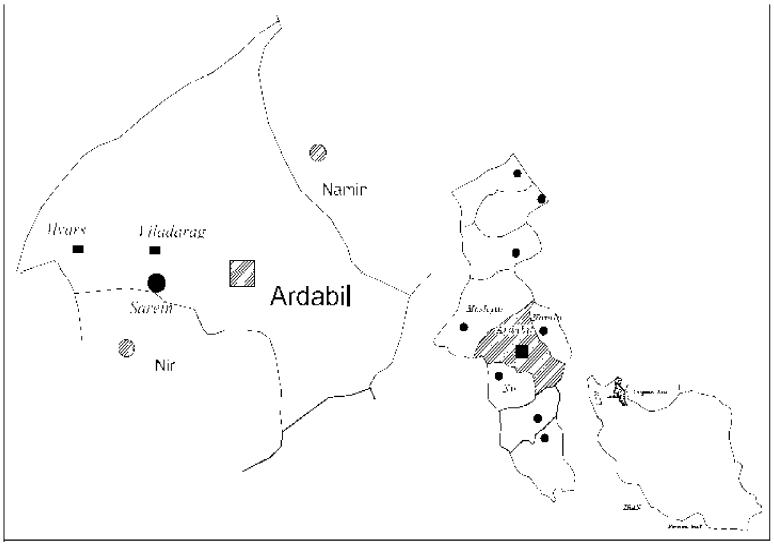

Fig. 1: Location of sampling region

Then the soil samples were placed in an oven at 100^{c} to eliminate any traces of water and were sieved through a 0.5 mm mesh-sized. About 300g of each meshed soil samples were transferred to Marinelli beakers of 1000 cm^3 capacity and left for four weeks to reach radioactive equilibrium [2]. All tests were carried out by the department of the Iran Atomic Energy Organization.

Detection Technique: Gamma spectrometry measurements were performed using high resolution gamma-ray spectrometer system consisting of a High Purity Germanium (HPGe) detector with a relative efficiency of 40%. This system contains P-type intrinsic germanium coaxial detector coupled to an integrated signal processor and multichannel analyser equipped with PC via an interface. (Canbbera, U.S.A)

Detector has a resolution FWHM (full width at half maximum) of 1.9 keV for the 1332 keV gamma line of ^{60}Co. The System was used for the measurement of the energy spectrum of the emitted gamma rays in the energy range between 80keV and 2000 keV. The efficiency was determined by standard multi nuclide source, having the same geometry with the measured samples. The counting time for each sample was 30000 seconds.

The activity concentration of natural radionuclides were determined by using 609 keV photopeak 0f ^{214}Bi for ^{226}Ra and the gamma transition of energy 583 keV due to ^{208}Tl for ^{232}Th . The activities of ^{40}K were determined from the peak of 1460 keV gamma - ray spectrum. [3,4]

The distribution of ^{226}Ra, ^{232}Th and ^{40}K in soil is not uniform. So uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) in Bq/kg. It has been calculated using the following relation [5, 6]:

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_{K} \quad (1)$$

where C_{Ra}, C_{Th} and C_{K} are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively. The index is useful to compare the specific activity of materials containing different concentrations of ^{226}Ra, ^{232}Th and ^{40}K. The external gamma absorbed dose rate in the air at 1 m above ground level was calculated from the measured activities of ^{226}Ra, ^{232}Th and ^{40}K in soil assuming the relation according to the following equation [5,3]:

$$D = 0.462C_{Ra} + 0.604C_{Th} + 0.042C_{K} \quad (2)$$

where D *is* the dose rate in nGy/h and C_{Ra}, C_{Th} and C_{K} are the specific activities (Bq/kg) of ^{226}Ra, ^{232}Th and ^{40}K, respectively. In the above equation, it is assumed that all decay products of ^{226}Ra and ^{232}Th are in radioactive equilibrium with their precursors.

To estimate the annual effective dose, the following must be taken into account: (a) the conversion coefficient from absorbed dose in the air to the effective dose and (b) the indoor occupancy factor. Using the dose rate data obtained from the concentration values of natural radionuclides in soil, adopting the conversion factor of 0.7 Sv/Gy from absorbed dose rate in air to the effective dose and outdoor occupancy factor (0.2) proposed by UNSCEAR [5], the annual effective doses was calculated:

Annual effective dose (Sv) = D×24×365 × 0.7× 0.2 (3)

The external hazard index, H_{ex}, due to the emitted gamma-rays of these samples were defined as [5,7]:

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \quad (4)$$

Where C_{Ra}, C_{Th} and C_K are the specific activities (Bq/kg) of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The value of *this index must be less than unity* in order to keep the radiation hazard insignificant. The maximum value of H_{ex} equal to unity corresponds to the upper limit of radium equivalent activity (370 Bq/kg).

RESULTS AND DISCUSSION

Table 1 shows the average activities of ^{226}Ra, ^{232}Th and ^{40}K radioisotopes for the 20 soil samples collected from different locations in Sarein and surrounded regions.

The geological formations in the study area are formed from volcano-sedimentary rocks. The debris, agriculture soils and other quaternary sediments in Sarain area formed due to alteration, transformation and sedimentation of these rocks .Therefore radioactivity of sediments in this area are related to radioactivity of source rocks and it is expected that activation of radionuclides at mentioned region to be in certain range.

The measured value of activity concentration of ^{40}K varies between 321 at East to 774 Bq/kg at North of Sarein, for ^{226}Ra it varies between 19.1 at West to 134 Bq/kg in Viladarag and for ^{232}Th it varies between 29.2 at East to 83.7 Bq/kg at North of Sarein with mean values of 506.86, 47.46 and 51.24 respectively (Fig 2). The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in collected soil samples were compared with those of similar investigations in other countries and the results were summarized in Table 2. It can be seen that, concentration of ^{226}Ra is 42% higher than world average, ^{232}Th is 41.6% higher than world average and ^{40}K is 7.4% higher than world average.

Table 1: Specific activity of radionuclides in soil samples at different locations in the municipal area of the Sarein district in Ardabil province (Iran).

	Radionuclide elements (Bq/kg)		
Sampling Location	Ra-226	Th-232	K-40
North of Sarein	70	83.7	774
East of Sarein	30.3	29	321
South of Sarein	23.1	35.1	431
West of Sarein	19.1	68.4	537
Center of Sarein	25.9	60.1	443
Villa Darag	134	54.9	624
Alvars	29.8	47.5	418

The results have presented that the highest mean activity concentration of ^{232}Th and ^{40}K are at North region of Sarein. Most of collected samples at north region of Sarein were of the type of Volcano-sedimentary rocks with iron-content cement. Iron-content solutions absorb more radioactive elements [8] and it was predicted that radioactivity of these samples must be more than other volcano-sedimentary rocks. These layers are limited to north region of Sarein. The maximum level of ^{226}Ra was observed in the sample collected from Viladareg. Collected samples from Viladarag were of the type of acid volcanic rocks with biotite and amphibole (dark minerals) and potassium-feldespat (light minerals), because of the existence of uranium minerals, it was expected that these samples show more radioactivity.

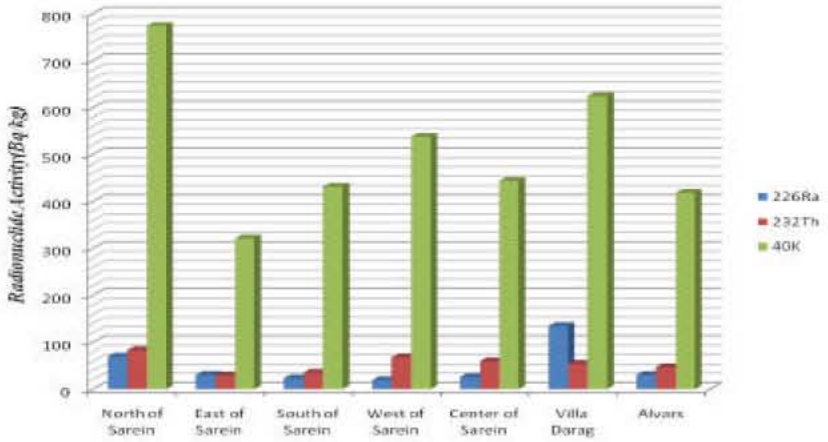

Fig. 2: Activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples of Sarein

Table 2: Comparison of specific activities of radionuclides in soil samples of Sarein city in IRAN with those in other countries as given in [5]

	Specific activity of radionuclides (Bq/kg)		
Samples	^{226}Ra	^{232}Th	^{40}K
Egypt[5]	17	18	320
United States[5]	40	35	370
Spain[9]	39	41	578
Taiwan[10]	30	44	431
South India[11]	35	29.8	117.5
Japan[12]	32	54	794
Bangladesh[13]	42	81	833
Nigeria[14]	16.2	24.4	348
Pakistan(Lahore)[4]	25.8	49.2	561.6
Thailand (Hattai)[15]	48	40	400
Turkey(Istanbul)[79]	21	37	342
Worldwide mean	33	36	474
Present study	47	51	509

Table 3: Radium equivalent activity, dose rate, annual effective dose and external hazard index at different locations in the urban area of the Sarein district in Ardabil province (Iran).

Sampling Location	Radium equivalent activity (Bq/Kg)	Dose Rate (nGy/h)	External Hazard Index	Annual effective dose (10^{-6} Sv)
North	243.87	112.88	0.67	138.44
East	94.24	43.91	0.26	53.85
South	103.46	49.14	0.29	60.27
West	154.50	72.00	0.43	88.30
Center	114.25	53.86	0.32	66.05
Villa Darag	256.19	116.45	0.70	142.81
Alvars	126.99	58.94	0.35	72.28
Average	156.21	72.46	0.43	88.86

The obtained values for radium equivalent activity, gamma dose rate and external hazard index are presented in Table 3. As it can be seen from Table 3, the radium equivalent activity (Ra_{eq}) values for the soil samples varied from 94.24 to 256.19 Bq/kg. These values are less than 370 Bq/kg, which are acceptable for safe use [5]. The measurements show that the values of the absorbed dose rates in the air due to the natural radioactivity in the soil, varies from 43.91 in East of Sarein to 116.45 nGy/h in Viladarag, by average value of 72.46 nGy/h, Considering that the World- averaged value is 57 nGy/h [1]. The calculated values of external hazard index obtained in this study vary from 0.26 to 0.7. The estimated external hazard index for all the samples is lower than unity. Also the calculated values of annual effective dose in this study vary from 0.053 to 0.143 mSv with average of 0.089 mSv. The world- average annual effective dose is approximately 0.5 mSv. The results for average annual effective dose are less than the world wide average value.

CONCLUSIONS

The Obtained Results from the Gamma Spectrometry of Soil Samples from Sarein Town in Iran Indicated That:

- Concentration of ^{226}Ra, ^{232}Th and ^{40}K is respectively 42%, 41.6% and 7.4% higher than world average.
- Considering the values of dose rate, external hazard index and annual effective dose, it is clearly observed that the hazard from external terrestrial radiation is low for inhibition in Sarein and this region is safe for tourists.

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