Measurement of concentrations of the natural radio-activities and Cs-137 in soil samples in the Al-Baha region of Saudi Arabia

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Abstract

Measurement of concentrations of naturally occurring radio nuclides together with Cs-137 deposited in soil have been carried out in the Al-Baha region of the Kingdom of Saudi Arabia. Soil samples collected from about fifty locations have been analyzed using high resolution hyper pure germanium spectrometers. Concentrations of the gamma emitting radio nuclides from naturally occurring uranium-radium and thorium series, Potassium-40, and Cesium-137 have been determined for the selected locations. Gamma-ray dose rates have been calculated from the measured concentrations of natural radioactivity in soil.
Keywords: natural radioactivity, Cs-137 fallout, NORM, radioactivity level in soil, Saudi Arabia.

1 Introduction

Naturally occurring radioactive material (NORM), arising from the decay of uranium-radium and thorium series and potassium-40, has been found in the earth's crust and soil, the underground water and even in living tissues and organs of any living organism. This presence has been recognized since the early 1930's. However it received minimal attention until the last few decades, when the role of terrestrial radiation as the main contributor to the collective effective dose of the world's populations has been recognized UNSCEAR [1–3]. Moreover, measurement of concentrations of some man-made radio nuclides such as Cs-137 and others in soil is too important to evaluate the contribution of

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those man-made radio nuclides to the population's effective dose as well as to evaluate the magnitude of the radioactive fallout in the region.

Measurement of the naturally occurring radiation and radioactivity in Saudi Arabia started in the early 1980's [4–9]. However an intensive and systemic study of the environmental radiation levels and concentrations of natural and man-made radio nuclides in soil, water and other segments of the environment has been started by the Institute of the Atomic Energy Research (IAER) of KACST since 1992. The present work is a part of this systematic study. It is devoted to the study of the concentrations of naturally occurring radio nuclides and Cs-137 in soil, and to the assessment of the gross gamma dose rates in selected locations in Al-Baha region of the Kingdom of Saudi Arabia.

Al-Baha region is situated in the South-Western part of the Kingdom of Saudi Arabia and located between latitudes of 41°E to 42°E and longitudes of 19°N to 20°N. Al-Baha region is situated on a chain of Sarawat Mountains at an elevation of more than 2500 meters above sea level. It consists of six cities which are Al-Baha, Baljurashy, Al-Mandaq, Al-Makhwah, Qelwah, and Al-Qara. Al-Baha city represents the centre of the region. The surface area of Al-Baha region is approximately 36000 square kilometres and divided into 31 administrative centres. Moreover, it is one of the most densely populated provinces in the Kingdom of Saudi Arabia with a population of 411,888 [11].

2 Materials and methods

2.1 Sampling and sample preparation

In this research, fifty soil samples were collected from different locations throughout the Al-Baha region. The coordinates of sampling locations were determined by Global Positioning System (GPS) and the map of Al-Baha region is shown in Figure 1. The samples were randomly selected from undisturbed sites situated in open areas far away from buildings and any other constructions, and the distance between the neighbouring sites was about 5-15 km. The soil sample representing a given site was collected from three different points forming an equilateral triangle of 10m length at a depth ranging from 0 to 30 cm below the surface and then the collected soil from the different points with equal portions was mixed together.

The mixed soil samples were dried in open air for enough time and then dried an oven at 100 ºC for about 24 hours to achieve a constant dry weight. After that, the dried soil samples were ground to obtain homogenous powder and sieved through a mesh size 2mm diameter. Finally, a one liter volume of each soil sample was weighed and transferred to one litre Marinelli beakers [9, 10]. After sealing the Marinelli beaker with a standard volume soil sample they were stored for one month to reach the secular equilibrium between the radium and thorium content of the soil samples and their daughters [9, 10].

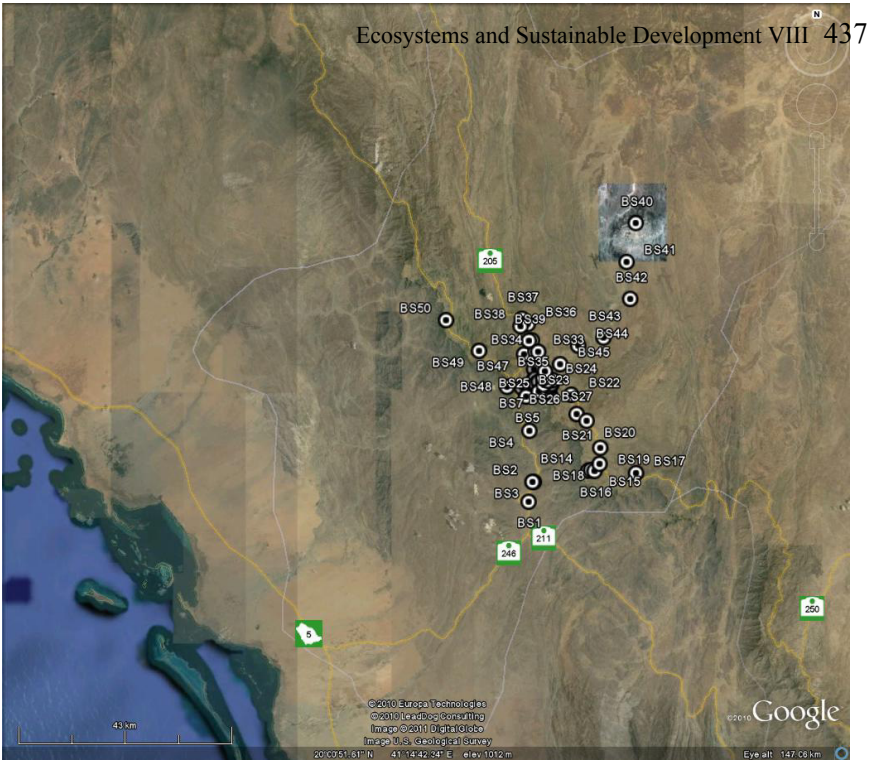

Figure 1: Map of Al-Baha region showing the locations of the collected samples (map produced by using Google Earth software).

2.2 Counting system and calibration

The samples were analyzed spectroscopically and gamma-ray spectra emitted from soil samples were measured using different high resolution hyper-pure germanium spectrometers with energy resolution better than 1.95 keV for the 1332 keV gamma-ray line of Co-60, and with relative efficiencies ranging from 20 to 40%. Energy and efficiency calibration of the spectrometers in the energy range from 60 to 3000 keV have been carried out in the same geometrical configuration used for measuring soil samples using a set of Ba-133, Eu-152, Eu-154, Am-241 and Ra-226 standard sources. All these standard sources were distributed homogeneously in one litre Marinelli beaker.

Gamma-ray spectra emitted from the soil samples were collected in 8000 channels of the PC for a time period of 24 hours to obtain satisfactory statistical errors. The different full-energy peaks of measured spectra were identified and analyzed using Gamma Vision and Genie 2000 analysis software's.

3 Results and discussion

Concentrations for U-238, Th-232, Ra-226, K-40, and Cs-137 of fifty sites, obtained from the analysis of the studied samples are given in table 1, in Bq/Kg

Table 1: Concentrations of radionuclide in soil samples and exposure rate in different sites of Al-Baha Region.

Sample No.	^{238}U (Bq/Kg)	^{232}Th (Bq/Kg)	^{226}Ra (Bq/Kg)	^{40}K (Bq/Kg)	^{137}Cs (Bq/Kg)	Exp. Rate Calc.(μR/hr)	*Longitude North*	*Latitude& East*
1	10.6	10.33	10.63	327.29	0.47	2.85	41 26 306	19 48 108
2	5.68	6.75	6.94	250.89	0.22	2.02	41 26 730	19 50 245
3	9.95	11.6	12.32	408.27	5.02	3.40	41 26 897	19 50 245
4	13.14	11.8	13.05	311.16	2.24	3.03	41 26 346	19 55 737
5	53.83	41.97	36.41	493.62	0.28	7.41	41 25 972	19 59 389
6	7.79	7.06	8.05	386.23	0.25	2.72	41 25 470	20 00 362
7	9.57	8.3	7.62	132.29	0.09	1.65	41 27 390	19 59 919
8	4.74	4.36	3.95	129.91	2.03	1.13	41 27 700	19 59 815
9	2.95	3.65	3.79	134.08	0.53	1.09	41 28 418	20 00 217
10	6.58	5.8	4.9	84.61	0.01	1.09	41 28 701	19 59 510
11	2.76	1.94	2.02	64.92	0.91	0.55	41 28 535	19 59 854
12	4.78	2.72	3.79	120.51	1.08	0.96	41 28 649	20 00 504
13	5.54	4.32	4.62	168.23	5.48	1.34	41 28 836	20 00 722
14	7.21	7.18	5.77	285.87	0.24	2.14	41 33 062	19 51 455
15	10.54	11.58	9.76	319.66	4.87	2.84	41 33 385	19 51 530
16	7.98	12.14	9.46	352	6.96	3.01	41 33 751	19 51 416
17	8.91	14.1	12.2	273.61	0.19	2.97	41 38 387	19 51 208
18	19.67	4.61	4.01	138.41	0.5	1.19	41 34 313	19 52 191
19	2.94	4.46	3.38	189.11	0.07	1.37	41 34 364	19 53 907
20	14.37	16.72	9.07	487.51	0.32	3.90	41 32 804	19 56 793
21	2.96	1.81	2.57	149.44	0.42	0.95	41 31 678	19 57 520
22	7.66	6.67	7.68	310.8	4.38	2.33	41 31 045	19 59 576
23	4.78	5.69	5.52	231.48	3.65	1.77	41 28 975	20 01 129
24	8.78	7.47	8.49	125.37	LLD	1.61	41 28 414	20 01 075
25	14.27	15.91	12.78	322.03	3.61	3.35	41 28 083	20 02 064
26	16.89	14.11	17.06	379.86	LLD	3.75	41 27 905	20 01 355
27	7.61	9.93	10.06	304.24	1.39	2.68	41 27 940	20 00 647
28	11.33	6.36	9.84	267.94	5.28	2.26	41 27 068	20 00 709
29	6.39	6.34	7.35	418.95	3.97	2.77	41 26 727	20 00 833
30	10.94	9.77	10.65	326.31	14.9	2.80	41 26 738	20 00 990
31	9.89	10.87	10.9	368.86	0.81	3.09	41 26 950	20 01 259
32	10.24	8.95	9.86	335	3.56	2.74	41 26 859	20 02 310
33	5.34	4.64	4.84	324.7	5.35	2.07	41 27 012	20 04 148
34	10.23	10.3	9.44	511.69	0.04	3.59	41 27 325	20 04 150
35	6.3	9.41	7.69	439.87	12.39	3.10	41 26 605	20 05 356
36	2.26	2.98	3.11	281.65	0.7	1.66	41 26 149	20 07 094
37	6.32	3.45	5.27	205.17	0.04	1.49	41 25 496	20 07 654
38	2.74	1.35	2.43	279.82	0.34	1.49	41 25 334	20 06 871
39	11.31	10.6	10.93	421.34	9.48	3.30	41 26 266	20 05 319
40	8.73	11.12	7.37	412.71	0.35	3.08	41 38 513	20 17 863
41	18.1	8.44	18.81	141.35	0.11	2.40	41 37 441	20 13 707
42	9.3	12.39	10.5	592.43	0.66	4.16	41 37 826	20 09 762
43	14.47	14.07	15.02	395.25	3.54	3.69	41 34 755	20 05 646
44	6.57	7.14	6.93	185.24	0.64	1.76	41 31 865	20 04 795
45	13.01	12.21	15.27	324.3	8.13	3.26	41 29 799	20 02 818
46	14.03	11.77	13.42	428.37	9.54	3.57	41 27 383	20 00 970
47	2.47	3.3	3.56	248.91	1.67	1.56	41 25 732	20 03 880
48	3.76	3.12	3.87	298.81	0.46	1.79	41 23 815	20 00 431
49	17.78	16.87	16.18	468.09	3.19	4.28	41 20 656	20 04 267
50	20.76	13.42	16.08	366.31	7.96	3.58	41 16 917	20 07 543

for dry soil. The uranium-238 was calculated from the 63.29 keV photo-peak which was completely isolated from any other photo-peaks in the spectra, while the Ra-226 was calculated from, 295.21, 351.92 and 609.31 keV photo-peaks

arising from its daughters in equilibrium. The 269.41, 338.40 and 911.07 keV photo-peaks were used to calculate the concentration of Th-232 in equilibrium with its daughters. The 661.66 and 1460.75 keV gamma-ray lines were used to calculate the concentrations of Cs-137 and K-40 respectively. For Ra-226 and Th-232 the given concentrations are the average ones for the three most intensive photo-peaks. The relative errors of the measured concentrations lie between 5% for the higher experimental concentrations and increases to about 20% for lower concentrations.

The minimum and maximum concentrations for U-238, Th-232, Ra-226, K-40, and Cs-137 together with the mean values over the whole region are given in table 2.The U-238 concentrations ranged from 2.26 Bq/kg to 53.93 Bq/kg with average value of 9.89Bq/kg, The Th-232 concentrations ranged from 1.35 Bq/kg to 41.97 Bq/kg with average value of 9.04Bq/kg, The Ra-226 concentrations ranged from 2.02 Bq/kg to 36.41 Bq/kg with average value of 9.10Bq/kg, The K-40 concentrations ranged from 64.92 Bq/kg to 592.43 Bq/kg with average value of 298.49Bq/kg, and The Cs-137 concentrations ranged from 0.01 Bq/kg to 14.90 Bq/kg with average value of 2.88Bq/kg. For the radio nuclides U-238, Th-232, Ra-226, and K-40 the highest concentration were found in soil sample number 5, this may due to the geological formation of the location.

Table 2: The range and average concentrations of radio nuclides and exposure rate in soil samples of Al-Baha region.

Sample No.	^{238}U (Bq/Kg)	^{232}Th (Bq/Kg)	^{226}Ra (Bq/Kg)	^{40}K (Bq/Kg)	^{137}C (Bq/Kg)	Exp. Rate Calc. (μR/hr)
Avg.	9.89	9.04	9.10	298.49	2.88	2.53
Min.	2.26	1.35	2.02	64.92	0.01	0.51
Max.	53.83	41.97	36.41	592.43	14.9	7.85

Table 3 shows comparison of concentration ranges of U-238, Th-232, Ra-226, K-40 and Cs-137 in the studied soil samples with the national and the international studies. It is seen from this table that the mean concentrations for all naturally occurring radio nuclides averaged over in the whole region are comparatively approximately similar to the national level [8, 12, 13]. Moreover, the mean concentrations for all naturally occurring radio nuclides averaged over in the whole region were found less than the international level for soil in United States, China, and Japan [2].

The gamma ray effective dose for each location, calculated from measured concentrations of Th-232, Ra-226 and K-40 and the conversion factors, that are used to convert concentrations to dose rate, given in reference[15] and corrected to give the effective dose rate. Using the mean values of the calculated dose rates (2.53 μR/hr) the average annual effective dose for Al-Baha region was evaluated to be 0.21mSv/year, which is comparatively less than the annual average dose (worldwide) from all natural sources of exposure, which is equal to 2.4 mSv/year [2, 3].

Table 3: Comparison of average concentrations of radio nuclides in soil samples of Al-Baha region to the national and international studies [2, 8, 12, 13].

Region	^{238}U (Bq/Kg)	^{232}Th	^{226}Ra	^{40}K	^{137}Cs
This work	9.89	9.04	9.10	298.49	2.88
Riyadh Region	12.91	17.79	17.91	200.9	2.18
Eastern Region	8.82	3.08	9.79	136.44	0.66
Tabouk Region	15.49	21.49	15.08	232.9	1.10
United State	35	35	40	370	-
China	33	41	32	440	-
Japan	29	28	33	310	-

4 Conclusions

The level of natural radioactivity and man-made radionuclide such as Cs-137 in soil samples from Al-Baha region has been measured using gamma-ray spectroscopy. The mean concentrations for all naturally occurring radio nuclides averaged over in the whole region were found less than the international level for soil in United States, China, and Japan. Moreover, the average annual effective dose for Al-Baha region was found comparatively less than the world average.

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