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Concentrations of Radionuclides in Soil and Exposure Rates of Different Provinces in Saudi Arabia

A.S. AL-KHELIEWI and K.S. AL-MOGABES
Institute of Atomic Energy Research (KACST)
P.O. Box 6086, Riyadh 11442, Saudi Arabia

ABSTRACT. Measurements of concentrations of naturally occurring and man-made radionuclides deposited in soil have been carried out in different provinces of the Kingdom of Saudi Arabia namely Western province, Eastern province, Central province, and Northern province. 220 samples from different sites have been carefully collected with the help of the global position system (GPS-100) in most of the sites. Hyper pure germanium spectrometers have been used to measure the concentrations of gamma emitting radionuclides from both uranium-radium series, thorium series, ^{40}K, and ^{137}Cs. Exposure rates have been measured 1 m above the soil surface and compared with those calculated based on the measured concentrations of gamma emitters radionuclides in soil. It has been found that the specific activities as well as the exposure rates are within the international averages.

Introduction

The total picture of natural background exposure is incredibly complex, with external radiation from space and from the ground, and with significant radioisotopes of more than a dozen primordial series elements and several cosmogenic radionuclides being inhaled and ingested[1]. Exposure to terrestrial radiation is of great importance, since most of the collective effective doses to the world populations are due to this radiation. The terrestrial background radiation emitted from soil surface to the surrounding environment arise mainly from naturally-occurring radionuclides[2]. Natural background radiation consists mainly of: radon and radon daughters, cosmic rays, cosmogenic radiation, terrestrial radiation and internal radiation (potassium-40, carbon-14, and other naturally-occurring radionuclides in the body[3].

Measurements of naturally-occurring and some man-made radionuclides in Saudi Arabia have been carried out by Martin[4] in 1982 at the campus of King Fahad University of Petroleum and Minerals in the Eastern province of Saudi Arabia. In 1984, Owain[5] measured the radiation level using TLD chips at the campus of King Saud University in Riyadh. In 1987 Al-Haj[6] measured the concentration of gamma emitting radionuclides in some locations of Riyadh region. The results of these studies are relatively consistent with the results obtained in this paper.

The concentration measurements of naturally-occurring and some man-made radionuclides are reported in this paper and can be used as a reference data to evaluate any future change of radiation levels.

Methodology and Techniques of Measurements

In this work, 220 samples have been collected from Western, Eastern, Central, and Northern provinces. Most of the collected samples were determined using a global positioning system (GARMIN GPS 100 SRVY II) which is a satellite based positioning and navigation system that provides precise position, velocity and time information. Thus, for future reference, all collection sites can be predetermined by using the receiver's computed position to navigate to a location whose coordinates have been previously entered. All samples from the Central province have been collected from sites without using GPS100 system and these sites are depicted in Fig. 1. The large number of samples (92) collected from the central province comparing to the other provinces is due to the large area of the region. Some of the measurements of these samples are represented in Table 1.

Measurements of the background radiation level in selected sites from which samples were collected have been accomplished using model ESP-2 Eberline smart portable radiation survey meter with a G.M. detector of HP-270 model. The measurements were taken at one meter above the soil surface.

All soil samples should be representative for their sites so they were collected at a depth up to 20 cm from three different points forming an equilateral triangle 10 meter length. One-litre Marinelli beakers made of polyethylene were used for samples counting. Each Marinelli beaker was sealed and stored for one month before counting to allow time for some radionuclides (^{238}U and ^{232}Th) to reach secular equilibrium with their daughters[7]. Some samples need to be crushed and grounded in order to assure the constancy of geometrical configuration and homogeneity of the soil samples.

Due to the large number of samples and to reduce the measurement time, soil samples were analyzed spectroscopically using three hyper pure germanium

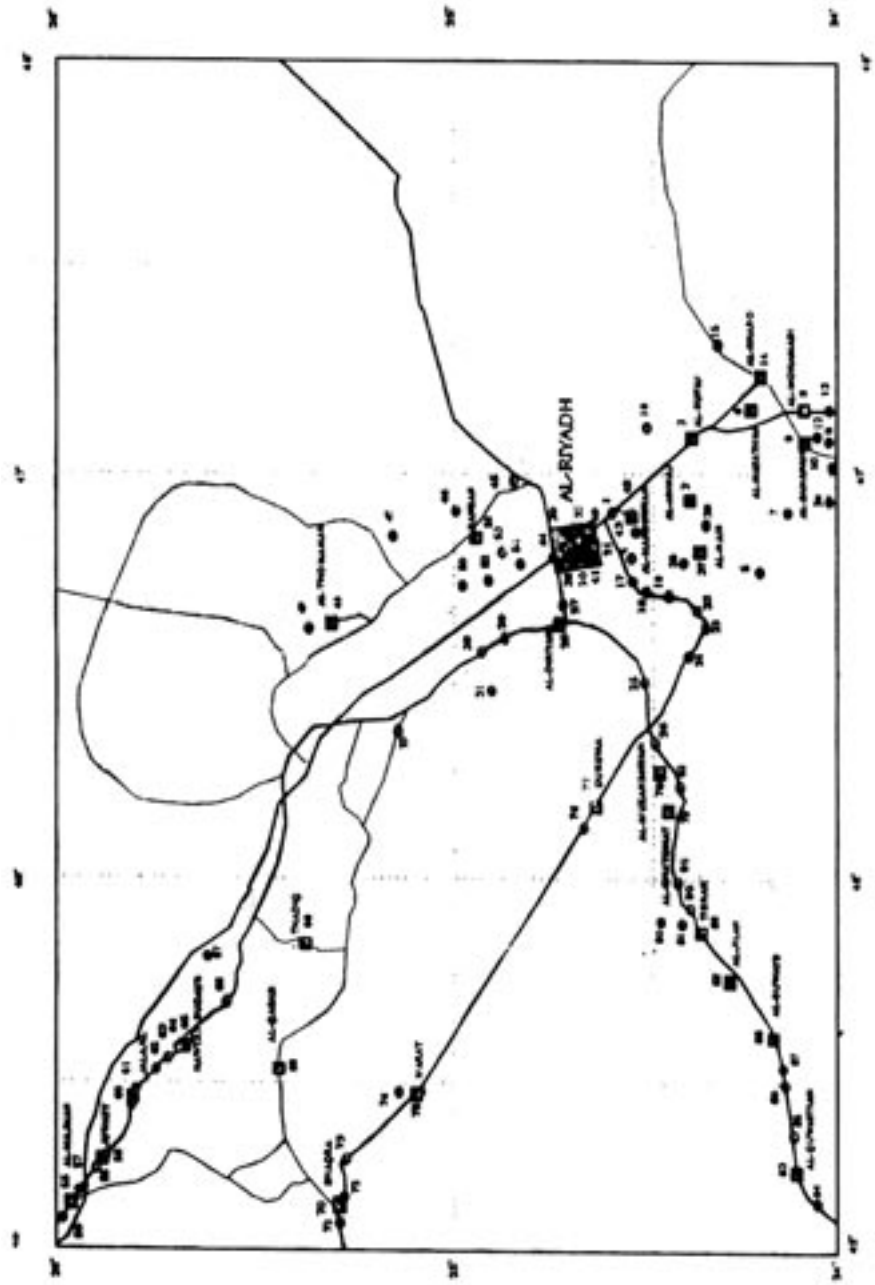

Fig. 1. The selected sampling sites in the Riyadh region.

TABLE 1. Concentration of radionuclides in soil samples in different provinces in Saudi Arabia.

	Northern Province					Western Province					Northern Province					Western Province				
	Specific Activity (Bq/Kg)					Specific Activity (Bq/Kg)					Specific Activity (Bq/Kg)					Specific Activity (Bq/Kg)				
	U238	Th232	Ra226	K40	Cs137	U238	Th232	Ra226	K40	Cs137	U238	Th232	Ra226	K40	Cs137	U238	Th232	Ra226	K40	Cs137
1	18.74	32.55	18.74	289.07	LLD	5.59	12.7	11.4	312.67	0.18	7.79	4.20	4.82	136.81	LLD	13.13	14.35	12.83	148.5	1.93
2	9.04	10.23	8.37	95.30	LLD	5.54	7.41	8.23	352.18	LLD	2.81	1.83	2.38	104.89	0.28	8.63	13.04	12.01	231.6	0.94
3	10.37	11.94	5.80	167.60	0.22	5.24	7.82	8.06	292.21	0.32	3.88	3.27	4.17	122.81	0.71	13.2	16.94	15.77	244.0	3.85
4	14.57	16.17	8.59	155.14	LLD	2.26	4.77	6.11	319.46	0.01	4.22	1.88	2.62	114.47	0.57	20.82	17.13	15.43	284.80	0.44
5	8.96	9.42	6.99	210.93	0.07	3.35	5.28	5.85	278.76	0.06	7.13	3.85	7.61	153.04	1.37	8.56	12.77	12.59	289.00	5.73
6	10.52	13.43	10.09	324.99	0.34	2.90	5.83	7.25	329.68	0.42	10.7	2.67	5.85	159.06	2.34	LLD	13.72	13.60	253.00	18.98
7	11.70	17.18	11.538	171.29	LLD	2.37	5.03	6.37	299.80	LLD	6.70	4.75	5.04	221.51	2.26	13.59	11.60	12.78	302.70	0.65
8	13.83	15.60	19.38	181.26	LLD	6.72	10.0	10.9	333.23	LLD	10.8	7.11	7.10	212.02	1.31	16.80	18.80	23.30	370.00	22.25
9	23.86	27.99	21.55	291.97	LLD	3.72	5.78	7.58	313.31	LLD	6.95	3.46	7.43	129.56	0.90	16.62	19.07	20.07	251.50	0.88
10	14.15	17.22	13.27	207.79	LLD	1.40	5.85	7.24	282.09	0.69	5.91	2.87	3.73	150.89	3.05	13.34	11.71	14.53	270.00	0.81
11	14.49	18.99	11.06	202.47	LLD	3.77	5.18	6.74	245.17	1.47	9.22	3.40	16.5	161.50	1.86	12.36	17.68	22.78	316.00	8.10
12	11.06	16.79	10.92	157.40	LLD	3.79	6.43	8.06	264.77	0.16	7.48	4.01	5.10	113.49	1.03	11.65	12.71	14.59	268.30	1.47
13	14.70	19.39	12.31	373.63	0.21	5.57	7.46	13.3	273.21	0.55	5.32	4.41	5.18	107.65	0.41	15.64	14.22	17.57	325.30	1.02
14	23.66	46.19	25.34	346.96	0.24	22.4	5.49	40.5	206.24	0.13	4.04	2.43	3.54	150.05	0.42	15.32	11.21	11.70	151.80	1.66
15	11.84	14.08	10.10	115.11	LLD	11.8	5.62	32.2	171.7	2.25	3.53	2.17	3.09	143.27	0.23	LLD	12.28	13.31	172.50	3.13
16	12.04	15.77	11.55	147.84	LLD	63.7	1.87	59.6	48.57	0.07	5.96	1.90	3.91	100.93	0.15	15.33	20.69	17.79	200.00	0.57
17	13.70	18.09	16.37	212.37	LLD	6.21	9.06	11.1	266.90	0.12	6.18	2.24	4.74	116.89	0.09	11.83	19.14	28.83	25.80	10.14

TABLE 1. (Cont.).

	Northern Province					Western Province					Northern Province					Western Province				
	Specific Activity (Bq/Kg)					Specific Activity (Bq/Kg)					Specific Activity (Bq/Kg)					Specific Activity (Bq/Kg)				
	U238	Th232	Ra226	K40	Cs137	U238	Th232	Ra226	K40	Cs137	U238	Th232	Ra226	K40	Cs137	U238	Th232	Ra226	K40	Cs137
18	10.21	19.60	12.68	193.04	0.23	5.53	4.06	6.26	246.63	0.07	5.87	2.52	5.68	117.61	1.06	23.0	18.80	20.70	233.60	0.49
19	15.14	19.98	13.39	189.61	LLD	5.91	5.23	10.4	254.52	0.15	9.96	2.87	7.44	147.95	0.02	LLD	4.75	10.51	58.40	0.55
20	20.95	31.162	19.94	348.98	LLD	44.2	7.92	25.7	214.15	0.71	7.76	2.06	5.65	135.79	LLD	18.07	19.23	19.64	17.43	1.83
21	9.75	17.81	10.55	227.83	LLD	4.11	8.74	9.05	341.50	0.08	7.56	3.06	6.59	152.09	LLD	21.37	24.0	22.02	251.10	1.43
22	15.35	19.91	16.74	231.74	0.67	34.6	1.84	7.62	89.01	0.08	4.87	4.39	5.53	138.90	0.44	18.16	19.81	20.50	247.90	1.83
23	16.77	21.24	15.76	185.00	LLD	4.68	5.55	7.18	335.97	0.16	5.87	2.54	6.45	135.42	0.37	LLD	14.03	14.52	158.00	5.61
24	8.53	14.12	9.00	110.87	LLD	13.3	8.33	9.02	317.17	0.15	7.41	2.69	6.09	184.44	0.79	LLD	18.26	16.33	194.70	1.21
25	29.42	56.70	28.56	425.83	LLD	12.6	7.89	8.73	300.14	0.14	13.5	2.87	7.92	148.25	0.37	16.71	17.63	17.01	181.10	1.49
26	17.49	22.03	17.73	237.85	LLD	5.38	4.76	4.85	184.03	0.09	16.2	3.01	16.9	109.09	0.37	LLD	8.36	16.94	56.10	3.87
27	12.00	15.79	11.44	166.41	LLD	4.72	8.44	9.72	314.69	0.14	8.49	3.37	6.82	124.99	0.44	19.83	12.87	14.16	99.70	3.63
28	11.01	12.03	8.92	142.64	LLD	4.09	8.36	8.27	328.23	0.01	9.17	2.59	7.37	165.11	0.32	LLD	15.58	14.72	243.10	14.90
29	21.39	23.44	19.29	408.45	LLD	12.4	12.4	10.2	390.11	LLD	5.83	2.56	5.80	177.57	0.50	13.80	15.85	17.14	178.30	3.13
30	14.83	22.33	15.17	172.48	LLD	8.52	11.6	12.7	387.74	0.06	6.16	2.58	5.73	140.00	1.47	LLD	12.60	13.48	79.40	8.05
31	18.73	33.86	21.95	422.18	0.45	4.84	6.68	9.02	274.76	0.10	9.98	2.59	5.97	131.80	0.12	12.16	12.84	12.40	227.80	1.69
32	27.30	31.79	23.56	508.70	LLD	3.17	6.65	7.83	273.46	0.28	14.7	2.48	32.3	134.77	0.98	19.95	19.70	19.98	126.00	1.95
33	15.61	17.72	17.12	181.95	LLD	5.06	6.93	6.76	42.51	0.48	21.5	3.31	96.6	127.92	1.51	15.89	18.71	29.21	271.40	12.58
34	20.46	25.12	17.44	221.78	LLD	6.45	5.77	10.1	230.24	0.28	13.7	3.03	19.4	134.66	0.68	LLD	18.91	21.69	154.10	27.87

TABLE 1. (Cont.).

	Northern Province					Western Province					Northern Province					Western Province				
	Specific Activity (Bq/Kg)					Specific Activity (Bq/Kg)					Specific Activity (Bq/Kg)					Specific Activity (Bq/Kg)				
	U238	Th232	Ra226	K40	Cs137	U238	Th232	Ra226	K40	Cs137	U238	Th232	Ra226	K40	Cs137	U238	Th232	Ra226	K40	Cs137
35	12.64	17.82	13.19	181.56	0.68	8.98	6.50	10.7	263.91	0.92	6.24	2.43	7.56	134.65	0.26	LLD	16.23	18.10	121.90	5.61
36	14.94	26.86	16.09	328.67	0.42	4.98	5.34	7.83	251.98	0.40	19.5	3.89	17.9	125.46	0.15	LLD	10.45	9.58	176.80	1.37
37	22.93	38.05	22.30	311.23	LLD	4.53	6.55	7.57	247.70	0.34	19.6	3.48	19.2	12.77	0.06	12.85	12.15	9.97	130.80	0.96
38	7.38	12.39	7.75	125.77	0.24						13.5	3.29	7.33	100.75	0.70	17.50	21.27	18.90	161.10	11.97
39	14.65	24.81	14.53	303.88	0.68						8.58	2.79	8.01	164.29	0.22	22.21	20.10	21.53	135.60	5.85
40	8.19	11.63	10.28	176.01	0.06						10.4	2.42	5.50	144.45	0.04	11.87	13.0	18.54	160.70	3.05
41	12.84	18.98	10.98	176.33	LLD						7.65	2.34	5.37	152.42	0.64	11.16	19.53	18.87	114.00	5.19
42	28.01	28.70	25.74	266.17	LLD						6.66	2.49	5.15	108.32	0.24	17.82	15.20	15.01	268.00	4.18
43	29.66	28.46	34.31	242.00	LLD						5.29	.05	4.34	97.46	0.43	14.42	14.16	13.77	178.30	1.92
44	13.75	22.53	13.79	266.68	LLD						13.2	5.07	9.41	157.64	LLD	15.68	5.38	11.70	41.90	2.93
45	14.79	19.08	14.03	206.33	LLD											16.88	15.22	14.91	113.00	1.48
46	11.97	17.26	11.76	122.10	LLD											18.61	16.28	14.90	100.90	2.94
47	14.30	17.91	12.50	213.66	0.24											LLD	15.08	12.65	187.30	4.17

spectrometers with energy resolution better than 1.95 KeV for the 1332 KeV gamma ray line and with relative efficiency ranging from 15 up to 40%. The different photo peaks were identified and analyzed using software Model A-30 BI ACDCAM 100 GELIGAM.

Energy and efficiency calibration[8] of the three used hyperpure germanium spectrometers in the energy range from 60 up to 3000 KeV were determined using a set of standard sources which are ^{133}Ba, ^{152}Eu, ^{154}Eu, ^{241}Am, and ^{226}Ra in the same geometrical configuration in which all soil samples were prepared. All these sources were distributed homogeneously in one litre Marinelli beakers.

The given concentrations were calculated using the gamma ray spectra emitted from the studied soil samples which were collected for a time period of about 24 hours. The 661.67 KeV photo peak was used to account for the concentration of ^{137}Cs and the 1460.8 KeV photo peak for ^{40}K. Concentrations of the ^{226}Ra and ^{232}Th radionuclides were calculated separately for different photopeaks and the given values are the average ones for the most intensive characteristic photo peaks for each nuclide. Concentrations of ^{226}Ra were calculated from 295.21, 351.92, 609.31, and 1764.49 KeV photopeaks respectively, while concentrations of ^{232}Th were calculated from 269.41, 338.40, 911.07, and 2614.53 KeV photopeaks respectively. All these photopeaks of ^{226}Ra and ^{232}Th are due to their daughters in equilibrium. For ^{238}U, a completely isolated 63.29 KeV photopeak was used to find the concentrations throughout the collected samples. The relative error of the measured concentrations ranged from 5 to 18% for different radionuclides and different concentrations with tendency to increase as the concentration decreases.

The specific activity (SA) was calculated according to the following equation

$$S.A.\ (Bq/kg) = C / \eta \,.\, f \,.\, w$$

Where

- C : the net counts per second under the photopeak area of interest.
- η : the photopeak efficiency in the beaker-detector fixed configuration.
- f : a fraction representing number of photons with the certain energy per one decay.
- w : the sample weight in kg.

The calculated exposure rates (ER) one meter above the soil surface were carried out using the experimentally obtained concentrations and conversion factors D_i of concentration to dose rate given in Ref.[9] for Ra-226, Th-232, K-40, and Cs-137.

The used equation is:

$$ER = \sum_i D_i \, (S.A)_i$$

Where $(S.A)_i$ is the concentrations (i.e. specific activity) for the i radionuclides and summation is carried out for ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs.

Results and Discussion

Results of the analyzed samples are given in Table 1, which shows the averaged measured radionuclides concentration in Bq/Kg for dry soil of ^{238}U, ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs. Most of specific activities were rounded to two digits.

It is clear that natural radioactivity concentration is within normal international range. From Table 1, it is noticed that equilibrium between ^{238}U and ^{226}Ra can be considered satisfactory in some samples while inequilibrium is clear in others. It is also noticed that the mean concentration of ^{137}Cs is quite low in most provinces. This may arise from the fact that there was a little effect of Chernobyl fallout on the area, so a very low concentrations of ^{137}Cs were deposited and the high rate of the wash down of ^{137}Cs due to the nature of soil in the area beside other meteorological factors.

The maximum, minimum, and averaged concentrations of the studied radionuclides in Western, Northern, Eastern, and Central provinces are given in Tables 3, 4, 5, and 6 respectively. The maximum concentration of Cs-137 radionuclide of 22.3 Bq/Kg, was found in a single location in the central part. This relatively high value of Cs-137 concentration was found in a very limited cultivated area with comparatively lower altitude with respect to other surrounding areas. Thus, relatively high concentrations may be attributed to wash down of Cs-137.

The maximum concentration of ^{40}K radionuclides was found in the northern province which was 509 Bq/Kg. The maximum value of the average calculated dose rate, was found in the Northern Province which was 0.26 mGy/year, which is comparatively much lower than the world average which is 0.46 mGy/year. The minimum value of the average calculated exposure rate was found in the northern province which was 0.122 mGy/year. According to the UNSCEAR REPORT OF 1993[2], larger surveys of exposure rates have been conducted during the last few decades in many countries in which half of the population of the world is represented, the international average dose rates vary from 0.21 to 0.74 mGy/year which assures that all calculated exposure rates in all provinces of the Kingdom are within the international average values.

TABLE 2. Longitude and latitude of samples location collected from different provinces.

Sample no.	Northern Province		Western Province		Eastern Province	
	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude
	East	North	East	North	East	North
1	36 : 29 : 836	28 : 34 : 969	39 : 31 : 836	21 : 21 : 574	49 : 09 : 961	25 : 21 : 744
2	36 : 24 : 893	28 : 35 : 136	39 : 27 : 247	21 : 21 : 002	49 : 15 : 303	25: 22 : 4 83
3	36 : 29 : 825	28 : 20 : 214	39 : 24 : 880	21 : 23 : 590	49 : 31 : 198	25 : 20 : 833
4	36 : 35 : 042	28 : 25 : 009	39 : 20 :180	21 : 25 : 138	49 : 29 : 678	25 : 17 : 988
5	36 : 20 : 038	28 : 25 : 058	39 : 16 : 566	21 : 27 : 496	49 : 37 : 442	25 : 24 : 145
6	36 : 34 : 958	28 : 09 : 989	39 : 15 : 599	21 : 30 :195	49 : 39 : 543	25 : 25 : 867
7	36 : 45 : 008	28 : 25 : 006	39 : 16 : 019	21 : 31 : 384	49 : 40 : 720	25 : 24 : 610
8	36 : 25 : 004	28 : 39 : 788	39 : 16 : 864	21 : 31 : 368	49 : 41 : 418	25 : 24 : 889
9	36 : 30 : 015	28 : 25 : 134	39 : 13 : 745	21 : 34 : 156	49 : 09 : 200	25 : 25 : 540
10	36 : 19 : 981	28 : 34 : 966	39 : 13 : 846	21 : 37 : 872	49 : 40 : 793	25 : 25 : 418
11	36 : 21 : 995	28 : 09 : 400	39 : 12 : 959	21 : 39 : 109	49 : 35 : 480	25 : 30 : 933
12	36 : 45 : 002	28 : 20 : 004	39 : 11 : 939	21 : 38 : 263	49 : 32 : 749	25 : 36 : 195
13	36 : 34 : 950	28 : 35 : 001	39 : 08 : 944	21 : 39 : 994	49 : 33 : 998	25 : 49 : 146
14	36 : 40 : 158	28 : 09 : 966	39 : 07 : 086	21 : 40 : 516	49 : 39 : 518	25 : 56 : 174
15	36 : 20 : 173	28 : 15 : 005	39 : 07 : 088	21 : 44 :149	49 : 38 : 284	25 : 58 : 789
16	36 : 30 : 026	28 : 29 : 917	39 : 05 : 757	21 : 42 : 752	49 : 59 : 238	26 : 20 : 634
17	36 : 20 : 047	28 : 39 : 735	39 : 05 : 955	21 : 40 : 770	50 : 01 : 638	26 : 23 : 228
18	36 : 50 : 001	28 : 29 : 987	39 : 06 : 002	21 : 38 : 264	50 : 00 : 997	26 : 25 : 217
19	36 : 40 : 046	28 : 20 : 040	39 : 06 : 174	21 : 36 : 006	50 : 06 : 055	26 : 27 : 571
20	36 : 49 : 448	28 : 40 : 358	39 : 07 : 314	21 : 33 : 345	50 : 07 : 782	26 : 29 : 443
21	36 : 39 : 988	28 : 34 : 555	39 : 09 : 351	21 : 32 : 250	50 : 06 : 228	26 : 24 : 762
22	36 : 35 : 016	28 : 19 : 821	39 : 09 : 176	21 : 31 : 449	50 : 05 : 439	26 : 24 : 290
23	36 : 34 : 860	28 : 30 : 614	39 : 10 : 612	21 : 27 : 617	50 : 07 : 497	26 : 24 : 306
24	36 : 50 : 170	28 : 24 : 834	39 : 11 : 072	21 : 26 : 615	50 : 10 : 932	26 : 21 : 930
25	36 : 29 : 996	28 : 40 : 000	39 : 11 : 787	21 : 23 : 998	50 : 11 : 465	26 : 15 : 856
26	36 : 19 : 814	28 : 29 : 905	39 : 12 : 327	21 : 27 : 054	50 : 09 : 767	26 : 18 : 139
27	36 : 50 : 010	28 : 10 : 010	39 : 14 : 339	21 : 29 : 095	50 : 10 : 793	26 : 19 : 106

Table 2. (Cont.).

Sample no.	Northern Province		Western Province		Eastern Province	
	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude
	East	North	East	North	East	North
28	36 : 24 : 947	28 : 25 : 099	39 : 15 : 041	21 : 29 : 785	50 : 11 : 556	26 : 20 : 419
29	36 : 50 : 002	28 : 14 : 998	39 : 13 : 411	21 : 29 : 464	50 : 09 : 802	26 : 23 : 393
30	36 : 40 ; 008	28 : 25 : 019	39 : 12 : 224	21 : 31 : 215	50 : 08 : 377	26 : 24 : 446
31	36 : 40 : 261	28 : 40 : 032	39 : 10 : 589	21 : 30 : 825	50 : 03 : 487	26 : 28 : 673
32	36 ; 44 : 889	28 ; 39 : 908	39 : 10 : 514	21 : 32 : 635	50 : 00 : 269	26 : 33 : 032
33	36 ; 29 : 996	28 : 14 : 989	39 : 09 : 524	21 : 35 : 818	49 : 59 : 483	26 : 34 : 060
34	36 : 20 : 016	28 : 20 : 005	39 : 08 : 309	21 : 38 : 699	49 : 59 : 686	26 : 32 : 837
35	36 : 30 : 206	28 : 10 : 014	39 : 08 : 544	21 : 46 : 789	50 : 01 : 540	26 : 29 : 464
36	36 : 49 : 998	28 : 35 : 046	39 : 08 : 972	21 : 50 : 403	50 : 08 : 929	26 : 19 : 979
37	36 : 39 : 992	28 : 29 : 993	39 : 07 : 288	21 : 53 : 705	50 : 08 : 723	26 : 18 : 988
38	36 : 24 : 990	28 : 09 : 788			50 : 10 : 947	26 : 16 : 316
39	36 : 35 : 000	28 : 40 : 000			50 : 11 : 960	26 : 18 : 883
40	36 : 35 : 025	28 : 14 : 984			50 : 13 : 171	26 : 17 : 752
41	36 : 44 : 341	28 : 14 : 484			50 : 12 : 306	26 : 12 : 274
42	36 : 40 : 558	28 : 15 : 072			50 : 09 : 623	26 : 10 : 980
43	36 : 49 : 989	28 : 19 : 989			50 : 07 : 547	26 : 05 : 554
44	36 : 45 : 086	28 : 29 : 914			50 : 03 : 187	26: 11 : 704
45	36 : 24 : 967	28 : 30 : 038				
46	36 : 44 : 985	28 : 09 : 989				
47	36 : 24 : 979	28 : 19 : 986				

Table 3. The range and average values of concentrations of measured radionuclides and exposure rates in western province.

	Range and average values in Bq/Kg					Exp. rate μR/hr
	U - 238	Ra - 226	Th - 232	K - 40	Cs - 137	Calculated
Minimum value	1.40	4.85	1.84	48.57	0.01	0.65
Maximum value	63.72	59.65	12.69	421.51	2.25	4.11
Average value	9.46	11.78	6.78	276.89	0.34	2.45

TABLE 4. The range and average values of concentrations of measured radionuclides and exposure rates in northern province.

	Range and average values in Bq/Kg					Exp. rate μR/hr
	U - 238	Ra - 226	Th - 232	K - 40	Cs - 137	Calculated
Minimum value	7.38	5.81	9.43	95.30	0.0	1.66
Maximum value	29.66	34.32	56.71	508.7	0.68	7.64
Average value	15.49	15.08	21.49	232.9	0.103	3.46

TABLE 5. The range and average values of concentrations of measured radionuclides and exposure rates in eastern province.

	Range and average values in Bq/Kg					Exp. rate μR/hr
	U - 238	Ra - 226	Th - 232	K - 40	Cs - 137	Calculated
Minimum value	2.81	2.38	1.83	12.77	0.04	0.89
Maximum value	21.46	96.58	7.11	221.51	3.05	7.61
Average value	8.82	9.79	3.08	136.44	0.66	1.59

TABLE 6. The range and average values of concentrations of measured radionuclides and exposure rates in central province.

	Range and average values in Bq/Kg					Exp. rate μR/hr
	U - 238	Ra - 226	Th - 232	K - 40	Cs - 137	Calculated
Minimum value	7.06	7.36	4.75	17.43	0.3	1.17
Maximum value	38.1	28.83	30.28	504.3	22.25	5.13
Average value	12.91	17.91	17.79	200.9	4.76	3.23

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تراكيز النـويدات المشعـة في التربـة ومعـدلات الجرعـة لمناطق مختلفـة في المملكة العربية السعودية

عبد اللّه صالح الخليوي و خالد سعد المقبس

معهد بحوث الطاقـة الذرية ، مدينة الملك عبد العزيز للعلوم والتقنية

الريـــاض – المملكة العربية السعودية

المستخلص . تم قياس تركيزات النويدات المشعة الطبيعية والتي من صنع الإنسان المترسبة في التربة في مناطق مختلفة من المملكة العربية السعودية ، وهذه المناطق تشمل المنطقة الغربية ، والمنطقة الشرقية ، والمنطقة الوسطى ، والمنطقة الشمالية . تم تجميع ٢٢٠ عينة من مواقع مختلفة باستخدام نظام تحديد المواقع في معظم المواقع . تم استخدام كواشف الجرمانيوم عالية النقاوة لقياس تراكيز النويدات المشعة الباعثة لأشعة جاما من سلسلتي اليورانيوم والثوريوم، وكذلك البوتاسيوم-٤٠، والسيزيوم-١٣٧ . تم قياس معدلات التعرض على ارتفاع متر واحد من سطح التربة ، وقورنت تلك المعدلات مع المعدلات التي حسبت بناء على تراكيز النويدات المشعة الباعثة لأشعة جاما في التربة . وقد وجد أن الأنشطة الإشعاعية ومعدلات الجرعة تقع ضمن المتوسط العالمي ، كذلك وجد أن أكبر معدل تعرض مقيس كان في المنطقة الشرقية .