Analysis of natural radioactivity and artificial radionuclides in soil samples in the Najran region of Saudi Arabia

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Abstract

Concentrations of ^{238}U, ^{232}Th, ^{226}Ra, ^{40}K, and ^{137}Cs in 43 soil samples obtained from Najran region were analyzed using high resolution hyper pure germanium spectrometers. The activity ranged from 1.08 Bq/Kg to 7.76 Bq/Kg, 8.56 Bq/Kg to 49.09 Bq/Kg, 8.67 Bq/Kg to 41.54 Bq/Kg, 202.85 Bq/Kg to 993.07 Bq/Kg and 0.08 Bq/Kg to 7.65 Bq/Kg, respectively. The mean concentrations for all naturally occurring radio-nuclides averaged over the whole region were found to be less than the international level for soil in the United States, China, and Japan. Moreover, the average annual effective dose for Najran region was evaluated to be 0.33mSv/year, which is comparatively less than the annual average dose worldwide from all natural sources of exposure (2.40 mSv/year).
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 living organisms. This presence has been recognized since the early 1930s. 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 radionuclides such as Cs-137 and others in soil is too important to evaluate the contribution of those

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man-made radionuclides 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 1980s [4–9]. However, an intensive and systemic study of the environmental radiation levels and concentrations of natural and man-made radionuclides in soil, water and other segments of the environment has been started by the Institute of 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 radionuclides and Cs-137 in soil, and to the assessment of the gross gamma dose rates in selected locations in the Najran region of the Kingdom of Saudi Arabia.

Najran region is situated in the South-Western part of the Kingdom of Saudi Arabia and located between latitudes of 44°E to 52°E and longitudes of 17°N to 20°N. Najran region consists of seven governorates with three geographical environments; a series of mountains in the west with elevation of 1800 m above the sea, valleys and plains (rich and good for cultivation) and the desert area in the east called the Empty Quarter desert. The surface area of Najran region is approximately 365,000 square kilometres which is the third largest region in the Kingdom of Saudi Arabia and divided into 54 administrative centres [10]. It has a population of ~620,000 [11].

2 Materials and methods

2.1 Sampling and sample preparation

In this research, fifty soil samples were collected from different locations throughout Najran region. The coordinates of sampling locations were determined by Global Positioning System (GPS) and the map of Najran 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 100ºC for about 24 hours to achieve 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 litter volume of each soil sample was weighed, transferred to one litter Marinelli beakers [9, 17]. After sealing the Marinelli beaker with a standard volume soil samples 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, 17].

2.2 Counting system and calibration

The samples were analyzed spectroscopically and gamma-ray spectra emitting from soil samples were measured using n-type high resolution hyper-pure

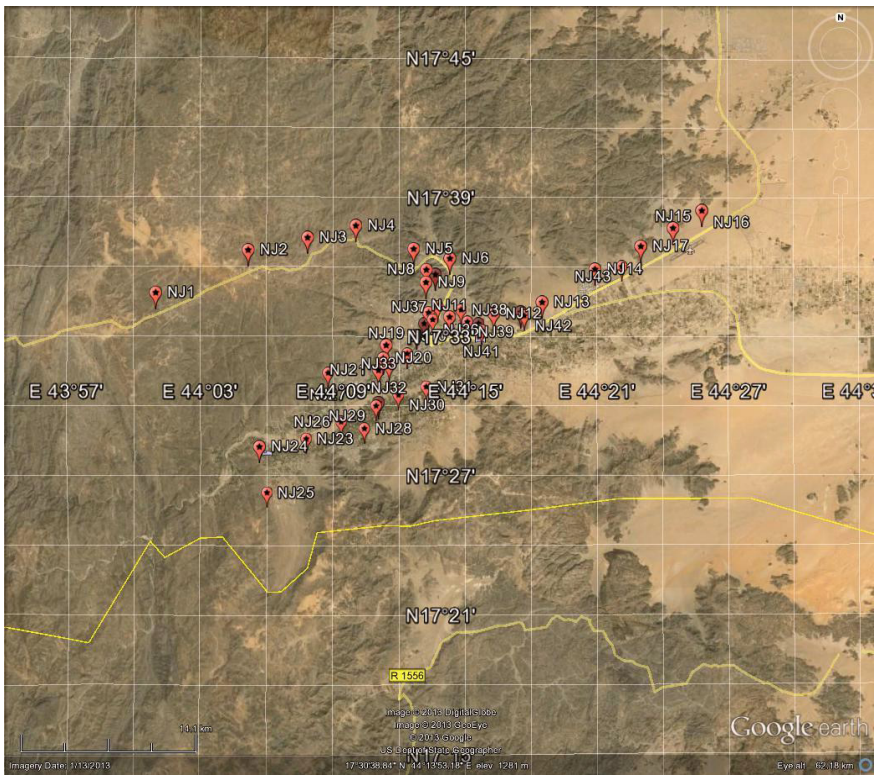

Figure 1: Map of Najran region showing the locations of the collected samples. (Map produced using Google Earth software.)

germanium spectrometers with an 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.

3 Results and discussion

Concentrations for U-238, Th-232, Ra-226, K-40, and Cs-137 of forty three sites, obtained from the analysis of the studied samples are given in table 1, in Bq/Kg 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 15% 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 and calculated exposure rates are given in the last three rows of the table 1. Moreover, the distributions of the concentrations of U-238, Th-232, Ra-226, K-40, and Cs-137 among the soil samples locations are presented in Figures 2–6, respectively.

The U-238 concentrations ranged from 1.08 Bq/Kg to 7.76 Bq/Kg with an average value of 2.87 Bq/Kg, the Th-232 concentrations ranged from 8.56 Bq/Kg to 49.09 Bq/Kg with an average value of 16.85/Kg, the Ra-226 concentrations ranged from 8.67 Bq/Kg to 41.54 Bq/Kg with an average value of

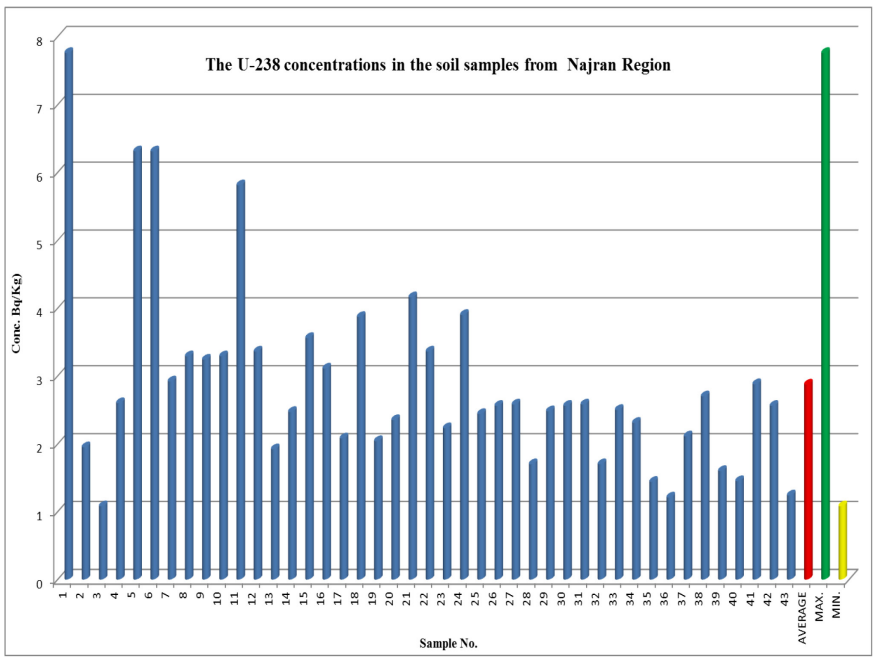

Figure 2: U-238 concentrations (Bq/Kg) in the soil samples from Najran region.

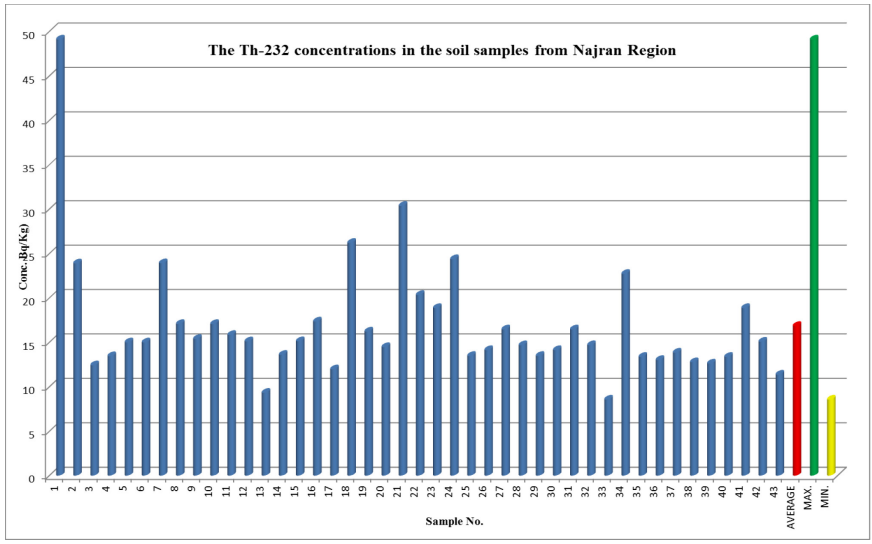

Figure 3: Th-232 concentrations (Bq/Kg) in the soil samples from Najran region.

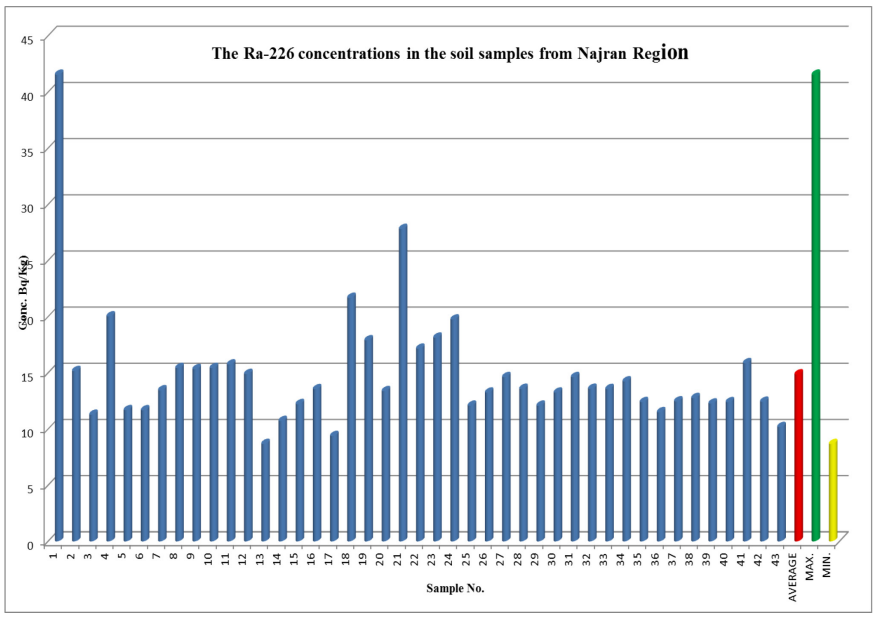

Figure 4: Ra-226 concentrations (Bq/Kg) in the soil samples from Najran region.

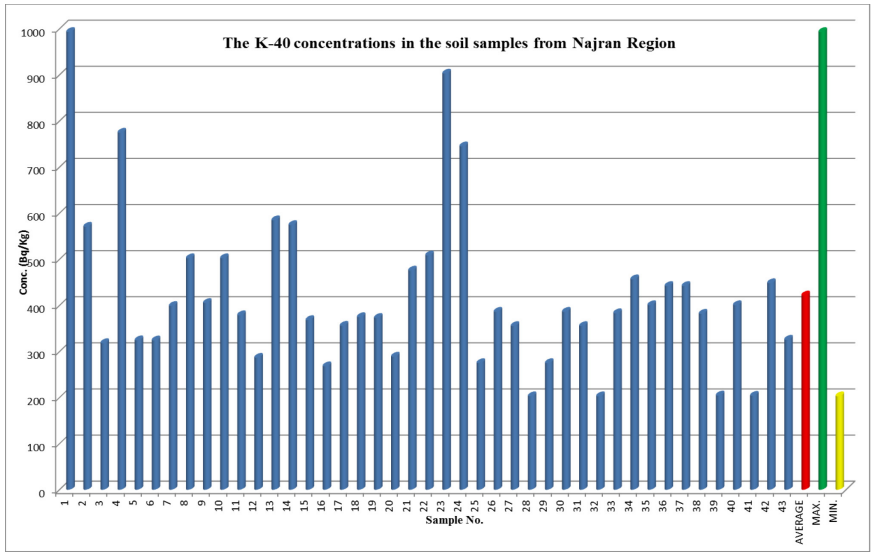

Figure 5: Ra-226 concentrations (Bq/Kg) in the soil samples from Najran region.

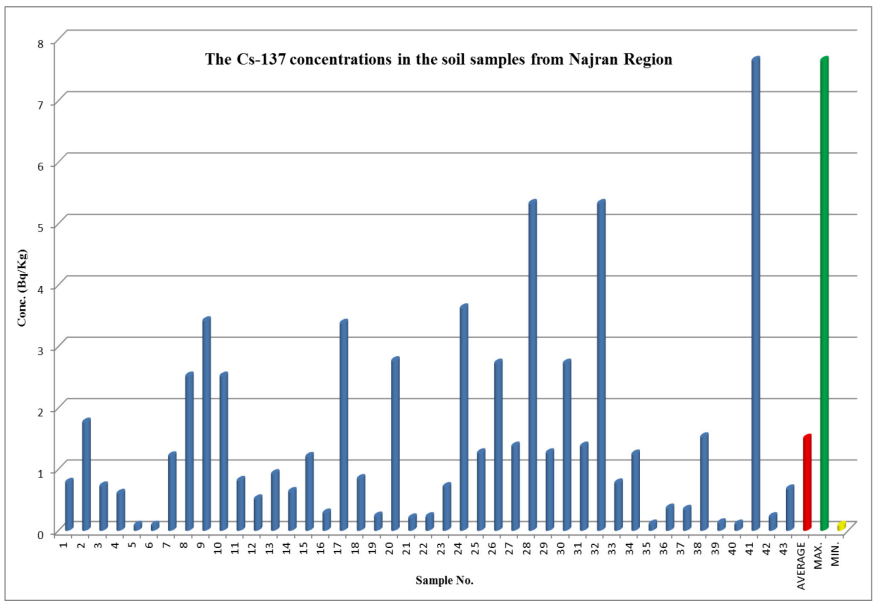

Figure 6: Ra-226 concentrations (Bq/Kg) in the soil samples from Najran region.

Table 1: Concentrations, ranges and average concentrations of radio-nuclides and exposure rates in soil samples in different sites of Najran Region.

Sample No.	Longitude North	Latitude and East	^{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)
1	17 34 157	44 00 997	7.76	49.09	41.54	993.07	0.78	10.45
2	17 35 993	44 05 168	1.95	23.89	15.16	570.58	1.76	5.16
3	17 36 535	44 07 848	1.08	12.42	11.27	318.14	0.72	2.99
4	17 37 051	44 10 035	2.60	13.45	20.03	774.66	0.60	5.65
5	17 36 061	44 12 655	6.31	15.03	11.68	324.25	0.08	3.22
6	17 35 656	44 14 301	6.31	15.10	11.67	324.00	0.08	3.22
7	17 34 967	44 13 640	2.92	23.91	13.45	398.71	1.21	4.29
8	17 35 174	44 13 230	3.29	17.07	15.43	502.28	2.51	4.40
9	17 34 630	44 13 212	3.24	15.39	15.33	405.23	3.41	3.84
10	17 33 318	44 13 331	3.29	17.07	15.43	502.28	2.51	4.40
11	17 33 136	44 14 287	5.81	15.84	15.75	378.58	0.81	3.78
12	17 33 275	44 16 300	3.36	15.12	14.90	286.41	0.51	3.27
13	17 33 771	44 18 502	1.92	9.33	8.67	584.63	0.92	3.80
14	17 35 200	44 20 917	2.47	13.60	10.72	574.26	0.63	4.18
15	17 36 980	44 24 481	3.56	15.13	12.22	368.06	1.20	3.46
16	17 37 742	44 25 805	3.11	17.35	13.55	267.89	0.28	3.25
17	17 36 192	44 23 010	2.08	11.97	9.38	355.79	3.37	3.01
18	17 33 341	44 17 533	3.87	26.20	21.68	374.51	0.84	4.86
19	17 31 910	44 11 408	2.04	16.22	17.9	372.71	0.23	3.92
20	17 31 342	44 11 274	2.35	14.47	13.37	288.73	2.76	3.13
21	17 30 834	44 11 059	4.16	30.37	27.81	475.58	0.20	5.98
22	17 29 427	44 11 049	3.36	20.34	17.15	508.37	0.22	4.76
23	17 27 936	44 07 765	2.23	18.87	18.13	902.85	0.71	6.47
24	17 27 527	44 05 646	3.90	24.37	19.75	744.93	3.62	6.26
25	17 25 617	44 05 995	2.44	13.48	12.08	274.75	1.26	2.92
26	17 28 670	44 09 354	2.56	14.13	13.24	386.09	2.72	3.54
27	17 30 781	44 08 760	2.58	16.46	14.62	355.15	1.37	3.65
28	17 28 384	44 10 417	1.70	14.68	13.58	202.85	5.32	2.78
29	17 29 361	44 10 942	2.48	13.48	12.08	274.75	1.26	2.92
30	17 29 831	44 11 960	2.56	14.13	13.24	386.09	2.72	3.54
31	17 30 188	44 13 223	2.58	16.46	14.62	355.15	1.37	3.65
32	17 31 070	44 11 544	1.70	14.69	13.58	202.85	5.32	2.78
33	17 31 618	44 12 356	2.50	8.56	13.56	383.00	0.77	3.16
34	17 32 438	44 12 785	2.31	22.71	14.24	456.55	1.24	4.51
35	17 32 915	44 13 128	1.44	13.37	12.40	400.47	0.10	3.49
36	17 33 087	44 13 520	1.21	13.02	11.50	442.02	0.36	3.60
37	17 33 647	44 13 749	2.11	13.85	12.46	441.94	0.34	3.72
38	17 33 511	44 14 808	2.70	12.77	12.76	381.81	1.52	3.39
39	17 32 995	44 15 096	1.60	12.62	12.27	204.55	0.12	2.56
40	17 32 922	44 15 602	1.45	13.37	12.39	400.47	0.10	3.49
41	17 32 633	44 15 750	2.88	18.87	15.86	203.87	7.65	3.22
42	17 33 255	44 17 692	2.56	15.08	12.43	448.19	0.22	3.83
43	17 35 388	44 22 141	1.24	11.37	10.18	325.54	0.672	2.88
Average			2.87	16.85	14.86	421.46	1.50	3.99
Maximum			7.76	49.09	41.54	993.07	7.65	10.45
Minimum			1.08	8.56	8.67	202.85	0.08	2.56

14.86 Bq/Kg, the K-40 concentrations ranged from 202.85 Bq/Kg to 993.07 Bq/Kg with an average value of 421.46 Bq/Kg and the Cs-137 concentrations ranged from 0.08 Bq/Kg to 7.65 Bq/Kg with an average value of 1.50 Bq/Kg. For the radio-nuclides U-238, Th-232, Ra-226, and K-40 the highest concentration were found in soil sample number 1, this may due to the geological formation of the location.

Table 2 shows a comparison of the mean concentration 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 radionuclides 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 radionuclides averaged over in the whole region were found less than the international level for soil in the United States, China, and Japan [2].

Table 2: Comparison of average concentrations of radio-nuclides in soil samples of Najran region to the national and international studies [2, 8, 12, 13, 16].

Region	^{238}U (Bq/Kg)	^{232}Th	^{226}Ra	^{40}K	^{137}Cs
This Work	2.78	16.86	14.86	421.46	1.50
Al-Baha Region	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 States	35	35	40	370	-
China	33	41	32	440	-
Japan	29	28	33	310	-

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 (3.99 μR/hr) the average annual effective dose for Najran region was evaluated to be 0.33 mSv/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].

4 Conclusions

The level of natural radioactivity (U-238, Th-232, Ra-226, and K-40) and man-made radionuclide such as Cs-137 in soil samples from Najran region has been measured using gamma-rays 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 the United States, China, and Japan. Moreover, the average annual effective dose for Najran region was evaluated to be 0.33 mSv/year, which is comparatively less than the annual average dose worldwide from all natural sources of exposure (2.40 mSv/year).

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