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Investigation of Radioactivity Levels in Soil at JUST Campus Prior to the Construction of JRTR

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ABSTRACT

An investigation of the background radiation level in soil samples collected from the campus of Jordan University of Science and Technology (JUST) was carried out. A random systematic approach was employed for selecting the sampling locations around the proposed site of Jordan Research and Training Reactor (JRTR). A counting system based on a High Purity Germanium (HPGe) detector coupled with GENIE 2000 spectroscopy software was used to analyze the samples. The average concentration of radionuclides ^{226}Ra, ^{232}Th, ^{40}K, ^{137}Cs and ^{238}U were found to be 20.84, 24.45, 312.39, 2.43 and 83.88 Bq/kg, respectively. Results were compared with published data available in the literature. The measured results will form the baseline for future monitoring of radiological impact of JRTR on JUST campus.

KEYWORDS: Soil, Natural radioactivity, Radiological impact, JRTR, JUST.

INTRODUCTION

Jordan University of Science and Technology (JUST) is a public, state-supported university located near ArRamtha, as shown in the location map presented in Figure 1, 70 km north of Amman, the capital, and 20 km east of Irbid, the second largest city in Jordan. The university campus covers an area of approximately 11 km² that is centrally located at international crossroads to Iraq and Syria and national roads to major cities in Jordan. Today, JUST has more than 900 full-time faculty members and around 22000 students. King Abdullah University Hospital (KAUH), JUST's teaching hospital and the largest hospital in northern Jordan is located within JUST's campus.

In 2007, JUST established the first and only Nuclear Engineering Department in Jordan, to provide Jordan's nuclear energy program with qualified nuclear engineers. Among other missions, and to provide training for the upcoming generations of nuclear engineers and scientists, Jordan Atomic Energy Commission (JAEC) has started the work in the construction of the first nuclear reactor in Jordan within JUST's campus. Jordan Research and Training Reactor (JRTR), which is a 5MW-multipurpose research reactor, is expected to be completed and operated by 2015.

Prior to the construction of any nuclear facility, it is necessary to carry out an investigation on the environmental background radiation level around the proposed site of the facility. This is essential to provide the background data for the environmental impact assessment of the nuclear facility. A number of studies have been performed on the evaluation of both natural and anthropogenic radioactivity in Jordan (Al-Jundi et al., 2009; Ahmad et al., 1997; Al-Hamarneh, 2005;

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Awadallah and Imran, 2007). But the data available from these studies remain scarce, as they were limited to certain geographical regions (Al-Amir et al., 2012; Al-Jundi et al., 2003; Al-Jundi and Al-Tarazi, 2008; Al-Hamarneh and Awadallah, 2009) and radionuclides (Al-Hamarneh et al., 2003; Al-Hamarneh, 2006; Hamideen and Sharaf, 2012) Moreover, there is a large variation in the reported data, which might be attributed to the large mesh size of the grid adopted in the sampling to allow the coverage of large regions under study. For example, in Irbid region, where JUST is located, the concentrations of the isotopes; ^{226}Ra, ^{232}Th, ^{40}K and ^{238}U were found to be within the range 8.5-217.7, 11.5-175.9, 4.3-41.9 and 29.8–361.8 Bqkg^{-1}, respectively (Al-Hamarneh and Awadallah, 2009). Therefore, it was necessary to establish a reference database for JUST before the commencement of the construction of the research reactor. This would provide essential information for future monitoring of any possible radiological releases from the research reactor and/or evaluation of the radiological hazards.

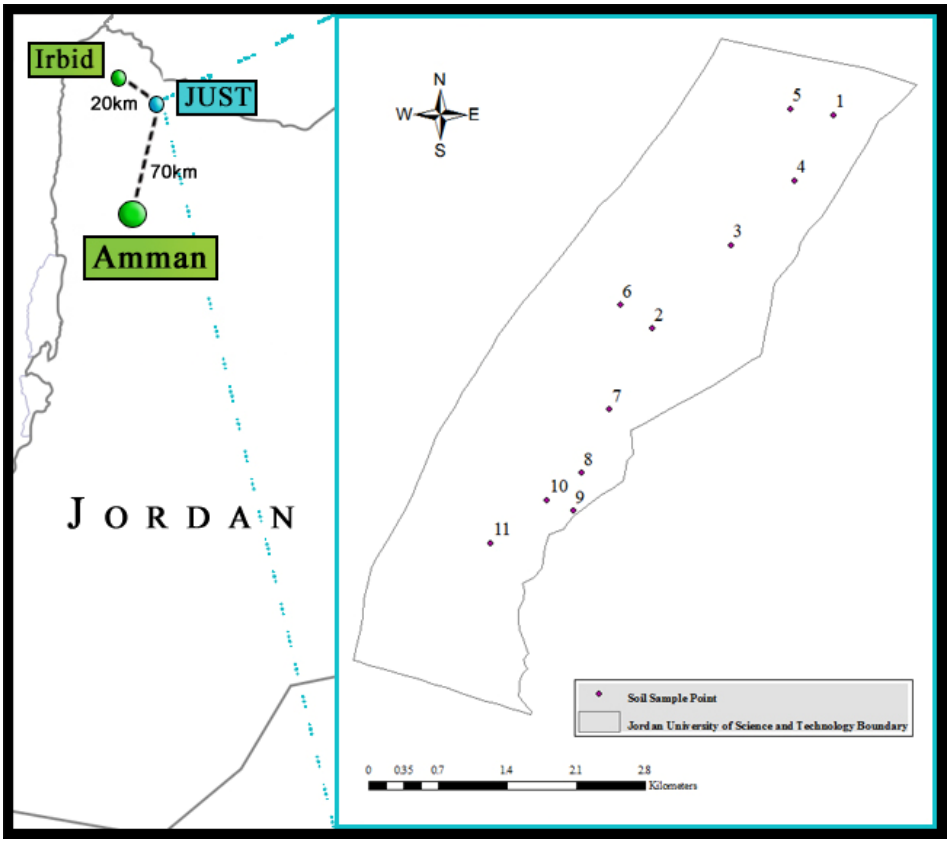


Figure 1: The location of Jordan University of Science and Technology and sampling sites

MATERIALS AND METHODS

Sample Collection and Preparation

Soil samples were collected during the mid of March 2012 from 11 locations within JUST campus around the proposed site of JRTR. A Systematic random sampling approach was employed for sample collection. The area around JRTR was subdivided using a square grid, then samples were collected from within each cell using the random selection procedures.

This approach has the advantage that it allows for the isolation of cells that may require additional sampling and analysis (IAEA, 2004). Surface soil samples were collected from undisturbed areas, at 5-cm depth, using a stainless steel sampler. Sampling locations are marked in Figure 1 and their identification details are listed in Table 1.

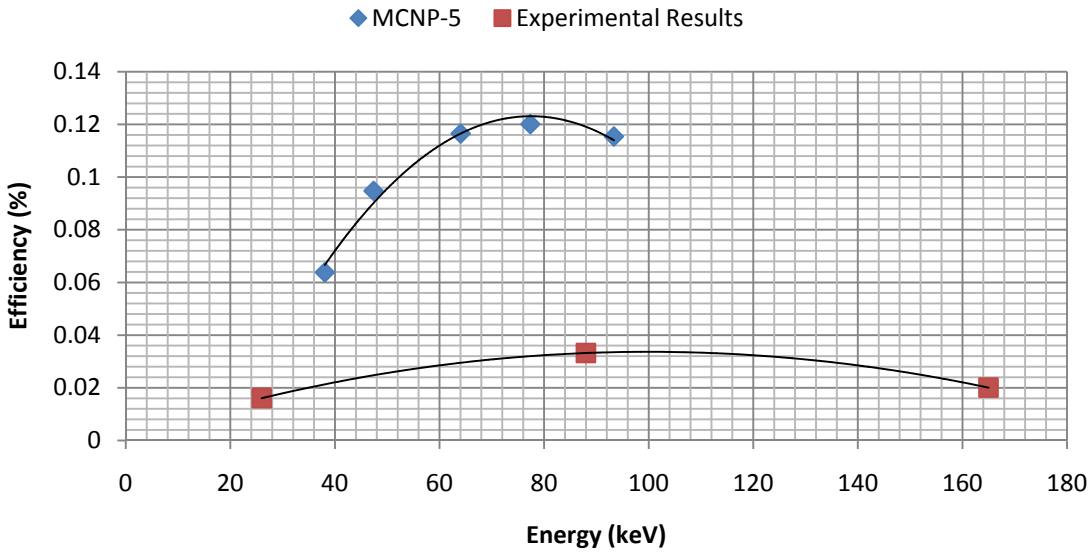
Table1. Sample identifications and GPS position locations

Sample number	Sample code	Weight (Grams)	GPS Position	
			LAT.	LONG.
1	K-6	83.15	32° 28' 6"	35° 56' 35"
2	D-11	94.51	32° 29' 29"	35° 59' 35"
3	C-11	89.86	32° 29' 50"	35° 59' 56"
4	B-12	91.03	32° 30' 12"	36° 0' 9"
5	B-11	82.71	32° 30' 14"	35° 59' 55"
6	E-8	82.93	32° 29' 10"	35° 58' 59"
7	J-6	88.05	32° 29' 2"	35° 59' 10"
8	G-8	99.98	32° 28' 36"	35° 58' 56"
9	H-7	90.79	32° 28' 15"	35° 58' 46"
10	I-7	93.36	32° 28' 3"	35° 58' 44"
11	J-6	79.57	32° 27' 52"	35° 58' 17"

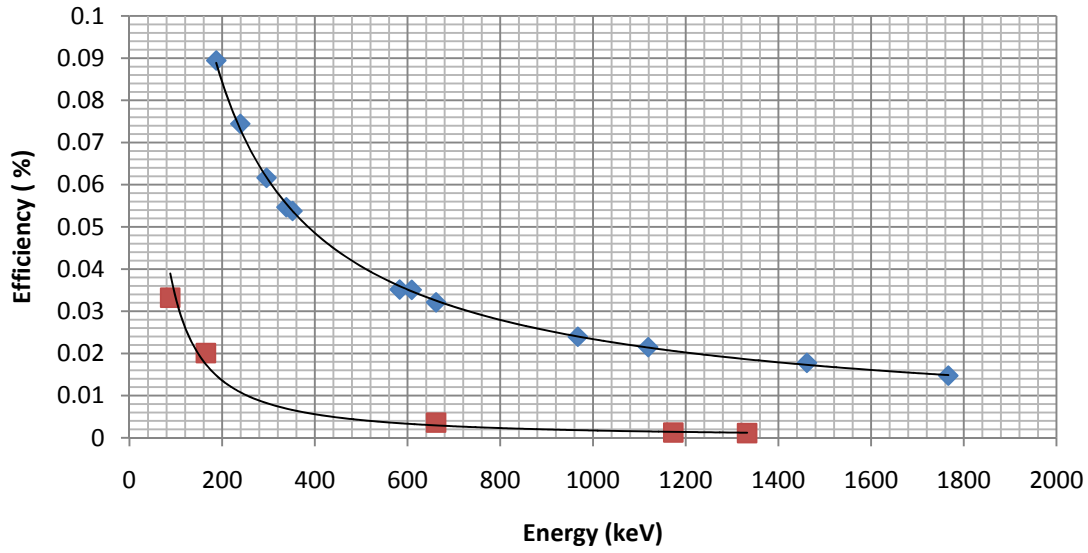
Collected soil samples were placed in a drying oven at a temperature of about 100^{o}C for 24 hours. Samples were then crushed, ground to fine powder and sieved using a 20/in^2 mesh screen. Although some homogenization was achieved via sieving, the fine powder was further homogenized through the use of a mixer for at least 15 minutes for each sample. Samples were then placed in plastic containers, weighed, airtight sealed and stored for more than 4 weeks before being counted by a gamma- ray spectroscopy system.

Instrumentation and Calibration

The system used for radioactivity measurements was based on a high-purity germanium (HPGe) n-type coaxial detector made by Princeton Gamma Tech (PGT). The system also employed a 16-K Multi Channel Analyzer (MCA) along with Genie 2000 v3.2.1 spectroscopy software. The system was calibrated for energy and efficiency using a standard soil source with the same geometry as the samples. The standard source was manufactured by Czech Metrological Institute. It has nine radioactive isotopes (^{40}K, ^{90}Sr, ^{106}Ru, ^{125}Sb, ^{129}I, ^{134}Cs, ^{137}Cs, ^{226}Ra and ^{232}Th) with 2.66 µCi activity. The calibration was further verified through modeling the counting system using the Monte Carlo code MCNP-5. Geometrical configurations of the crystal, including the end cap aluminum encapsulation, were taken into account when modeling the system. Figure 2 shows both experimental and MCNP efficiency calibration curves. MCNP-5 was used to predict the crystal efficiency. The experimental approach using the standard source was used to calibrate the complete counting system, including the amplifier and other electronic components. Both fitted functions show similar trend of monotonic increase followed by gradual decrease. The effect of amplifier and multichannel analyzer on measured pulses cannot be taken into account during simulation. Therefore, the experimental values of system efficiency were used to calculate the concentration of investigated radioisotopes. Part (a) of Figure 2 shows the efficiency for energies below 180 keV; whereas part (b) shows the efficiency for energies up to 1800 keV.



(a)



(b)

Figure 2: Efficiency calibration curves of the gamma ray spectroscopy system (a) Energy below 180 keV (b) Energy up to 1800 keV

RESULTS AND DISCUSSION

Table 2 summarizes the results obtained from the collected samples. The table lists the concentration of radionuclides found in each sample, followed by the minimum and maximum values of each radionuclide for all samples. The average concentration of each radionuclide is shown along with the associated uncertainty. The average specific activity of the radionuclides in Bq/kg (dry weight) were found to be

20.84 for ^{226}Ra, 24.45 for ^{232}Th, 312.39 for ^{40}K, 2.43 for ^{137}Cs and 83.88 for ^{238}U. The uncertainties in the measured values were less than 4% for ^{226}Ra, ^{232}Th and ^{40}K, while the uncertainty in the specific activity for ^{238}U fluctuated between 4.78% and 6.06% with an average value of 5.37%. On the other hand, the uncertainty in ^{137}Cs concentration was less than 19%. The relatively high error associated with ^{137}Cs concentration is due to the low value found in the samples. One sample had ^{137}Cs concentration below the minimum detectable level, while the highest concentration was 4.66 Bq/kg.

Table 2. Specific activities of radionuclides in soil samples from JUST campus around JRTR site

Sample No.	Ra-226		Th-232		K-40		Cs-137		U-238	
	(Bq/kg)	σ (%)	(Bq/kg)	σ (%)	(Bq/kg)	σ (%)	(Bq/kg)	σ (%)	(Bq/kg)	σ (%)
1	21.80	2.23	25.10	3.38	399.74	1.64	3.08	10.36	81.39	5.75
2	19.45	2.24	23.79	3.08	302.11	1.86	1.75	15.81	90.79	4.82
3	20.29	2.18	27.15	2.99	318.13	1.92	2.05	14.88	81.38	5.83
4	18.01	2.36	24.49	3.05	292.15	1.90	1.87	15.03	93.69	4.78
5	21.97	2.04	22.62	3.10	298.96	1.76	3.29	8.48	79.53	5.38
6	22.92	2.34	24.27	3.32	292.69	1.99	2.72	11.37	85.10	5.38
7	20.85	2.10	23.78	3.18	305.42	1.86	-	-	90.34	4.95
8	17.02	2.28	19.58	3.41	239.74	2.04	1.32	18.55	73.97	5.50
9	19.61	2.28	26.01	2.86	310.34	1.75	2.75	10.22	72.48	6.06
10	27.24	1.71	29.83	2.68	357.63	1.67	3.21	9.28	80.62	5.85
11	20.04	2.23	22.33	3.40	319.39	1.81	4.66	6.51	93.38	4.82
Min.	17.02	2.28	19.58	3.41	239.74	2.04	0.00	0.00	72.48	6.06
Max.	27.24	1.71	29.83	2.68	399.74	1.64	4.66	6.51	93.69	4.78
Average	20.84	2.18	24.45	3.13	312.39	1.84	2.43	10.9	83.88	5.37

In the literature, the reported radiation levels from soil do not cover JUST region. But some data on Irbid district, in general, can be found. Moreover, the published data is distributed over a wide range. For example, ^{226}Ra concentration in Irbid zone was given to be in the range from 8.5 to 217.7 Bq/kg, while the range of values for the concentration of this radioisotope within JUST campus was found to be from 17.02 to 27.24 Bq/kg (Al-Hamarneh and Awadallah, 2009). Similarly, the measured concentration for ^{232}Th was found to be from 19.58 to 29.83, that of ^{40}K from 239.74 to 399.74 and that of ^{238}U from 72.48 to 93.69, as compared to 4.3 to 41.9, 29.8 to 361.8 and 11.5 to 175.9, respectively (Al-Hamarneh and Awadallah, 2009). The available data on the concentration of ^{137}Cs in soil is even scarcer and the only values in Irbid region are 12.11 and 24.83 Bq.kg^{-1} (Al-Hamarneh et al., 2003), as compared to the measured values at JUST campus which were found to be up to 4.66 Bq.kg^{-1}.

CONCLUSIONS

The background radiation levels in 11 soil samples collected during March 2012 from JUST campus, around the construction site of Jordan Research and Training Reactor, were measured. A gamma-ray spectroscopy system based on a high purity germanium (HPGe) detector was used for the determination of the concentrations of the different radionuclides. The system was calibrated using a standard soil source with nine radioisotopes of known activity. The calibration was further verified through modeling the detector using the Monte Carlo code MCNP-5. The average concentrations (Bq/kg dry weight) of radioactivity in the soil samples were found to be 20.84± 2.18 % for

^{226}Ra, 24.45± 3.13% for ^{232}Th, 312.39 ± 1.84% for ^{40}K, 2.43 ± 10.95% for ^{137}Cs and 83.88 ± 5.37% for ^{238}U. The range of the measured values for the concentrations of the different radionuclides in the samples compares favorably with reported data for other sites around JUST campus. The results of this study will offer a radioactive background level data to evaluate the radiological environmental impact after the operation of JRTR.

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