Journal of Radiation and Nuclear Applications
An International Journal

http://dx.doi.org/10.18576/jrna/080305

Review Study of Natural Radioactivity in the Soil of the Kingdom of Saudi Arabia

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Received: 02 Jul 2023, Revised: 04 Jul 2023, Accepted: 24 Aug. 2023.
Published online: 1 Sep 2023.

Abstract: Radioactivity can be found in different amounts in nature, such as in Soil, water, and air. Radioactivity has health-related effects on individuals. Therefore, it is important to recognize protection and shielding methods against radiation for public health. So that in this work, we have studied the natural Radioactivity in the Soil in the various regions of the Kingdom of Saudi Arabia (Madinah, Makkah, Asir, Al-Baha, Najran, the Eastern Province, Riyadh, Al-Qassim), where we have reviewed the concentrations of Radioactivity for naturally occurring terrestrial radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in soil samples which were studied in different articles about the regions of the Kingdom of Saudi Arabia**.** Accordingly, the internal and external exposure values were calculated and compared with the safety standards approved by the International Commission for Radiation Protection. The results of this work showed that the values of the external exposure hazards index and internal exposure hazard index are less than one in the selected areas were identical to the International Commission recommendation. Thus, there are no health-related concerns to the individuals living in these regions and their surrounding environment.

Keywords: Radioactivity, Radionuclides, Saudi Arabia.

1 Introduction

The exposure of humans to radiation can happen through two major routes: external exposure and internal exposure. Internal exposure is caused by radioactive materials inside the body. In contrast, external exposure denotes the radiation source outside the body. Both routes can cause potential risks and health hazards. External exposure typically happens once people are in close contact with radioactive sources such as X-ray machines, nuclear power plants, or radioactive materials. This kind of exposure can damage the skin.

In contrast, internal exposure happens when radioactive materials are either inhaled, ingested, or absorbed into the body through wounds. Then, these radioactive materials release radiation from inside the body, causing potential damage to the internal organs, tissues, and cells. Understanding the routes of exposure is important for evaluating and controlling the risks related to radiation **[**1 and 2**]**.

Similar to medications, radiation's effects depend on how much humans are exposed to. Therefore, the amount of radiation received is referred to as the dose, and the measurement of these doses is known as dosimetry **[**3**]**. The biological effects of radiation exposure on the whole body depending on the total dose, cell type, radiation type, age of the person, stage of cell division, body part exposed, general health, tissue volume exposure, and the time interval between the doses received.

The fact that nuclear radiations have enough energy to produce ionization distinguishes them fundamentally from more frequent radiations. The damage manifests as modifications to the cell's structure and operation. Clinical signs like radiation sickness, cataracts, or, in the long run, cancer may appear in the human body as a result of these alterations [1]. Two unique types of harm can result from cellular alterations brought on by radiation; i) Harmful tissue reactions and ii) Stochastic effects

Radioactive nuclides in the environment can be linked to both artificial and natural sources. The radionuclides ^{238}U and ^{232}Th from the natural series, and the non-series radionuclides, ^{40}K, are the primary environmental concern radionuclides, significant

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contributors to background radiation, and the total effective radiation dose absorbed by humans **[**4**]**.

Natural radionuclides have been the components of the Earth since its existence. It is widely spread in the Earth's environment and exists **[**5**]**.

Human exposures are subjected to numerous degrees of ionizing radiation from extra-terrestrial sources primarily including cosmic radiation from Earth's outer atmosphere and terrestrial or naturally occurring radioactive sources such as gamma rays released from ^{40}K and radionuclides of ^{238}U and ^{232}Th through decay series present in Soil, rocks, and water **[**6**]**.

Soil plays an important role in human and environmental health. Soil has a considerable effect on human and environmental health, whether those effects are positive or negative **[**7**]**. Most of the radiation we are exposed to comes from radionuclides left over from billions of years ago, which are primordial radiation sources **[8]**. A high fraction of the Radioactivity released into the environment is deposited in soils. In addition, natural radionuclides are present in soils at concentrations that depend on the geological substrate. Can have the levels of radioactivity present in Soil can have an effect on human and environmental health. Negative impacts from Radioactivity include air pollution from radionuclide dust, soil contamination, aquatic sediment contamination, and bioaccumulation of radionuclides in ecosystems; and the impact on human health includes lung cancer, genetic mutations, and other complication **[**9**]**. Environmental impacts of radionuclides in Soil can include damage to ecosystems, including effects on soil quality, water quality, and biodiversity **[**10**]**. Soil contaminated with radionuclides can negatively affect soil microorganisms, disrupting and reducing the ability of the Soil to support plant growth. Contaminated Soil can impact the quality of water sources as radioactive particles can leach into groundwater. This can ultimately impact the quality and availability of water sources for drinking, and agriculture. The levels of Radioactivity in the Soil can impact agricultural quality, impacting the productivity of crops grown in that Soil **[**8 , 11**]**.

2 Environmental Hazard indexes

2.1. External hazard index (Hex)

External hazard is an index hazard widely used in the study as it represents external exposure to humans. The value of this index must be less than unity (unity value = 1) in order to keep the radiation hazard insignificant. The maximum value of Hex equal to unity corresponds to the upper limit of radium equivalent activity (370 Bq/kg). The external hazard index is calculated using the following equation [12];

$$H_{ex} = (ARa/370) + (ATh/259) + (AK/4810) \quad (1)$$

Where ARa, ATh, and AK are the activity concentration of the radioactive series.

2.2 Internal Hazard index

Radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products is quantified by the internal hazard index Hin, which is given by the equation [13];

$$H_{in} = (ARa/185) + (ATh/259) + (AK/4810) \quad (2)$$

Where ARa, ATh, and AK are the activity concentration of the radioactive series. This review covers the amounts of natural Radioactivity emitted from Saudi Arabia's Soil, comparing the radiation levels in 13 different provinces by discussing internal and external exposure factors.

3 Results

The research studies conducted to investigate the soil radioactivity in the 13 provinces **(Figure 1)** of Saudi Arabia between 1992 and 2022.

Fig. 1: Saudia Arabia map [14].

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3.1. Study of Radioactivity in the Soil of different regions.

The regions studied are; Madinah region, Makkah region, Al-Baha region, Asir region, Najran region, Eastern region, Riyadh region and Qassim region.

The results for soil radionuclides concentration are summarized in the following tables; i) The western region, which includes the governorates of the regions of Madinah and Makkah, is shown in **Table 1** through **Figure 2**. ii) The South region, which includes the following regions, Al-Baha, Asir, and Najran, is shown in **Table 2** and **Figure 3**. iii) The eastern region is shown in **Table 3** in **Figure 4.** IV)The Riyadh region is shown in **Table 4** and **Figure 5**.

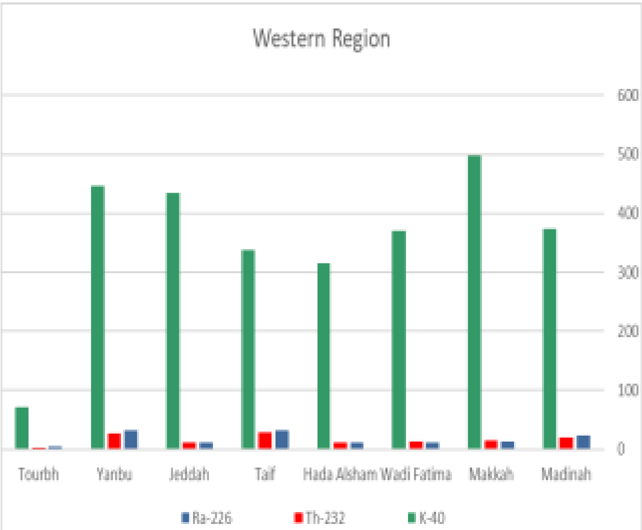

Fig. 2: Average activity of ^{226}Ra, ^{232}Th, and ^{40}K (Bq/kg) in soil from different areas in Western region.

Table 1: Concentration of radionuclides in the Western Region.

Location	Activity (Bq Kg^{-1}) Ra	Th	K	H_{ex}	H_{in}	References
Madinah	9.36	11.03	316.4	0.133	0.158	[12]
	37.54	27.95	300.64	0.271	0.373	[13]
	21.36	20.4	506.3	0.241	0.299	[14]
Makkah	12.45	14.05	498.1	0.191	0.225	[15]
Wadi Fatima	12.16	12.6	369.87	0.158	0.19	[16]
Hada Alsham	11.21	11.38	314.7	0.139	0.169	
Taif	45.2	43.35	114	0.313	0.435	[17]
	20.2	25.25	560.25	0.268	0.323	[12]
Jeddah	9.3	7.4	369	0.130	0.155	[18]
	12.5	14.1	498.1	0.191	0.225	[13]
Yanbu	22.51	14.28	380.26	0.195	0.255	[19]
	40.65	42.89	513.16	0.382	0.492	[20]
Tourbh	4.5	3.32	71	0.039	0.051	[21]

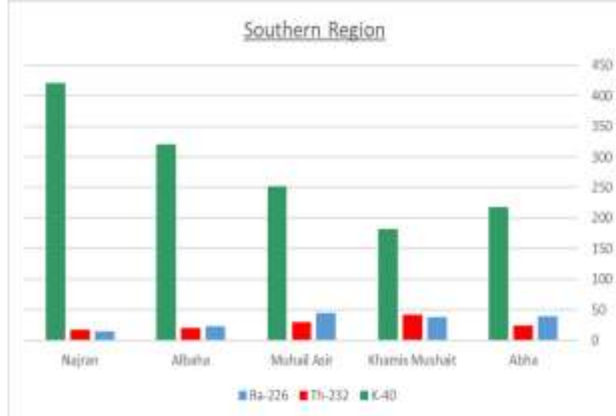

Fig. 3: Average activity of ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg) in soil from different areas in Southern Region.

Table 2: Concentration of radionuclides in the Eastern Region.

Location	Activity (Bq Kg^{-1}) Ra	Th	K	H_{ex}	H_{in}	References
Abha	38.67	23.49	217.87	0.24	0.34	[22]
Khamis Mushait	38.2	41.9	182.5	0.30	0.41	
Muhail Asir	44.1	29.3	251.5	0.27	0.38	
Albaha	9.10	9.04	298.49	0.12	0.15	[23]
	37	32	343	0.29	0.39	[24]
Najran	14.86	16.85	421.46	0.19	0.23	[25]

Table 3: Concentration of radionuclides in the Southern Region.

Location	Activity (Bq Kg^{-1}) Ra	Th	K	H_{ex}	H_{in}	References
Dammam	16.73	10.4	419.78	0.22	0.17	[26]
Al-Rakkah	23	20	233	0.18	0.24	[27]
Ras Tanura	23.19	7.73	278	0.15	0.21	[28]
Al-Khobar	22.7	14.8	392	0.19	0.26	[29]
Al-khafji	34.81	0.50	115.62	0.12	0.21	[28]
Mneefa coast	5.72	0.55	138.49	0.04	0.06	
Al jubail	7.63	3.75	173.52	0.06	0.09	[29]

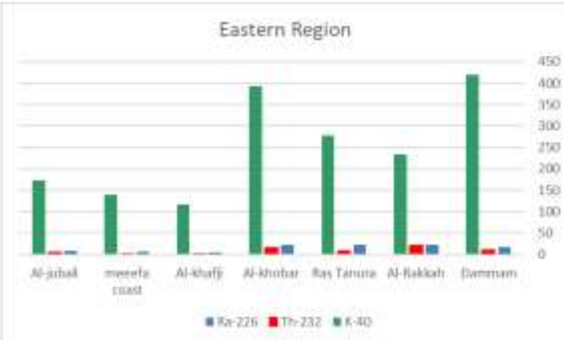

Fig.4: Average activity of ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg) in soil from different areas in Southern Region.

Table. 4 Concentration of radionuclides in the Riyadh Region

Location	Activity (Bq/kg)				H_{ex}	H_{In}	References
	Ra	Th	K	U			
Arrayed	9.83	5.93	99.4	–	0.07	0.09	
Oyenah	11.38	7.58	144	–	0.08	0.12	[30]
Mzahmiyah	7.22	5.8	91.7	–	0.06	0.08	
Sajir	–	26.0	307.94	28.30	0.24	0.31	
Huraimla	–	21.76	252.53	23.73	0.20	0.26	[31]
Thadeq	–	15.88	174.4	16.89	0.14	0.18	
Buraidah	21.8	18.5	708.2	–	0.27	0.33	
Al-Zulf	11.4	8.7	191.8	–	0.10	0.13	[32]
Al-Majmaah	9.2	7.65	276.05	–	0.11	0.13	

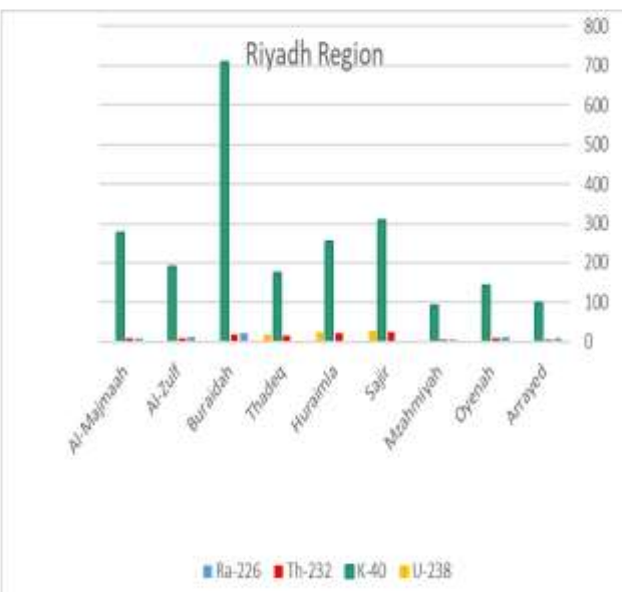

Fig. 5: Average activity of ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg) in soil from different areas in Eastern Region.

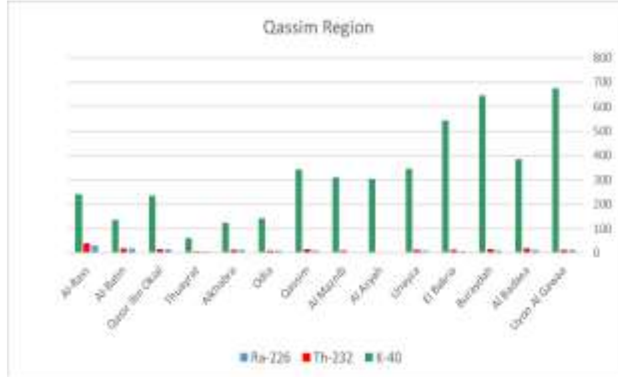

Fig. 6: Average activity of ^{226}Ra, ^{232}Th and ^{40}K and ^{238}U (Bq/kg) in soil from different areas in Riyadh Region.

Through this work, we have compared the results and interpreted them in selected regions of the Kingdom of Saudi Arabia which are summarized in **tables 1, 2, 3 and 4**. The external and internal hazard indicators were calculated, and the values in these studies were less than 1, which agrees with the recommendation of the International Commission on Radiological Protection of nuclear radiation **[**33**]**. The results are within allowable and safe limits for exposure to natural indoor and outdoor radiation. Based on previous studies and tables for regions, we found that the lowest values of radioactivity concentrations emitted by ^{226}Ra were in the Al-Asyah region (3 Bq/kg) **(Table 4)**. The lowest value of radiation emitted by 232Th is in the Al-Khafji region (0.5 Bq/kg) **(Table 3)**. Finally, the lowest radiation value (71 Bq/kg) emitted by ^{40}K in the Tourbh region is in **Table 1**. In other areas, we found high radioactivity values. Moreover, according to the radioactivity values emitted by ^{226}Ra, the highest in the region Muhail Asir is (44.1 Bq/kg) **(Table 2)**. The Highest value of ^{232}Th was detected in Khamis Mushait (41.9 Bq/kg) **(Table 3)**. Eventually, the highest level of radioactivity concentration for 40K is (747 Bq/kg) in Al Badaea **(Table 4)**. We hoped that there would be more than these studies to construct a radiological database map for these radionuclides in Saudi Arabia, so, we recommend investigating more studies to cover every province.

4 Conclusions

The radionuclides distribution in different localites on Saudi Arabia indicates that most regions under study have low radionuclide concenterations, so, they have low environmental parameters values and lie in the permisible level ranges. On the contrary, other locations show high radioelement contents and could be hazard and to some extent deviate the permiscible levels in some parametrs. The source rocks of the low activity levels could be sedimentary or metamorphic rocks with low radioelement contents. On the other hand, the rocks of high activity could be related to the surrounding granitic rocks wit high radioelement contents. So, we need more detailed work for accurate investigation in order to build new base map for Saudi Arabia.

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