Evaluation of the activity of $^{238}$U, $^{40}$K, and $^{232}$Th in soil samples at Yanbu Al-Bahr City in KSA

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Abstract — The activity of radionuclides Uranium-238, Thorium-232, and Potassium-40 in soil samples collected from different areas in Yanbu city were analyzed using Gamma Spectrometry based on the HPGe detector CANBERRA model, with a relative efficiency of 40%. The activity concentrations for these radionuclides were compared with the world average activity of the soil, it was found that the activity of $^{238}$U in samples ranged from (19.4 - 30.8) Bq/kg. And for $^{232}$Th, the activity in samples ranged from (8.7 - 26.6) Bq/kg. While the activity of $^{40}$K in samples ranged from (332.1 - 638.0) Bq/kg. In addition, the average dose rate in the air is 50.84 nGy/h. It can be said that the activity of $^{238}$U, $^{232}$Th, and $^{40}$K in the study areas and the dose rate in the air is within the average world limits, (UNSCEAR 2000).

Keywords — Activity; Concentration; Potassium-40; Uranium-238; Thorium-232; Soil.

I. INTRODUCTION

Around the world, some areas are having extremely high background radiation levels, which can cause hazards to human life. So, it is useful to study natural terrestrial radiation for many reasons. The most common terrestrial radioactive elements that produce gamma rays are uranium-238, thorium-232, and potassium-40, which can be found on the earth's surface and contain measurable amounts of natural radioactivity [1], [2]. The environment constitutes about 85% of public exposure to terrestrial gamma radiation (UNSCEAR, 2000). Naturally occurring radioactivity and the resulting external exposure due to gamma radiation are affected by a wide range of factors, depending on the geological and geographical conditions and varying in each region of the world [3]-[5]. Rocks like granite and sedimentary rocks are associated with higher radiation levels. Many researchers around the world, thus, are interested in measuring soil radioactivity, which led to a wide range of nationally representative surveys in recent decades.

II. STUDY AREA

This study was carried out in Yanbu city, it is a coastal city in the western region of KSA, within the emirate of Al-Madinah Al-Munawwarah region. Selecting district locations from the center of the city gives a realistic picture of the whole city (Fig. 1).

Fig. 1. The location of the city on the KSA map.
III. Experimental Work

The concentration of radioactive nuclides is the goal of this work. To accomplish this project, samples are taken from several regions with various topographies, soil types, morphologies, and climates. A highly unique selection was made to provide a more accurate picture of radiation and concentration in the dose.

IV. Sampling and Sample Preparing

At 30 cm depth soil samples were collected from all districts, each weighing about 1 kg, and stones and organic wetter were removed from these samples. The sample was placed in a 120 °C oven for approximately 15 hours to dry, then crumpled and passed through a 2 mm sieve to even out the size. The homogenized soil sample was sealed in a plastic container and left for at least 30 days prior to gamma spectroscopic analysis to achieve a permanent equilibrium between radon and its decay products [6]-[8].

V. Results and Discussion

The radioactive decay concentrations of collected soil samples are compared with national and international radioactive decay concentration values of 35, 30, and 400 Bq/kg for the 238U series, 232Th series, and 40K, respectively. Then, the world average dose rate in the air which is 55nGy/h was compared with that calculated from the following formula:

\[
D_{air} = (0.462C_U + 0.621C_{Th} + 0.0917C_K) \text{nGy/h}
\]

where \(C_U\), \(C_{Th}\), and \(C_K\) is the concentration of U, Th, and K respectively.

We can observe that the radioactivity concentrations are normal over all of the city and within the average of 54.14 nGy/h. And the average radioactivity concentration of 238U, 232Th, and 40K are 22.51 Bq/kg, 14.28 Bq/kg, and 380.26 Bq/kg respectively.

| Sample | 238U | error | 232Th | error | 40K | error | D.R nGy/h |
|--------|------|-------|-------|-------|-----|-------|-----------|
| S1     | 22   | 3.1   | 14    | 3.7   | 350 | 1.1   | 51.34     |
| S2     | 25   | 3.0   | 20    | 2.6   | 330 | 1.1   | 54.70     |
| S3     | 21   | 3.2   | 9.1   | 4.4   | 336 | 1.1   | 46.41     |
| S4     | 19   | 3.5   | 13    | 4.1   | 402 | 1.4   | 54.03     |
| S5     | 20   | 3.2   | 8.7   | 4.5   | 332 | 1.1   | 45.46     |
| S6     | 30   | 2.7   | 26    | 2.8   | 253 | 1.1   | 53.97     |
| S7     | 20   | 3.2   | 8.8   | 4.4   | 370 | 1.1   | 48.82     |
| S8     | 19   | 3.2   | 9.1   | 3.7   | 378 | 1.3   | 51.95     |
| Avg.   | 22.51| 3.1   | 20    | 2.6   | 380 | 0.263 | 50.84     |
| UNSCEAR| 35   | 30    | 400   | 4.0   |     |       | 71.48     |

**TABLE I: The Activity of 238U, 232Th and 40K**

![Fig. 2. Uranium concentration.](image-url)
VI. CONCLUSION

The determination of the radiation background is important for assessing health hazards. The average radioactivity concentrations of $^{238}$U, $^{232}$Th, and $^{40}$K in soil samples were found to be lower than the maximum permissible levels reported in the global average, and the annual effective outdoor dose rate is lower than the corresponding permissible global average limit. The data obtained in this study can be used as basic radiation data for future research.

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