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Evaluation of Natural Radioactive Concentration Levels in a Selection of Buzrgan Oil Drilling Wells in Maysan Governorate, Iraq

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ABSTRACT

From the BUCN-157D well in southern Maysan city, Iraq, the concentrations of 226Ra, 232Th, and 40K radionuclides are measured for soil and rock at various depths. utilizing an HPGe detector with an energy resolution of utilizing a high-resolution gamma spectrometry setup (≤1.8 keV) for the 60Co gamma transition at 133 MeV. The samples of rock and dirt came from a depth of 150–3500 m. The natural radionuclide activity concentrations were compared with equivalent values from other nations. The average activity for the isotopes of 226Ra, 232Th, and 40K were 10.1, 9.433, and 390.55 Bq/kg, respectively. Radium equivalent activities, gamma dose rate, internal and external hazard indices, representative level index, and internal and external yearly effective dose equivalent had average values of 53.66 Bq/kg, 26.54 nGy/h, 0.17, 0.15, 0.42, 0.13 mSv/y, and 0.03 mSv/y, respectively. All measurements were determined to be below their respective allowed limits for (226Ra, 232Th, and 40K) specific activity, radium equivalent, absorbed dose rate, indoor and outdoor yearly effective dose rates, internal and external hazard indices, and gamma index.

1. Introduction

Natural radioactive materials (NORMs) of the uranium series, thorium series, and potassium-40 are present everywhere in the earth's crust. The composition of the soil and rocks affects the concentration of these radionuclides. All humans receive radiation doses from these nuclides. Reservoir rock in oilfields contains trace levels of naturally occurring uranium, thorium, and their radioactive offspring [1-5]. The daughter radioisotopes of ^{238}U and ^{232}Th produced by their radioactive decay exhibit a wide range of physical characteristics, such as varying half-lives, decay modes, and radiation types and intensities. [6-9]. The oil and gas sector generates a range of radioactive wastes. Pipe scales, drilling mud, and sludge are a few examples of items that, when used as tools and materials that may be recycled, can include more NORM. It would be able to operate in a productive and steadily safer manner if all participants in the petroleum industry had a similar understanding of radiation dangers and protection ideas [10-15]. This paper aims to Assess the hazard indices for soil and rock samples with different depths.

2. Study Area

As seen in the *Figure 1*, the Buzrgan oil reserves are near to the Iraq-Iran border in the Missan province in southeast Iraq[16]. It is about 175 kilometers north of Basra city. Structurally, the Buzurgan oil field is a NW-SE axis anticline that ranges about 353.4 km^2, two domes, one in the north and one in the south, as seen in Figure 2 [17-20].

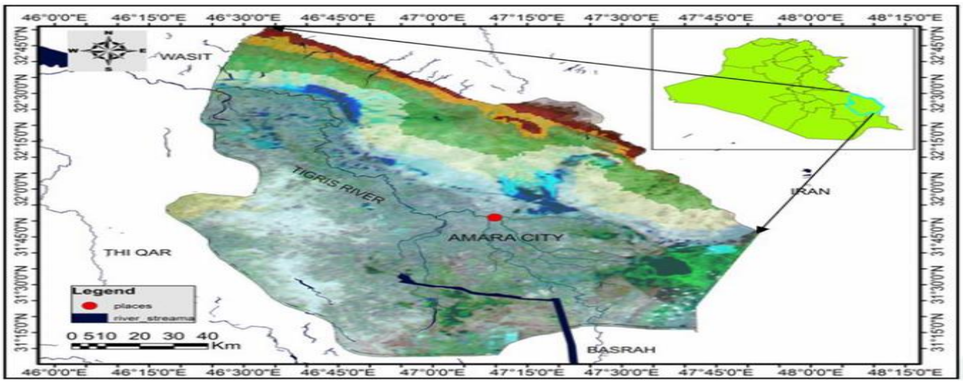

Figure 1: The location of Maysan City[16, 21]

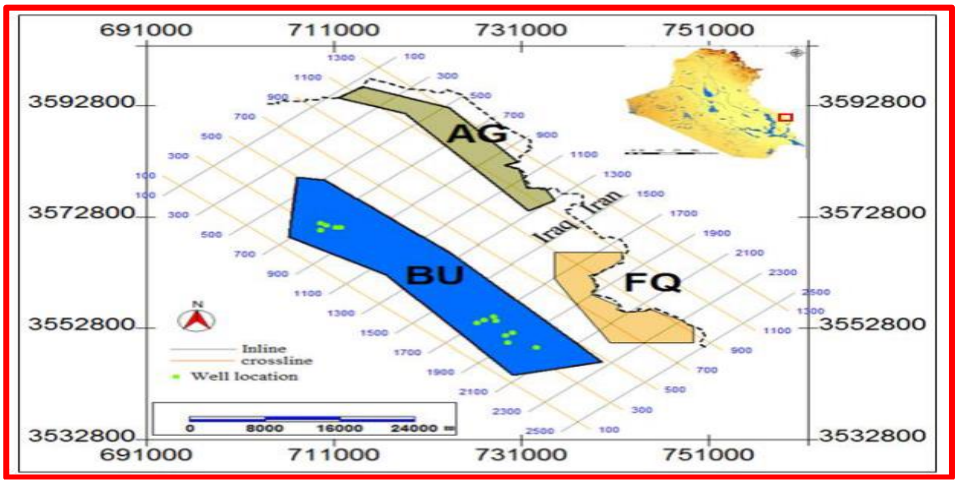

Figure 2: Location of Buzurgan oil field [22-24]

3. Materials and Methods

Two soil and ten rock samples from different depths (different formations) were collected from the BUCN-157D well located in the Buzurgan oil field of Maysan Governorate, which is in southern Iraq, with different depths ranging from 1900 to 4500 m. These collected samples were then air dried to eliminate moisture, crushed and milled to a fine powder, and then sieved with a 0.3 mm mesh size. For gamma measurements, the solid samples were weighed, packed in Marinelli beakers, and sealed.

4. Activity Concentrations

For the quick and easy identification and quantitative analysis of radionuclides that generate gamma rays, gamma spectrometry is used. The discrete gamma energy lines of distinct radionuclides are employed in this non-destructive radiometric approach to directly quantify gamma-emitting radionuclides. The sophisticated data collection and calculation system used in this study's gamma spectrometry includes the following[25-28]:

a) Germanium of high purity (HPGe) is employed as a detector.

b) Preamplifier: Due to its necessity for the detector's low-noise functioning, this essential detection unit component is located quite close to the detector.

c) Amplifying linearly: This often integrates into the multichannel analyzer (MCA) and amplifies the pulse by a factor of several hundred. It molds the pulse for more precise analysis and has a voltage of several volts.

d) With a range of 0-5000 D.C. volts, the detector is supplied with high voltage using the bias high-voltage power source. To avoid damaging the detector, it must be raised gradually**.**

5. .Estimation of the Radiological Hazard Indices

5.1 Radium Equivalent Activity Concentration Index (Ra_{eq})

A useful index to match the distinct activity of materials with various concentrations of ^{226}Ra, ^{232}Th, and ^{40}K is the radium equivalent (Ra_{eq}) index in $Bqkg^{-1}$. It was defined under the presumption that the gamma dose rates produced by 10 $Bqkg^{-1}$ of ^{226}Ra, 7 $Bqkg^{-1}$ of ^{232}Th, and 130 $Bqkg^{-1}$ of ^{40}K were equal. The radium equivalent activity index is given as [29-32]:

$$Ra_{eq} = C_{Ra} + 1 \cdot 43C_{Th} + 0 \cdot 077C_k \leq 370 \qquad (1)$$

where C_{Ra}, C_{Th} and C_k are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, respectively. To reduce radiation risks, it is not recommended to utilize materials with Ra_{eq} concentrations higher than 370 Bq/kg [33].

5.2 Gamma Dose Rate

The radiological risk resulting from external exposure to radiation generated by naturally occurring radionuclides in the human environment was calculated using the dose rate caused by the concentrations of the radionuclides in the samples. The dose conversion factors for converting the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K into doses ($nGyh^{-1}$ per $Bqkg^{-1}$) are 0.427, 0.662, and 0.043, respectively [34-36]. Equations are used to calculate gamma dosage [29]:

$$D\left(\frac{nGy}{h}\right) = 0 \cdot 462C_{Ra} + 0 \cdot 621C_{Th} + 0 \cdot 0417C_k \qquad (2)$$

5.3 AEDE, or Annual Effective Dose Equivalent

A dose conversion ratio of 0.7Sv/Gy and the absorbed dose rate are used to compute the annual effective dose equivalent that a member receives outside. The occupancy factors were 0.2(5/24) and 0.8(19/24) for the indoor and outdoor environments, respectively [37, 38]. Utilizing the following equations, AEDE is calculated:

$$(\text{Outdoor})\ \text{AEDE}(\text{ms/y}) = \text{Adsorption dosage (nGy/h)} \times 8760\,\text{h/y} \times 0 \cdot 7\, sv/Gy \times 0 \cdot 2 \times 10^{-6} \qquad (3)$$

$$(\text{Indoor})\text{AEDE}\big((\text{ms/y})\big) = \text{Adsorption dosage (nGy/h)} \times 8760\,\text{h/y} \times 0 \cdot 7\, sv/Gy \times 0 \cdot 8 \times 10^{-6} \qquad (4)$$

The world average annual effective dose equivalent (AEDE) from outdoor or indoor terrestrial gamma radiation is 0.460 ms/y [39].

5.4 External and Internal Hazard Indices

The external danger index has been defined as another criterion. The primary goal is to keep the activity concentration (A) of ^{226}Ra, ^{232}Th, and ^{40}K below the allowable dosage rate of 1mSv/y determined by the evaluation of the external hazards index (H_{ex}) the following equation to separate gamma radiation from the oil field's natural gamma radiation. [40, 41]:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \qquad (5)$$

Human internal radiation exposure from ^{222}Rn and its offspring was frequently evaluated using the internal hazard index (H_{in}). It is determined by applying the subsequent expression [42]:

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \qquad (6)$$

The radiation hazard must be less than unity for this index's value to be considered significant.

The upper bound of Ra_{eq} (370 Bq/kg) corresponds to a value of H_{in} equal to unity [43].

5.5 Gamma Radiation Representative Level Index ($I_{\gamma r}$)

Gamma radiation associated with the naturally occurring radionuclides in the samples is evaluated using a representative level index. Regarding the negligible radiation danger, the value of (I) must be less than unity. It was calculated using the equation below [44, 45]:

$$\mathbf{I_{\gamma r}} = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_k}{1500} \qquad (7)$$

The annual exposure rate owing to the excessive external gamma radiation induced by surface materials is likewise correlated using this gamma index [46]. When $I_{\gamma r} \leq 1$ equivalent to a yearly less than or equal to 1 mSv effective dosage, and when $I_{\gamma r} \leq 0.5$, equivalent to a yearly effective dose of less than or equal to 1mSv [29].

6. Results and Discussion

The general findings for the soil and rock samples examined for NORM isotopes have been provided in the concentration of the radioactive isotope Ra-226 ranged from 3.7 Bq/kg in sample 7 for the same formation to 14.5 Bq/kg in sample 9 for the Lower Fars formation.

Table 1 . Due to the characteristics of the rocks examined, the concentration of the radioactive isotope Ra-226 ranged from 3.7 Bq/kg in sample 7 for the same formation to 14.5 Bq/kg in sample 9 for the Lower Fars formation.

Table 1. BUCN-157D well properties and the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K for soil and rock samples

Sample code	sample Type	Formation	Depth (m)	Well name	Ra-226 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)
1	**Soil**	**NF***	**150**	**BUCN-157D****	**10.3**	**12.3**	293.8
2	**Soil**	**NF**	**500**	**BUCN-157D**	**14.3**	**19.4**	369.4
3	**Rock**	**NF**	**1000**	**BUCN-157D**	**12.5**	**17.8**	373.8
4	**Rock**	**Upper Fars**	**1500**	**BUCN-157D**	**13.1**	**17.9**	481.7
5	**Rock**	**Upper Fars**	**2000**	**BUCN-157D**	**14.3**	**15.2**	493.9
6	**Rock**	**Upper Fars**	**2300**	**BUCN-157D**	**9.9**	**3.4**	487
7	**Rock**	**Lower Fars**	**2500**	**BUCN-157D**	**3.7**	**2.7**	272.5
8	**Rock**	**Lower Fars**	**2700**	**BUCN-157D**	**8.5**	**6.3**	429.5
9	**Rock**	**Lower Fars**	**2800**	**BUCN-157D**	**14.5**	**2.9**	352
10	**Rock**	**Middle Lower Kirkuk**	**3000**	**BUCN-157D**	**4.3**	**2.5**	309.2
11	**Rock**	**Hartha**	**3400**	**BUCN-157D**	**6.3**	**1.6**	259.8
12	**Rock**	**Hartha**	**3500**	**BUCN-157D**	**9.5**	**11.2**	564
Max					**14.5**	**19.4**	564
Min					**3.7**	**1.6**	259.8

Mean					**10.1**	**9.433**	390.55

. Not Found , **. Buzurgan China North-157 Deviational

Table 2 shows that 53.66 Bq/kg was the total average value of the gamma dose rate's radium equivalent activities (Ra_{eq}) for all soil and rock samples. This result is also regarded as normal, however the highest Ra_{eq} value for sample 4 was 75.79 and the lowest Ra_{eq} value for sample 7 was 28.54 Bq/kg. All of Raeq's soil and rock samples' outcomes were shown in *Figure 3*.

Table 2. Hazard indices in BUCN-157D well

N	Ra_{eq} (Bq/kg)	D (nGy/h)	H_{in}	H_{ex}	$I\gamma r$	$AEDE_{in}$ (mSv/y)	$AEDE_{out}$ (mSv/y)
1	**50.51**	**24.44**	**0.16**	**0.14**	**0.39**	**0.12**	0.03
2	**70.49**	**33.8**	**0.23**	**0.19**	**0.54**	**0.17**	0.04
3	**66.74**	**32.15**	**0.21**	**0.18**	**0.51**	**0.16**	0.04
4	**75.79**	**36.92**	**0.24**	**0.2**	**0.59**	**0.18**	0.05
5	**74.07**	**36.3**	**0.24**	**0.2**	**0.58**	**0.18**	0.04
6	**52.26**	**26.65**	**0.17**	**0.14**	**0.42**	**0.13**	0.03
7	**28.54**	**14.56**	**0.09**	**0.08**	**0.23**	**0.07**	0.02
8	**50.58**	**25.45**	**0.16**	**0.14**	**0.41**	**0.12**	0.03
9	**45.75**	**22.93**	**0.16**	**0.12**	**0.36**	**0.11**	0.03
10	**31.68**	**16.22**	**0.1**	**0.09**	**0.26**	**0.08**	0.02
11	**28.59**	**14.56**	**0.09**	**0.08**	**0.23**	**0.07**	0.02
12	**68.94**	**34.47**	**0.21**	**0.19**	**0.55**	**0.17**	0.04
Max	**75.79**	**36.92**	**0.24**	**0.2**	**0.59**	**0.18**	0.05
Min	**28.54**	**14.56**	**0.09**	**0.08**	**0.23**	**0.07**	0.02
Average	**53.66**	**26.54**	**0.17**	**0.15**	**0.42**	**0.13**	0.03

Gamma dose rate (D) averaged out throughout the entire sample was determined to be 26.54nGy/ h. According to sample 4, the maximum value was 36.92 nGy/h, which is below the allowable value, and sample 7, the minimum value was 14.56 nGy/h. *Figure 3*.

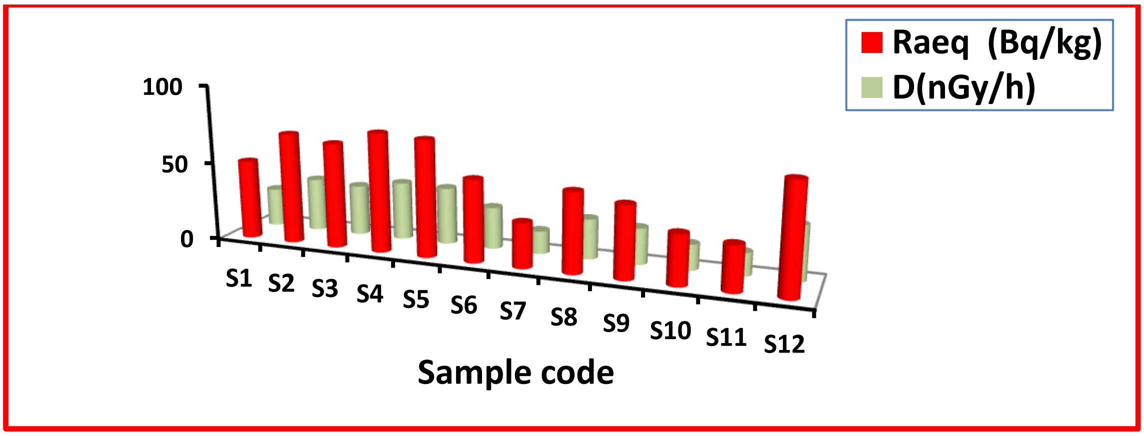

Figure 3: A histogram showing the radium equivalent activity and dose in soil and rock samples of the BUCN-157D well

The exterior and interior hazard indices (H_{ex}, H_{in}) had overall average values of 0.15 and 0.17, respectively. Samples 4 and 5 had a maximum H_{ex} value of 0.2, whereas samples 7 and 11 had a minimum H_{ex} value of 0.08. In contrast, samples 4 and 5 had a maximum value for H_{in} of 0.24 and samples 7 and 11 had a minimum value of 0.09 for H_{in}. It was discovered that the H_{ex} and H_{in} for the entire soil and rock were below unity and within the usual range.

For all soil and rock samples that were tested both indoors and outdoors, the average annual effective dose equivalent (AEDE) from terrestrial gamma radiation was 0.13 and 0.03 mSv/y, respectively. The maximum value of AEDE (indoor) was 0.18 mSv/y in samples 4 and 5, and the minimum value was 0.07 mSv/y in the samples 7 and 11, while the maximum value of AEDE (outdoor) was 0.05 mSv/y in sample 4, and the minimum value was 0.02 mSv/y in the samples 7, 10, and 11. *Figure 4* shows radium equivalent activities, gamma dose rate, internal and external hazard indices, representative level index, and internal and external yearly effective dose equivalent.

For soil and rock samples, the representative level index (I_r) average value was 0.42; sample 4 had the highest value, 0.59; and sample 7 had the lowest value, 0.23. Comparison information with the other nations included in *Table 3* shows that in the present study, the activity is lower compared with the other countries.

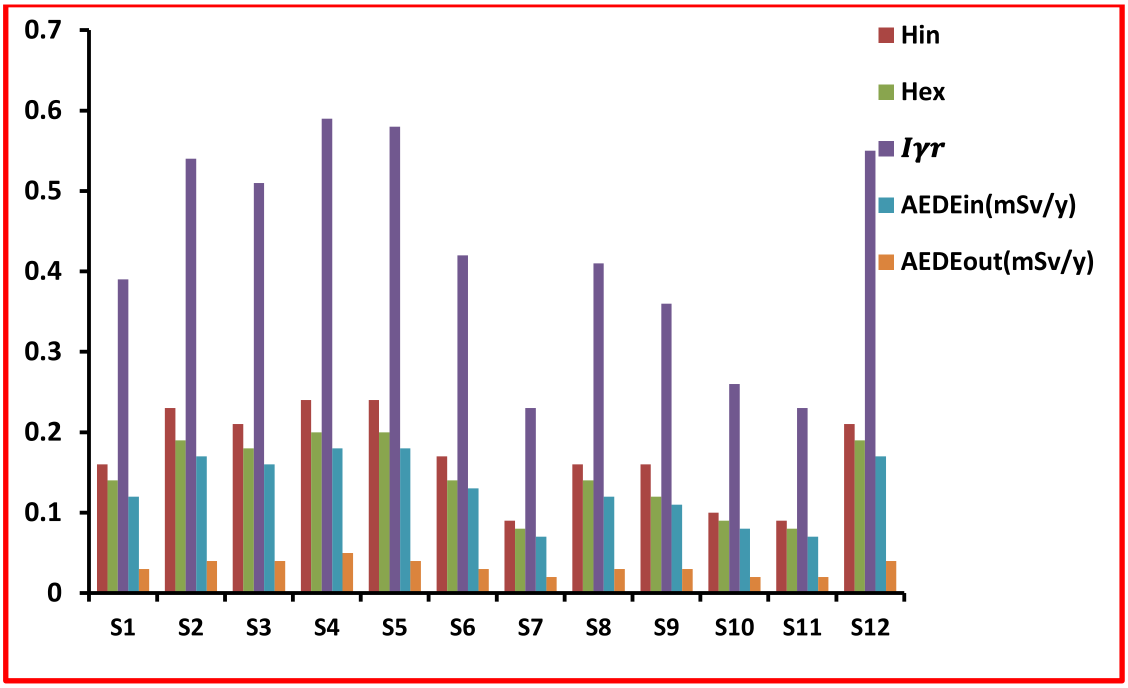

Figure 4: The radiological hazard indicators for each sample in the BUCN-157D well are H_{ex}, H_{in}, I, AEDE $_{out}$ (mSv/y), and AEDE $_{in}$ (mSv/y).

Table 3. Comparison of the samples' natural radiation levels to those in other nations.

Country	Ra-226 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)	Reverence
Erbil-Iraq	**11.77-91.31**	**5.75-53.80**	**3.71-502.30**	[47]
Zubair-Iraq	**47.72-2214.01**	**22.49-464.37**	**184.4-23364.6**	[48]
Egypt	**NA***	**3.99 -42.13**	**88.68-762.49**	[49]
Egypt	**17**	**18**	**320**	[50]
USA	**35**	**40**	**370**	[50]
Malaysia	**67**	**82**	**331**	[50]
Spain	**32**	**33**	**470**	[50]
Buzrgan-Iraq	**3.7-14.5**	**1.6-19.4**	**259.8-564**	Present study

***.Not Analyzed**

7. Conclusions

The present work used a gamma ray spectroscopy system with an HPGe detector to estimate the primordial radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in soil and rock samples from petroleum well BUCN-157D situated in Buzurgan oilfield, Maysan Governorate, southern Iraq. The average values of ^{226}Ra, ^{232}Th, and ^{40}K that were measured were lower than the average world values that UNSCEAR 2008 reported. The estimated, analyzed, and discussed variables included the radium equivalent (Raeq), external and internal hazard indices, representative index (I), absorbed dose rates (D), and internal and external annual effective dose (AEDE).

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Conflict of interest

Authors declare that they have no conflict of interest.

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