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Determination of Health Risk Coefficients for Natural Radioactive Elements in Crude Oil Produced from Al Gharraf Oil Field

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Abstract

Natural radioactive materials (NORM) that accompany oil and gas production pose a real problem for the environment and man, where can these radioactive substances that pose a significant threat to workers in extraction of crude oil if the concentrations of these substances exceeded the permissible limits. Natural radioactivity due to U-238, Th-232, Ra-226, Ra-228 and K-40 in crude oil samples collected from al Gharraf oil field in Thi Qar province, south of Iraq measured using gamma ray spectrometry system based on 3" x 3" NaI (Tl) scintillation detector. The radioactivity concentrations of U-238,Th-232,Ra-226,Ra-228 and K-40 values in the studied oil samples are ranged (0.92-5.0 Bq / kg) with average of 2.592 Bq / kg ,(3.423-4.30 Bq) / kg with average of 3.819 Bq / kg , (1.611-6.811 Bq / kg) with an average of 3.802 Bq / kg, (1.15-4.62 Bq / kg) with an average of 2.947 Bq / kg and (60.45-138.88 Bq / kg) with average of 97.324 Bq / kg , respectively. The equivalent concentrations for each of Ra -226 and Th-232 and K-40 has been calculated for all samples was found between (7.60-24.04) Bq / kg with average of 15.92 Bq / kg , (5.39-16.98) Bq / kg with average of 10.74 Bq / kg and (98.78-313.10) Bq/Kg with average of 98.78 Bq / kg respectively . The absorbed dose for these concentrations were calculated using three equations supported by ICRP, UNSCEAR and BECK and found that the absorbed dose according to ICRP,UNSCEAR and BECK for all samples ranged between (1.378-5.675) $nGyh^{-1}$with average (3.416) $nGyh^{-1}$, (11.00-3.85) $nGyh^{-1}$ with average (6.991) $nGyh^{-1}$ and (11.496-3.881) $nGyh^{-1}$ with average (7.480) $nGyh^{-1}$, respectively. The calculated values of the annual effective dose rate and excess lifetime cancer risks (ELCR) are in between $(1.690 - 6.960\,\mu Sv.y^{-1})$ with average($4.190\ \mu Sv.y^{-1}$) and ($0.591x10^{-4}$ -$2.436591x10^{-4}$) with average ($1.465x10^{-4}$) , respectively. The external and internal hazard index also calculated and found are ranged between ($0.021 - 0.065\ Bq/Kg$) and (0.023-0.08 (Bq/Kg) with average (0.041) and (0.049)Bq/Kg, respectively. The measured activity concentrations of radionuclides were compared with the worldwide reported data. This study shows that the measured crude oil samples do not pose any significant source of radiation hazard and are safe for workers in these areas so that all the measured and calculated parameters is within the limits allowed by the recommendations of ICRP,WHO,UNSCEAR .

Keywords: NORM, Crude Oil Radioactivity, Radiation Hazard, Al-Gharraf Oil Field, Gamma Ray Spectroscopy

1. Introduction

Crude oil or petroleum (used for the same meaning) is a liquid originally formed from hydrocarbons and also contains a small percentage of sulfur, oxygen and nitrogen. Is formed and collected in the ground and remains stable in its place until it appears to the surface of the earth by several natural factors such as cracks or fractures of land or extracted by man by drilling wells and flows from them under a certain pressure or by external pumping and vary crude oil significantly from one area to another field to else. Crude oil is found in nature either in a solid or semi-solid state such as an asphalt crater or it can be present in a liquid state such as crude oil or in gaseous states such as natural gas.

Crude oil is primarily hydrocarbons or is a replacement hydrocarbon, in which the two main components are carbon (83-87%) and hydrogen (10-14%) with three elements of low importance (sulfur (0.1 to 3% and rarely up to 7 %), Nitrogen (often less than 0.1 and sometimes up to 2%) and oxygen up to 1.5%. [1]

The world cares about the protection from ionizing radiation due to the abundance of sources in our daily lives and the harm it causes to humans and the surrounding environment. Perhaps one of the most important conditions for prevention from ionizing radiation are radiation knowledge of what it is and its impact on humans in addition to knowledge of natural and industrial radiation sources [2]. NORM is commonly referred to Natural Occurring Radioactive Materials, and TENORM is also referred to Technologically Enhanced Natural Occurrence Radioactive Materials [3].

Both terms are used in the oil and gas industry to express radioactive materials of natural origin found in crude oil and its equipment. Includes natural radioactive substances (NORM). Long-lived radioactive elements such as uranium, thorium, potassium and some of their radioactive decay products such as radium and radon. These elements exist in the earth and within the tissues of all living things. The naturally occurring radioactive material is widely found in oil and gas and its residues, sand, mud, soil, rock, coal, groundwater, metallic minerals and nonmetallic minerals, including fertilizers and raw materials such as phosphate and apatite (metal used as a source of phosphorus). Metallic ores are found to be associated with NORM and include tin ores, niobium, rare earth, some copper and gold [3].

2. Material and Methods

2.1. Area of the study

The current study included the Gharaf oil field located in the north-west of the city of Rifai in the province of Thi Qar, about 5km away, and coordinates 31 43 43 14`N and 4666 28˵ W. About 85 Km north of the city of Nasiriyah. The field was discovered since 1984 and contains crude oil in a reservoir of 17.5 km length and 5.5 km width. Figure (1) shows the location of the field with maps and images.

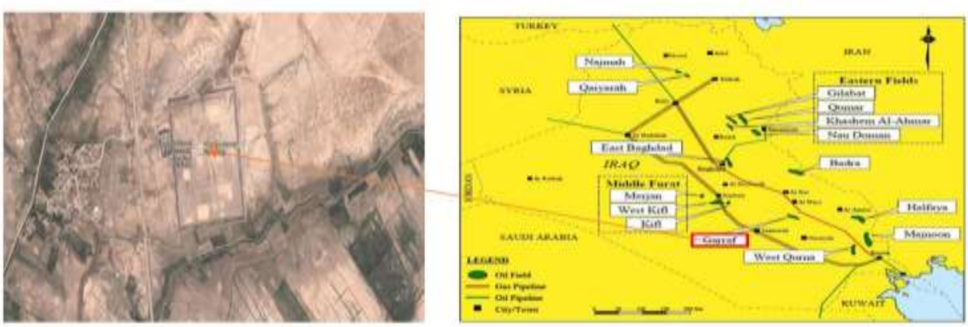

Fig. (1): Al-Gharraf oil field location, Rifai city in province of Thi Qar.

2.2. Sample preparation and measurements

In order to determine the radioactivity concentration of natural radioactive elements in crude oil samples gamma-ray spectroscopy technique was used to measure and analysis the samples.

Fifteen sample of crude oil were collected in small 1.5 liter containers. Samples were studied according to the location of wells or reservoirs taken from them. The samples were left for a month to obtain the acceptable radioactive equilibrium of the natural radioactive elements. Approximately from each sample were weighted to fit with the size of 1 kg Marielle Becker was counted for 10 h by a 76 mm x 76 mm Teledyne isotope D1212 NaI (Tl) scintillation detector with resolution 7.5% Kev at the 661.76 Kev Cs-137 source. An efficiency curve in an identical geometry was measured by using a certified standard natural radioactive source (ThO2-S7), was produced by British laboratory equipment company PANAX with specific activity of 3570 ± 20 Bq /g of multiple gammas over a range of energies. The radioactivity concentration for each radionuclide was determined using equation (1) after measuring and analyzing the energy peaks of sample spectrum and after determining the Minimum Detectable Activity (MDA). Figure (2) shows the measurement system and figure (3) representing the measured spectrum of one of the samples CST1 measured with counting time of 30000 seconds. The radioactivity concentration of Uranium-238 calculated depending on the radioactivity concentration of Bismuth-214 and Thorium-232 depending on radioactivity concentration of Thalium-208 while, the radioactivity concentration of radium-226 and radium-228 determined based on the radioactivity concentration of bismuth-214 and Actinium-228 respectively. Potassium-40 was measured by its single energy (1460.8 Kev). Table 3-6 contains the natural radionuclides used to calculate the radioactivity concentration of Uranium-238, thorium-232, radium-226, radium-228 and potassium-40.

Fig. (2): Gamma spectroscopy system used in the present study.

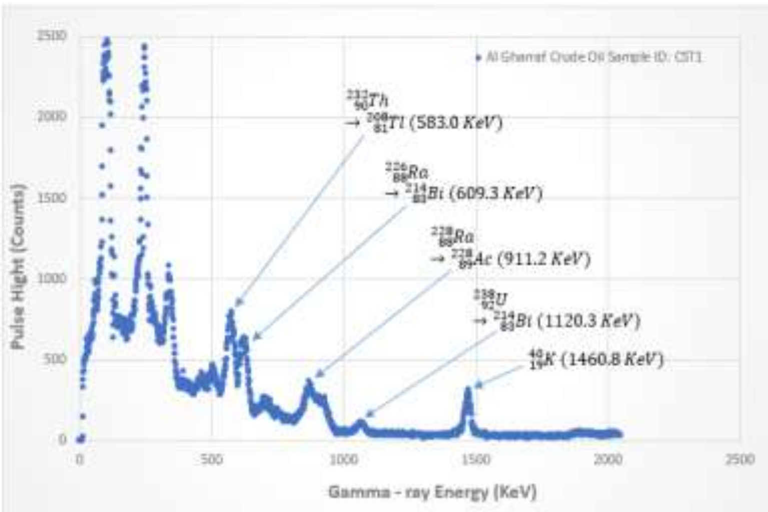

Fig. (3): The measured spectrum of the crude oil sample ID CST1 with a Measuring time of 30000 seconds.

Table (1): Natural radionuclides used to calculate the radioactivity concentration of Uranium-238, thorium-232, radium-226, radium-228 and potassium-40.

Parent	Daughter	Energy	Intensity

		(Kev)	(%)
$^{238}_{92}U$	$^{214}_{83}Bi$	1120.3	15
$^{232}_{90}Th$	$^{208}_{81}Tl$	583.0	84
$^{226}_{88}Ra$	$^{214}_{83}Bi$	609.3	46
$^{228}_{88}Ra$	$^{228}_{89}Ac$	911.2	29
$^{40}_{19}K$	Natural	1460.8	11

3. Assessment of Radiation Hazards

3.1. Minimum Detectable Activity

The Minimum Detectable Activity (MDA) is very important if low-concentration radioactive elements such as NORM are detected. The sample count rate is often the same as the radiation background count. Radiation background without the sample should be measured with the same measurement conditions and preferably at the same time Measurement for sample. (MDA) depends on the detection limit level (LLD) and the counting efficiency of the detection system [4]. The LLD detection limit level of the detector system can be calculated from the following equation:

$$LLD = (4.66x\sigma_b) + 3 \qquad (1)$$

The minimum effectiveness of MDA detection can be calculated from the following equation:

$$MDA = \frac{LLD}{k.t} \qquad (2)$$

Or as follows:

$$MDA = \frac{(4.66x\sigma_b)+3}{k.t} \qquad (3)$$

Where σ_b is the standard deviation of the radiation background and t is the measurement time of the radiation background and the sample k is a coefficient that contains both the efficiency of the detection system and the abundance of the element under measurement and the weight of the sample according to the following formula:

$$k = \varepsilon(E_\gamma).I_\gamma(E_\gamma).W \qquad (4)$$

Where W is the weight of the sample measured in Kg. Equation (3) can be redrafted as follows:

$$MDA = \frac{(4.66x\sigma_b)+3}{\varepsilon(E_\gamma).I_\gamma(E_\gamma).W.t} \qquad (5)$$

Equations (1) and 3) are valid for use only when the sample and radiation background time is equal and otherwise the following general equations are used:

$$LLD = 3.29\sqrt{n_b t_s\left(1+\frac{t_s}{t_b}\right)} +3 \qquad (6)$$

$$MDA = \frac{3.29\sqrt{n_b t_s\left(1+\frac{t_s}{t_b}\right)}+3}{\varepsilon(E_\gamma).I_\gamma(E_\gamma).W.t} \qquad (7)$$

Where n_b is the rate of the detection of the radiation background detection for the time period t_b and t_s the total time period of the sample [4]. The Minimum Detectable Activity (MDA) was calculated in present study using eq. (3) as shown in table (2).

Table (2): Minimum detection activity (MDA) of measurement system Used to determine the radioactivity concentrations of targeted Elements in crude oil samples.

Nuclide	$E_\gamma(KeV)$	$I_\gamma\%$	Element Concentratic (Bq/Kg)	MDA (Bq/Kg)
$^{232}_{90}Th(^{208}_{81}Tl)$	583	84	3.423	0.164
$^{226}_{88}Ra(^{214}_{83}Bi)$	609.318	46	1.611	0.167
$^{228}_{88}Ra(^{228}_{88}Ac)$	911.204	29	1.150	0.247

$^{238}_{92}U(^{214}_{83}Bi)$	1120.3	15	0.920	0.382
$^{40}_{19}K(Natural$	1460.83	10.7	60.45	3.90

3.2. Radioactivity Concentration

The concentration of the specific radiation activity is defined as the activity of each unit of mass of the radioactive material and measured in Curies per gram or Bq/Kg, the radiative quality of A for each radioactive counterpart measured by Bq / kg and can be calculated using the following equation [5]:

$$A(Bq/Kg) = \frac{N}{t.I_{\gamma}(E_{\gamma}).\varepsilon(E_{\gamma}).m} \qquad (8)$$

Where N is the net area under the gamma-ray peak measured for the spectrum after subtraction of the radiation background, t measurement time (sec), $I_{\gamma}(E_{\gamma})$ intensity of measured gamma ray energyE_{γ}, $\varepsilon(E_{\gamma})$ is the efficiency of gamma ray energy line and M is the weight of the sample Kg.

3.3. Radium Equivalent Activity (Ra_{eq})

The equivalent concentration value of the radium element (Ra _eq) used to estimate the hazards associated with substances containing radium-226, thorium-232 and potassium-40 radionuclides, calculated to assume a concentration of 370 Bq / kg for radium 226 in this substance or 260 Bq / kg for thorium - 232 or 4810 Bq / Kg of potassium-40 which produces the same dose for gamma rays. The equivalent radium efficiency (Ra _eq) can be calculated using the following equation [6]:

$$Ra_{eq}(Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \qquad (9)$$

Where A_{Ra}, A_{Th} and A_{K} are the efficiencies of radium, thorium and potassium, respectively, and measured by Bq/Kg. This indicator can be circulated on both potassium and thorium according to the following equations:

$$Th_{eq}(Bq/kg) = A_{Th} + 0.7A_{Ra} + 0.055A_{K} \qquad (10)$$

$$K_{eq}(Bq/kg) = A_K + 18.46A_{Th} + 13.24A_{Ra} \quad (11)$$

3.4. The External Hazard Index (H_{ex})

This term is used to determine the external risk of gamma rays and to estimate the expected gamma dose that may be exposed to external agents when they deal with substances containing gamma rays. The objective of this factor is to ensure that the effective dose of this radiation does not exceed permissible limits. The external risk factor can be calculated using the following equation:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (12)$$

Where H_{ex} is the external risk factor, A_{Ra}, A_{Th} and A_K are the radioactivity concentration of radium-226, thorium-232 and potassium-40, respectively, measured by Bq/Kg [7].

3.5. The Internal Hazard Index (H_{in})

The internal risk factor determines the dose limits received by workers in fields containing normal radiation activity, which reached the workers by swallowing or inhaling. The internal risk factor is a measure of radiation dose control and is given by the following formula:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (13)$$

Where A_{Ra}, A_{Th} and A_K are the radioactivity concentrations of radiation activity in (Bq / Kg) for radium-226, thorium-232 and potassium-40, respectively, where internal risk factor values should be less than one in the ideal environment to get a proper job opportunity for respiratory organs because they have dangerous respiratory effects [8].

3.6. Absorbed Gamma ray Dose (D_{γ})

The absorbed dose is the absorbed energy in the mass unit of the body exposed to radiation. This term is used for all types of radiation, energies, and all objects and materials. The rates of the absorbed doses due to gamma ray radiation of a naturally occurring radionuclide (^{226}Ra, ^{232}Th,^{40}K) calculated based on the recommendations of ICRP [nGy / h] using the following equation[9] :

$$D_{\gamma(ICRP)} = 0.427A_{Ra} + 0.662A_{Th} + 0.043A_K \quad (14)$$

The conversion factors used to calculate the absorption rate of gamma rays for each radioactivity concentration (1 Bq/Kg) are for radium-226 (0.462 nGy/h) and (0.604 nGy/h) for thorium-232 and (0.0417 nGy/h) for potassium-40. Also, the absorbed dose can be calculated using the relationship derivate by Beck [10]:

$$D_{\gamma(Beck)} = 0.420A_K + 0.429A_{Ra} + 0.666A_{Th} \quad (15)$$

And according to the formula adopted by UNSCEAR [11],

$$D_{\gamma(UNSCEAR)} = 0.533A_{Ra} + 0.827A_{Th} + 0.0537A_K \quad (16)$$

3.7. Representative level index ($I_{\gamma r}$)

It is used to estimate the level of gamma rays radiation risk associated with natural radionuclides in the measured samples, a factor representing the OECD index can be calculated from the following equation derived by the OECD [12]:

$$I_{\gamma r(OECD)} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (17)$$

Where the radioactivity concentration of radium-226 (A_{Ra}), thorium-233(A_{Th}) and potassium-40 (A_K), respectively are in Bq/Kg.

3.8. The Annual Effective Dose (AED)

To calculate the effective annual dose, consider the conversion factor from the absorbed dose to the effective dose and the internal survival factor. To calculate the effective dose of the gamma-emitting element, UNSEAR2000 [13] has adopted the conversion coefficient of 0.7 Sv / Gy as a conversion factor from the absorbed dose in air to the annual effective dose received by adults. The calculations adopted that 80% of the person life time spent in dwelling and 20% of time spent abroad. From these data, the annual effective dose was calculated as follows:

$$AED_{in}\,(mSv/y) = D_\gamma(nGy/h)x10^{-6}x\,8760h/y\,x0.8x0.7\,Sv/G \quad (18)$$

$$AED_{out}(mSv/y) = D_\gamma(nGy/h)x10^{-6}x\,8760h/y\,x0.2x0.7\,Sv/G \quad (19)$$

Where the number (8760) is the number of hours per year

3.9. Excess Lifetime Cancer Risk (ELCR)

It is a factor used to calculate the risk of gamma ray associated to radionuclides in the studied samples. It gives the percentage of those who develop cancer as a result of the annual effective doses received. ELCR calculated as follows:

$$ELCR = AEDxDLxRF \qquad (20)$$

Since AED is the annual effective dose, DL is the expected life expectancy of approximately 70 years and RF is the risk of fatal injury per Sievert and is equal to 0.05 for the general public according to ICRP [9].

4. Results and Discussion

The mean values of measured activity concentrations of selected radionuclides of ^{238}U, ^{232}Th, ^{226}Ra, ^{228}Ra and ^{40}K in Crude oil samples from all fifteen sites in Al-Gharraf oil field are shown in Table 2. The activity concentrations of ^{238}U, ^{232}Th, ^{226}Ra, ^{228}Ra and ^{40}K are in the range from (0.92-5.0 Bq / kg) with average of 2.592 Bq / kg ,(3.423-4.30 Bq) / kg with average of 3.819 Bq / kg , (1.611-6.811 Bq / kg) with an average of 3.802 Bq / kg, (1.15-4.62 Bq / kg) with an average of 2.947 Bq / kg and (60.45-138.88 Bq / kg) with average of 97.324 Bq / kg , respectively. The equivalent concentrations for each of Ra -226 and Th-232 and K-40 has been calculated for all samples was found between (7.60-24.04) Bq / kg with average of 15.92 Bq / kg , (5.39-16.98) Bq / kg with average of 10.74 Bq / kg and (98.78-313.10) Bq/Kg with average of 98.78 Bq / kg respectively, are shown in table (3). The absorbed dose for these concentrations were calculated using three equations supported by ICRP, UNSCEAR and BECK and found that the absorbed dose according to ICRP,UNSCEAR and BECK for all samples ranged between (1.378-5.675) $nGyh^{-1}$with average (3.416) $nGyh^{-1}$, (11.00-3.85) $nGyh^{-1}$ with average (6.991) $nGyh^{-1}$ and (11.496-3.881) $nGyh^{-1}$ with average (7.480) $nGyh^{-1}$, respectively, and the calculated values of the annual effective dose rate and excess lifetime cancer risks (ELCR) are in between $(1.690 - 6.960\ \mu Sv.y^{-1})$ with average$(4.190\ \mu Sv.y^{-1})$ and

($0.591x10^{-4}$ -$2.436591x10^{-4}$) with average ($1.465x10^{-4}$) , respectively, while the external and internal hazard index also calculated and found are in ranged between ($0.021 - 0.065\ Bq/Kg$) and (0.023-0.08 Bq/Kg) with average (0.041) and (0.049)Bq/Kg, respectively, as shown in table (4) The measured activity concentrations of ^{238}U, ^{232}Th, ^{226}Ra, ^{228}Ra and ^{40}K were compared with world-wide reported values as shown in Table (5). This study shows that the measured crude oil samples do not pose any significant source of radiation hazard and are safe for workers in these areas so that all the measured and calculated parameters is within the limits allowed by the recommendations of ICRP,WHO,UNSCEAR. The results shown in Table (2) indicate that average value of ^{226}Ra (2.80 ± 1.67 Bq/kg) < ^{232}Th (3.42 ± 1.85 Bq/kg) < ^{40}K (97.32 ± 9.87 Bq/kg). Radium equivalent activity (Ra_eq) owing to activity concentration of the three natural radionuclides from all samples varies from (7.60-24.04) Bq / kg.

The average value of (Ra_eq) is 15.92 Bq / kg ± 3.9 Bq/kg, which is much less than the threshold value of 370 Bq/kg. The average values of hazard coefficients computed in this work is much less than the reported world-wide.

5. Conclusion

The present work has been carried out to establish a base line data regarding concentration levels of naturally occurring radionuclides of ^{238}U, ^{232}Th, ^{226}Ra, ^{228}Ra and ^{40}K in Crude oil and the corresponding radiation doses in Al-Gharraf oil field, city of Rifai in the province of Thi Qar. Measured average activity concentrations of the five radionuclides are found less than the world's average values. Calculated values of hazard coefficients are also lower than the world average of about 0.5 mSv per year. It is concluded that there is no potential radiological health risk associated with the crude oil samples of al-Gharaaf oil field investigated during this work. The data generated here may be useful for the introduction of radiation safety standards by the State Authorities for the protection of general population from radiation hazards owing to terrestrial sources.

Table (3): Measured radioactivity concentrations of ^{238}U, ^{232}Th, ^{226}Ra, ^{228}Ra and ^{40}K in Al-Gharraf crude oil field.

Sample ID	^{238}U (Bq/kg)			^{232}Th (Bq/kg)			^{226}Ra (Bq/kg)			^{228}Ra (Bq/kg)			^{40}K ((Bq/kg)		
CS1	3.56	±	1.89	3.77	±	1.94	3.73	±	1.93	2.98	±	1.73	110.15	±	10.50
CS2	0.92	±	0.96	1.42	±	1.19	0.91	±	0.95	1.56	±	1.25	60.45	±	7.77
CS3	1.56	±	1.25	2.62	±	1.62	1.62	±	1.27	2.42	±	1.55	85.11	±	9.23
CS4	2.93	±	1.71	4.14	±	2.03	3.08	±	1.75	3.55	±	1.88	108.10	±	10.40
CS5	2.03	±	1.42	2.55	±	1.60	2.42	±	1.56	2.28	±	1.51	86.93	±	9.32
CS6	1.14	±	1.07	2.25	±	1.50	1.05	±	1.03	2.17	±	1.47	65.36	±	8.08
CS7	2.20	±	1.48	3.72	±	1.93	2.46	±	1.57	3.38	±	1.84	90.90	±	9.53
CS8	1.88	±	1.37	2.66	±	1.63	1.77	±	1.33	2.13	±	1.46	79.54	±	8.92
CS9	1.98	±	1.41	3.03	±	1.74	1.79	±	1.34	2.74	±	1.66	103.38	±	10.17
CS10	2.72	±	1.65	3.78	±	1.94	2.81	±	1.68	3.15	±	1.77	115.95	±	10.77
CS11	2.73	±	1.65	3.69	±	1.92	3.17	±	1.78	3.06	±	1.75	99.43	±	9.97
CST1	5.02	±	2.24	5.27	±	2.30	5.81	±	2.41	4.52	±	2.13	138.88	±	11.78
CST2	4.61	±	2.15	4.68	±	2.16	5.36	±	2.31	3.88	±	1.97	135.04	±	11.62
GIF1	2.70	±	1.64	3.96	±	1.99	2.92	±	1.71	3.88	±	1.97	80.53	±	8.97
GIF2	2.90	±	1.70	3.83	±	1.96	3.12	±	1.77	3.14	±	1.77	100.12	±	10.01
Average	2.59	±	1.61	3.42	±	1.85	2.80	±	1.67	2.99	±	1.73	97.32	±	9.87
Max	5.02	±	2.24	5.27	±	2.30	5.81	±	2.41	4.52	±	2.13	138.88	±	11.78
Min	0.92	±	0.96	1.42	±	1.19	0.91	±	0.95	1.56	±	1.25	60.45	±	7.77

STDEV	1.15	± 1.07	1.00	± 1.00	1.39	± 1.18	0.79	± 0.89	22.53	± 4.75

Table (4): The equivalent concentrations of ^{226}Ra, ^{228}Ra and ^{40}K and the Ratio of radioactivity concentration of ^{238}U /^{226}Ra and ^{226}Ra /^{228}Ra in Al-Gharraf crude oil field.

Sample ID	Ra_eq *(Bq/kg)*	Th_eq *(Bq/kg)*	K_eq *(Bq/kg)*	^{238}U /^{226}Ra	^{226}Ra /^{228}Ra
CS1	17.604	12.44	229.14	0.954	1.265
CS2	7.601	5.39	98.78	1.010	0.913
CS3	11.921	8.44	154.94	0.962	1.084
CS4	17.319	12.24	225.23	0.952	1.166
CS5	12.763	9.03	166.08	0.839	1.118
CS6	9.302	6.58	120.82	1.084	1.039
CS7	14.780	10.44	192.15	0.894	1.102
CS8	11.693	8.27	152.01	1.061	1.248
CS9	14.089	9.97	183.09	1.106	1.106
CS10	17.139	12.12	222.88	0.968	1.199
CS11	16.097	11.37	209.45	0.861	1.206
CST1	24.041	16.98	313.10	0.864	1.166
CST2	22.448	15.86	292.37	0.860	1.206
GIF1	14.780	10.43	192.24	0.924	1.019
GIF2	16.309	11.52	212.17	0.929	1.221
Average	15.192	21.48	197.63	0.951	1.137
Max	24.041	16.98	313.10	1.106	1.265
Min	7.601	5.39	98.78	0.839	0.911
STDEV	4.885	4.27	63.70	0.089	0.703

Table (5): Gamma ray absorption dose calculated according to ICRP60, Beck and UNSCEAR recommendations, annual effective dose AED Calculated according to the ICRP60 recommendations as well as the hazard coefficients.

Sample ID	D_{ICRP} $nGy.h^{-1}$	D_{BECK} $nGy.h^{-1}$	$D_{UNSCEAR}$ $nGy.h^{-1}$	AED_{ICRP} $\mu Sv.y^{-1}$	$ELCR * 10^{-4}$	I_{yr} $Bq.Kg^{-1}$	H_{ex} $Bq.Kg^{-1}$	H_{in} $Bq.Kg^{-1}$
CS1	4.060	8.665	7.91	4.979	1.743	0.102	0.048	0.058
CS2	1.378	3.881	3.85	1.690	0.591	0.048	0.021	0.023
CS3	2.444	5.989	5.66	2.997	1.049	0.070	0.032	0.037
CS4	4.033	8.552	7.79	4.946	1.731	0.097	0.047	0.055
CS5	2.599	6.222	6.17	3.188	1.116	0.077	0.034	0.041
CS6	2.019	4.733	4.26	2.476	0.867	0.053	0.025	0.028
CS7	3.444	7.239	6.51	4.224	1.478	0.081	0.040	0.047
CS8	2.603	5.915	5.44	3.193	1.117	0.067	0.032	0.036
CS9	2.897	7.212	6.76	3.553	1.243	0.084	0.038	0.043
CS10	3.705	8.552	8.04	4.544	1.590	0.100	0.046	0.054
CS11	3.649	7.802	7.34	4.475	1.566	0.091	0.043	0.052
CST1	5.675	11.496	11.00	6.960	2.436	0.137	0.065	0.081
CST2	5.110	10.766	10.50	6.266	2.193	0.130	0.061	0.075
GIF1	3.814	7.175	6.21	4.678	1.637	0.077	0.040	0.048
GIF2	3.817	8.000	7.36	4.682	1.639	0.091	0.044	0.052
Average	3.416	7.480	6.99	4.190	1.466	0.087	0.041	0.049
Max	5.675	11.496	11.00	6.960	2.436	0.137	0.065	0.081
Min	1.378	3.881	3.85	1.690	0.591	0.048	0.021	0.023
STDEV	1.263	2.263	2.17	1.549	0.542	0.027	0.013	0.017

Table (6): Natural radioactivity of the elements studied in the present Research compared to their concentrations in global research and Studies in crude oil, with reference to the concentration of the Radiation effectiveness of these elements in the materials Accompanying the crude oil.

Radionuclides	Crude oil (Bq /Kg) (Wwrl) [14]	Crude oil (Bq /Kg) (Present work)	Produced water (Bq/Kg)	Hard scale (Bq/kg)	Sludge (Bq/kg)
U-238	0.0001-10	0.92- 5.02	0. 3-1000	1.0-500	5.0-10.0
Ra-226	0. 1- 40	1.611- 6.8	2.0 -120k	100-15M	50.0-800k
Th-232	0.03-2.0	3.42- 4.30	0.3-1.0	1.0- 2.0	2.0-10.0
Ra-228	0.05-20	1.15- 4.62	300 - 180k	50.0 - 2.8M	500-50k
K-40	1.0- 623.0	60.5-138.8	---------	---------	--------

Wwrl: Word wide reported levels of NORM, k: kilo (10^3), M: million (10^6)

6. References

[1]. Terje S., "Handling and Disposal of NORM in the Oil and Gas Industry", WM'99 Conference (1999).

[2]. Knoll G. F., "Radiation detection and Measurement", 2nd Edition, John Wiley and Sons, New York (1989).

[3]. Richard T. and Dieter B., "Man-Made and Natural Radioactivity in Environmental Pollution and Radiochronology", Environmental Pollution, Springer (2004).

[4]. Mirjana B. and Scepan S., "Radioactivity of Sand from Several Renowned Public Beaches and Assessment of the Corresponding Environmental Risks", Journal of the Serbian Chemical Society, Vol.74, No.4, PP.461-470, (2009).

[5]. Harb S., El-Kamel A. H., Abd El-Mageed A. I. Abbady A. and Wafaa R., "Concentration of U-238, U-235, Ra-226, Th-232 and K- 40 for Some Granite Samples in Eastern Desert of Egypt", Proceedings of

the 3rd Edition Environmental Physics Conference, Aswan, Egypt (2008).
[6]. Jose A., Jorge J., Cleomacio M., Sueldo V. and Romilton dos S.," Analysis of the K-40 Levels in Soil Using Gamma Spectrometry", Brazilian Archives of Biology and Technology Journal, 48,221- 228, (2005).
[7] .Thormod H. and David H. M., "Radiation and Health", Taylor and Francis Group, New York and London (2003).
[8]. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), " Biological Effects of Low Doses of Ionizing Radiation: A Fuller picture", Report to the General Assembly, United Nations (1994).
[9]. ICRP,"1990 Recommendations of the International Commission on Radiological Protection", Publication 60, Annals of the ICRP 21(1-3), Pergamon Press, Oxford (1991).
[10]. Beck H. L., Decompo J. and Gologok J.," The radiation field in air Due to distributed gamma ray sources in ground. Health and safety Laboratory AEC: Report HASL 258, (1972).
[11]. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)," Ionizing Radiation Sources and Biological Effects", Report to the General Assembly, United Nations, New York (1982).
[12]. NEA-OECD, Nuclear Energy Agency, “Exposure to radiation from Natural radioactivity “OECD, Paris (1979).
[13]. UNSCEAR. REPORT Vol. I sources and effects of ionizing Radiation, annex a: dose assessment methodologies. New York: United Nations Scientific Committee on the effects of atomic Radiation; 2000.
[14]. David O., "Radiation Exposure to Nature Radioactivity in Crude Oil And Petroleum Waste from Oil fields in Ghana; modelling, risk Assessment and regulatory control", Ghana (2015).

الملخص

تشكل المواد المشعة الطبيعية المنشأ المصاحبة لصناعة النفط والغاز والتي تختصر بكلمة (NORM) مشكلة حقيقية على البيئة والانسان حيث يمكن ان تكون هذه المواد بتراكيز كبيرة

نتيجة لعمليات استخراج واستخلاص النفط الخام . اجريت هذه الدراسة لتقييم المخاطر الاشعاعية المحتملة على العاملين والبيئة المحيطة الناتجة عن هذه المواد المشعة المصاحبة للنفط الخام المنتج من حقل الغراف النفطي في محافظة ذي قار . اختير 15 بئراً وموقعاً لإخذ عينات النفط الخام وبعد تجميع العينات في المختبر اجريت القياسات الطيفية باستخدام منظومة كاشف ايوديد الصوديوم المنشط بالثاليوم NaI(Tl) بأبعاد "3"x3 حيث تم قياس وحساب تراكيز الفعالية الاشعاعية لكل من اليورانيوم-238 والراديوم-226 والثوريوم- 232 والراديوم-228 والبوتاسيوم-40 في العينات المدروسة فكان تركيز اليورانيوم -238 $({}^{238}_{92}U)$ لجميع العينات يتراوح بين $(0.92-5.02)\ \frac{Bq}{kg}$ بمعدل $2.592\ \frac{Bq}{kg}$ و تركيز الثوريوم – 232 $({}^{232}_{90}Th)$ يتراوح بين $(3.423-4.30)\frac{Bq}{kg}$ بمعدل تركيزقدره 3.819 كذلك بالنسبة الراديوم – 226 $({}^{226}_{88}Ra)$ فكان تركيزه يتراوح بين $(1.611-6.811)\frac{Bq}{kg}$ وبمعدل تركيز قدره $3.802\ \frac{Bq}{kg}$ وايضا تركيز الراديوم – 228 $({}^{228}_{88}Ra)$ يتراوح بين $(1.15-4.62)\frac{Bq}{kg}$ وبمعدل تركيز $2.947\ \frac{Bq}{kg}$ واخيرا تركيز البوتاسيوم – 40 $({}^{40}_{19}K)$ يتراوح بين $(60.45-138.88)\frac{Bq}{kg}$ وبمعدل $97.324\ Bq/Kg$. كذلك حسبت التراكيز المكافئة لكل من الراديوم-226 والثوريوم-232 والبوتاسيوم فكانت قيمة تراكيز مكافىء عنصر الراديوم-226 Ra_{eq} لجميع العينات يتراوح بين $(7.60-24.04)\ Bq/Kg$ بمعدل $15.92\ Bq/Kg$ ومكافىء عنصر الثوريوم-232 $\mathrm{Th_{eq}}$ يتراوح بين $(5.39-16.98)\ Bq/Kg$ بمعدل $10.74\ Bq/Kg$ وكذلك مكافىء عنصرالبوتاسيوم- 40 $\mathrm{K_{eq}}$ يتراوح بين $(98.78-313.10)\ Bq/Kg$ كما حسبت الجرعة الممتصة من ثلاث معادلات معتمدة من قبل هيئات ومنظمات معتبرة هي ICRP,BECK,UNSCEAR فكانت D_{ICRP} تتراوح قيمتها بين (1.378-5.675) $nGyh^{-1}$ وبمعدل (3.416)) $nGyh^{-1}$ و D_{BECK} تراوحت قيمتها بين (3.881-11.496) $nGyh^{-1}$ وبمعدل مقداره (7.480) $nGyh^{-1}$ اما $D_{UNSCEAR}$ فتراوحت بين (3.85-11.00) $nGyh^{-1}$ وبمعدل قدره (6.99) $nGyh^{-1}$ كما حسبت الجرعة الفعالة السنوية لاشعة كاما فكانت تتراوح بين (1.690-6.960) $\mu Sv.y^{-1}$ وبمعدل قيمته (4.190) $\mu Sv.y^{-1}$ اما معامل زيادة احتمالية خطر الاصابة بالسرطان فكانت تراوح قيمته بين

($0.591x10^{-4}$-$2.436591x10^{-4}$) وبمعدل ($1.465x10^{-4}$). كما حسب معاملي الخطورة الخارجي H_{ex} والداخلي H_{in} للعينات المقاسة حيث تراوحت قيمتهما بين Bq/Kg (0.065-0.021) و Bq/Kg (0.023-0.081) و بمعدل (0.041) و Bq/Kg (0.049) على التوالي. النتائج التي تم الحصول عليها تشير الى ان تراكيز العناصر المشعة المستهدفة في الدراسة كانت ضمن الحدود المسموحة رغم التباين في قيم تراكيز العناصرالمشعة الطبيعية حسب العينات وكذلك بالنسبة الى المكافئات الاشعاعية والجرعة الممتصة والجرعة الفعالة السنوية ومعامل كاما التقديري وعامل زيادة خطر الاصابة بالسرطان ومعاملات الخطورة الخارجية والداخلية جميعها ضمن الحدود المسموحة حسب توصيات ICRP,WHO,UNSCEAR .