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Measuring the concentration of uranium in the Qayyarah oilfield and refinery

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ABSTRACT

In this research, the Concentrations of uranium and radon gas were measured in the samples collected from the Qayyarah refinery and field, which is located south of Mosul. The samples included soil and water associated with the production of oil, sludge and crude oil. After prepared samples, the radioactivity was measured using the CR-39 solid-state nuclear trace detector. Radon levels ranged between 10.79-19.67 Bq/kg in soil samples, and in water samples 7.25 Bq/l, in sludge samples 13.42-16.96 Bq/kg and in crude oil 8.57 Bq/kg. While uranium concentration levels, ranged in soil samples from 0.870 - 1.457ppm, in water samples 0.585 ppm, in sludge samples 1.299 - 1.369 ppm, and in crude oil samples 0.692 ppm. These results indicate that it is within the internationally permissible limits, as the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) determined the value of uranium in soil at 32 Bq/kg and in water at 50 Bq/l, and the International Atomic Energy Agency (IAEA) determined the value of uranium in The slag has a value of $(8 - 5 \times 10^5)$ Bq/kg, and the International Association of Oil and Gas Producers (IOGP) has determined the value of uranium in crude oil $(800 - 4 \times 10^5)$ Bq/kg and therefore does not pose any danger to the lives of workers in the refinery. field and environment.

Introduction

Natural radioactive elements such as uranium and thorium are there found in the soil [1]. Where uranium is one of the most important natural radioactive elements. It is found in nature in the form of three isotopes, which are U238, whose percentage in nature is estimated at 99%, U235, which is estimated at 0.720%, and U234 by 0.005%. U238 is one of the most common elements in the Earth's crust, with a long half-life of 4.6 billion years [2]. Uranium slowly decays by emission of alpha particles. It enters the human body through ingestion or inhalation and settles in the bones, liver and kidneys. The kidneys are the most sensitive organ to uranium toxicity. In the bones, uranium causes bone necrosis, which shows its long-term effect. Uranium is decomposed into radium, which is the main cause of cancer. Uranium is present in oil and gas reservoirs, where it accompanies oil and water during its extraction to the surface and is then transported to oil equipment and tanks. Workers in this field are exposed to uranium during exposure to mud, sludge and water during oil extraction [3], as well as during maintenance of contaminated equipment and pipes, as well as exposure to toxic gases; Like radon gas, which belongs to the uranium series, radon is characterized by its ability to move in the air from one place to another without any obstruction, which makes the possibility of exposure to a large number of workers in the oil industry [4]. Several research and recommendations have been published by the International Atomic Energy Agency on the possibility of the presence of radioactive elements in the oil industry, as well as methods of treatment and safety [5]. A study was conducted in Turkey by researchers by collecting soil samples, crude oil, sludge and water, measuring the level of radiation and determining the extent of its danger [6]. Our study aims to measure the concentration of uranium in the Qayyarah refinery and field by collecting samples of soil, slag and water associated with the production of oil and sludge.

Materials and working methods

1- **Study area**

The study area included the collection of soil and water samples associated with the production of oil, crude oil and sludge from the Qayyarah refinery and oilfield, which is located south of Mosul. Figure (1) shows the locations of sample collection in the Qayyarah Refinery and Field.

Fig. 1: Sample collection sites in Qayyarah Refinery and Field

2- Collecting samples:

Soil samples were taken from the Qayyarah refinery and field at a depth between 5-15 cm around the oil tanks and places , oil leakage and near the pipes and keeping them in sealed plastic bags. the sludge, was taken from the oil tanks and kept in airtight plastic bags. While the water samples associated with the production of oil, were taken from the wet oil separation plant. Also the crude oil, was collected from the oil tanks the water and oil samples were preserved in plastic bottles of 1 l capacity.

3- The method of work

The The radon concentrations were measured using the CR-39 nuclear trace detector, after grinding the soil and slag samples to obtain a fine powder ready to work, then weighing the samples using a sensitive scale (0.001 gm), placing them in sealed plastic cups, as well as placing the water and oil samples in sealed plastic cups. To prevent the interaction of the air inside the samples with the outside air, the samples are left for 30 days to obtain the ideal balance between radium and radon by 99%, and the percentage is calculated through the following law of radiation balance [7]:

$$A_{\mathrm{Rn}} = A_{Ra}(1 - e^{-\lambda_{Rn} t})$$

Where A_{Ra} represents the activity of radium, A_{Rn} is the effectiveness of radon, t is the time required to reach the equilibrium state, and λ_{Rn} is the radon decay constant of $0.1814\ \mathrm{d}^{-1}$

Then a second cup similar to the first one is prepared and placed over the first cup containing a filter paper and a piece of CR-39 detector and left for another 30 days for the purpose of irradiating the reagents (Figure 2 shows the irradiation system). The detectors were placed inside the water bath at a temperature of $70\ C^{\circ}$ for 3 hours, to show the traces formed on the surface of the detector and clearly visible under the microscope. A 400X magnification lens was used to watch the traces formed on the surface of the detector as a result of the emission of alpha particles from the samples and their collision with the surface of the detector. The background radiation was 180 $\mathrm{Tr.cm^{-2}}$.

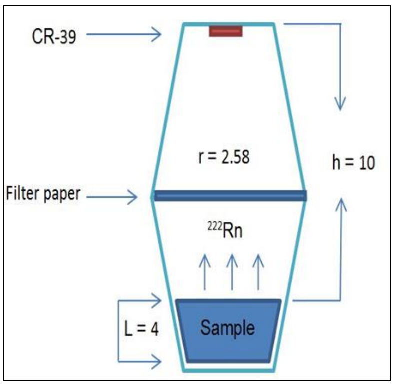

Fig. 2: Irradiation system

Mathematical equations were used to calculate the radioactivity of radon gas and the concentration of uranium:

1- Measurement of radon concentration (C_a) using the following relationship [8] [9] :

$\rho = KC_aT$ ... ... (1)

Where ρ represents the trace density in $Tr.cm^{-2}$ and K represents the diffusion constant in ($Tr.\frac{cm^{-2}}{h^{-1}Bq.m^{-3}}$) and C_a represents the radon concentration in the air $Bq.m^{-3}$ and T is the irradiation time in days.

2- Calculate the diffusion constant K from the following relationship:

$$K = \frac{1}{4}r\left(2Cos\theta - \frac{r}{R\alpha}\right) \text{... ... . (2)}$$

Where r represents the cup radius That equals 2.58 cm and Rα represents the range of alpha particles in the air resulting from radon gas its equals 4.16 cm and θ represents the angle with a value of 35°.

3- Calculation of the radon concentration (Cs) in the samples:

$$Cs = \frac{\lambda_{Rn} h\ C_a T}{L} \text{... ... . (3)}$$

λ_{Rn} represents the radon decay constant of $0.1814\ d^{-1}$, h represents the sample height with a value of 10 cm and L is the sample thickness with a value of 4 cm

4- Finding the radioactivity of radon A_{Rn} produced from the samples:

$A_{Rn} = C_S V$ ... ... (4)

$V = L\pi r^2$ ... ... (5)

Where V is the volume in m^3

5- Finding the number of radon atoms N_{Rn} in the samples:

$A_{Rn} = N_{Rn}\lambda_{Rn}$ ... ... (6)

6- Using the law of radiation balance, the number of uranium atoms in the samples can be found through the following equation:

$\lambda_U N_U = \lambda_{Rn} N_{Rn}$ ... ... (7)

7- Finding the mass of uranium in samples W_U :

$$W_U = \frac{N_U A_U}{N_{av}} \text{... ... . (8)}$$

Where N_U represents the number of uranium atoms, A_U is the mass number of uranium, and N_{av} is Avocader's number.

8- Calculation of the concentration of uranium in the samples $\mathbf{C_U}$ **:**

$$C_U = \frac{W_U}{W_S} \text{... ... . (9)}$$

Where W_S is the mass of the sample in gm

Results and discussion

The radioactivity of radon gas and the concentration of uranium were measured in soil, water, crude oil and slag sample. The highest radioactivity of radon gas and uranium concentration in soil samples in Qayyarah field, where the value of radon gas was 19.67 $(Bq/kg)$and the value of uranium concentration was 1.587(ppm) , and the lowest value was for radon gas and uranium concentration were in Qayyarah refinery where the value of radon gas 10.79 (Bq/kg) and a uranium concentration value of 0.87 (ppm). When comparing the results we obtained with the United Nations Committee on the Effects of Atomic Radiation (UNSEARS), whose value is 32(Bq/kg) [10] ,we find that what we obtained falls within the internationally permissible limit. As for the water samples associated with oil production, the radioactivity value of radon gas 7.25 (Bq/l) was and the concentration of uranium 0.585 (ppm) . When comparing the results we obtained with the global permissible limit, we find that what we obtained falls within it, which is UNSEARS 50 (Bq /l) [11] .As for crude oil samples, the radioactivity of radon gas was 8.57 $(Bq/kg)$and the concentration of uranium 0.692 (ppm) . When comparing the result with the International Association of Oil and Gas Producers (OGP) whose value is $(800 - 4 \times 10^5)$ (Bq/kg) . [12]we find that is within the internationally permissible limit. As for slag samples, the highest radioactivity of radon gas and uranium concentration was in Qayyarah refinery, where the value of radon was 16.96(Bq/kg) and the value of uranium concentration 1.369 (ppm) . The lowest radioactivity of radon gas and uranium concentration was in Qayyarah field, where the value of radon was is 13.42(Bq/kg) and the value of uranium concentration is 1.299 (ppm). When comparing the sludge results with the International Atomic Energy Agency (IAEA) with a value of $(8 - 5 \times 10^5)(Bq/kg)$ [5] we find that falls within the permissible limit globally.

Table 1: shows the location of the sample and its weight, as well as the density of traces, the concentration of radon in the air space, and the concentration of radon in the samples

No	Location	Samples	p $Tr.cm^{-2}$	C_a $Bq.m^{-3}10^3$	C_s $Bq.m^{-3}10^3$	Sample weight (gm)
1	Qayyarah field	Soil	1565	0.919	12.5029 ± 0.316	78.68
2	Qayyarah field	Soil	1970	1.158	15.7546 ± 0.355	77.50
3	Qayyarah field	Soil	2035	1.196	16.2716 ± 0.361	75.32
4	Qayyarah field	Soil	2029	1.193	16.2308 ± 0.360	79.13
5	Qayyarah field	Soil	2308	1.357	18.4619 ± 0.384	78.45
6	Qayyarah refinery	Soil	1742	1.024	13.9315 ± 0.334	79.62
7	Qayyarah refinery	Soil	1372	0.806	10.9656 ± 0.296	80.23
8	Qayyarah refinery	Soil	1294	0.761	10.3534 ± 0.288	80.23
9	Qayyarah refinery	Soil	1467	0.862	11.7275 ± 0.306	80.22
10	Qayyarah refinery	Soil	1778	1.045	14.2172 ± 0.337	80.23
11	Qayyarah refinery	water produced	847	0.497	6.762 ± 0.232	78
12	Qayyarah field	Sludge	2055	1.208	16.4348 ± 0.363	81.00
13	Qayyarah refinery	Sludge	1626	0.956	13.0064 ± 0.323	81.00
14	Qayyarah field	crude oil	1001	0.588	7.9997 ± 0.253	78

Table 2: shows the radioactivity of radon gas, the number of uranium atoms, the mass of uranium in the samples, and the concentration of uranium in the samples.

No	Location	Samples	A_{Rn} (Bq)	A_{Rn} (Bq/kg)	$N_U \times 10^{17}$	$W_U \times 10^{-6}$	$C\,U$ (ppm)
1	Qayyarah field	Soil	1.0452	13.28	2.133	84.328	1.072 ± 0.027
2	Qayyarah field	Soil	1.3171	16.99	2.688	106.269	1.371 ± 0.031
3	Qayyarah field	Soil	1.3603	18.06	2.776	109.749	1.457 ± 0.033
4	Qayyarah field	Soil	1.3569	17.15	2.769	109.472	1.383 ± 0.031
5	Qayyarah field	Soil	1.5434	19.67	3.149	124.495	1.587 ± 0.033
6	Qayyarah refinery	Soil	1.1647	14.63	2.377	93.974	1.180 ± 0.028
7	Qayyarah refinery	Soil	0.9167	11.43	1.871	73.969	0.922 ± 0.025
8	Qayyarah refinery	Soil	0.8655	10.79	1.766	69.819	0.870 ± 0.024
9	Qayyarah refinery	Soil	0.9804	12.22	2.001	79.101	0.986 ± 0.026
10	Qayyarah refinery	Soil	1.1886	14.81	2.426	95.912	1.195 ± 0.028
11	Qayyarah refinery	water produced	0.5653	7.25	1.154	45.623	0.585 ± 0.020
12	Qayyarah field	Sludge	1.3739	16.96	2.804	110.856	1.369 ± 0.030
13	Qayyarah refinery	Sludge	1.0873	13.42	2.663	105.281	1.299 ± 0.032
14	Qayyarah field	crude oil	0.6688	8.57	1.365	53.965	0.692 ± 0.022

Conclusion

The radioactivity of radon gas and the concentration of uranium in soil, crude oil and water samples associated with oil and sludge production collected from Qayyarah refinery and field were measured using CR-39 detector. The results we obtained showed that it is within the permissible limit globally, but it requires continuous monitoring to maintain the levels of Naturally Occurring Radioactive Materials.

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قياس تركيز اليورانيوم في مصفى و حقل القيارة النفطي

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الملخص

تم في هذا البحث قياس تركيز اليورانيوم والنشاط الاشعاعي لغاز الرادون في النماذج التي تم جمعها من مصفى وحقل القيارة التي تقع جنوب الموصل. وشملت النماذج التي تم جمعها التربة والماء المصاحب لانتاج النفط والخبث والنفط الخام. تم تحضير النماذج وقياس النشاط الاشعاعي وذلك باستخدام كاشف الاثر النووي للحالة الصلبة ذو نوع $CR-39$. كانت مستويات النشاط الاشعاعي لغاز الرادون في عينات التربة تتراوح من $10.79 - 19.67$ Bq/kg وفي عينات الماء 7.25 Bq/l وفي عينات الخبث $13.42 - 16.96$ Bq/kg وفي النفط الخام 8.57 Bq/kg. اما مستويات التركيز اليورانيوم فقد تراوحت في عينات التربة 0.870− 1.457 ppm وفي عينات الماء 0.585 ppm وفي عينات الخبث 1.299 – 1.369 ppm وفي عينات النفط الخام 0.692 ppm . وتشير هذه النتائج الى انها ضمن الحدود المسموح بها عالميا حيث حددت لجنة الامم المتحدة العلمية المعنية باثار الاشعاع الذري (UNSCEAR) قيمة اليورانيوم في التربة بمقدار 32 Bq/kg وفي الماء 50 Bq/l ، وحددت الوكالة الدولية للطاقة الذرية (IAEA) قيمة اليورانيوم في الخبث بقيمة $(8 - 5 \times 10^5)$ Bq/kg وحدد الاتحاد الدولي لمنتجي النفط والغاز (IOGP) قيمة اليورانيوم في النفط الخام $(800 - 4 \times 10^5)$ Bq/kg وبالتالي لاتشكل اي خطورة على حياة العاملين في المصفى والحقل والبيئة.