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Radon Level Measurements in Soil and Sediments at Oil Field Area and Its Impact on the Environment

Abstract- *Radon concentration, radium content, uranium concentration and rates of radon exhalation as a function of mass and area in 10 soil and 5 water sediment samples collected from one of the oil fields in Basrah governorate southern Iraq using CR-39 SSNTD were measured. Obtained results of radon concentrations range from 434.67 Bq.m^{-3} to 1947.99 Bq.m^{-3} with mean value of 985.26 Bq.m^{-3} and from 61.18 Bq.m^{-3} to of 2237.77 Bq.m^{-3} with mean value of 1215.16 Bq.m^{-3} in sediment and soil samples, respectively. The values of radium content for sediment and soil samples extended from 1.96 Bq.kg^{-1} to 9.75 Bq.kg^{-1}, with an average value of 4.45 Bq.kg^{-1} and from 0.28 Bqkg^{-1} to 10.11 Bq.kg^{-1} with mean value of 5.49 Bqkg^{-1}, respectively. Uranium concentration in ppm was calculated and its values were found to range from 0.36 to 13.07 ppm, which are comparable with different places around the world. The mass and surface radon exhalation rates vary from 0.079 Bqkg^{-1}h^{-1} to 2.88 Bqkg^{-1}h^{-1} with a mean value of 1.41 Bqkg^{-1}h^{-1}, and from 1.37 Bqm^{-2}h^{-1} to 49.98 Bqm^{-2}h^{-1} with a mean value of 24.47 Bqm^{-2}h^{-1}, respectively. Radium content is observed to be positively correlated with uranium concentration and with rates of radon exhalation in the study area, respectively.*

Keywords- *CR-39; Uranium, oil deposits, radon, alpha tracks, exhalation rates*

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1. Introduction

The primary wellsprings of radiation in soils and rocks are the naturally occurring radionuclides ^{238}U, ^{232}Th and ^{40}K. These radionuclides are gamma emitters, which pose external exposure risks, as well as ^{222}Rn isotope, which produced from the decay of ^{226}Ra, which in turn is derived from ^{238}U. Understanding radioactivity levels of different types of radionuclides in the earth's crust play an important role in health physics. Radon is considered as the main exposure source (about 55%) to human life due to its emission to alpha particles and is estimated to be the second leading cause of a lung cancer after smoking [1]. Diffusion of radon from the soil into the air depends on several parameters, such as uranium and radium content in soil and rocks; porosity of the soil or rock; Soil moisture, size of the soil grain, type of mineral content in the soil and permeability of the soil all together. Radon concentration may also be affected by air pressure and air temperature [2].

Many soil parameters effect the movement of radon through it; those are porosity, lithology, defects and basic characteristics like cracks, pressure, and junctions [3].

Not many researches on measuring the concentrations of radon in soils and rocks were achieved in Iraq. For instance, Khadim et al. [4], measured radon concentration in soil samples taken from Al–Anbar, Wasit, Diayala and Baghdad nearby sites using CR–39 plastic track detectors. Their results show that maximum concentration was recorded in Al–Ramadi city with value of 143.1 Bq.m^{-3}, however its minimum value was found in Diayala governorate, which was equal to 21.504 Bq.m^{-3}. Concentrations of Rn and Th of soil-gas in Al-Kufa city in Iraq were estimated by Al-Hamidawi et al. [5], using electric radon meter (RAD-7) in 20 locations for three depths of (50, 100 and 150) cm. They found that the emanation rate of radon and thoron gas varied from one location to another, depending on the geological formation and depth. Radon and uranium for twenty-six samples of soil from the Babylon cement plant were measured by Ahmed and Hussein [6]. Their results show that the concentrations of radon are between (91.931-30.645) Bq.m^{-3}.

The objective of the current research is to estimate the concentrations of radon, radium content and uranium concentration for 10 soil and 5 water sediment samples of an oil field area located in southern parts of Iraq. Since exhalation rates of radon as a function of mass (E_M) and area (E_A) from the soil or sediments is considered as one of the most remarkable parameters in estimating ecological radon level, hence E_M and E_A were calculated.

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2. Experimental Work

I. Sample preparation

The measured soil and sediment samples were taken from 16 sites located in one of the largest oil fields situated in the north of Basrah (one of the biggest provinces in southern Iraq). The sites of the collected samples from the study area are illustrated in the map given in Figure 1.

The samples were dehydrated for few days until they get rid of their humidity, after drying, the samples were grined to a fine powder then sieved with 200μm cross section size. A weight of thirty grams of each sample were put at the bottom of a plastic cup (height = 7.5 cm, diameter = 6 cm). CR-39 detector (1.5 × 1.5) cm^2 and 200μm thickness was sticked in the inner side of the cover of the cup (distance = 6.5 cm from the sample). Then the dosimeters were kept aside for 85 days, which is long enough to record alpha particles emitted from radon in the samples. Then, CR-39 plastics were treated in 6.25N NaOH at 80°C for 4 h. After chemical treatment, CR-39 plastics were analyzed for α-tracks utilizing an optical magnifying lens with 10×40 amplification.

II. Calculation

Radon concentrations C_{Rn} (Bq m^{-3}), effective radium content C_{Ra} (Bq kg^{-1}), uranium concentration C_U (ppm) and exhalation rates in the study area were calculated using equations given in references [7,8,9,10]. Calibration factor CF is calculated using the formula given in reference [11], the calculated value of CF is equal to 0.04891 Track cm^{-2} d^{-1} /Bqm^{-3}.

3. Results and Discussion

Radon concentrations in the soil and sediment samples are shown in Figure 2. The symbol SW refer to water sediment samples while SS refer to soil samples. The results indicate that the highest value of radon concentration in sediment samples found in sample SW02 with the value of 1947.99 $Bq.m^{-3}$ and the lowest value was 434.67 $Bq.m^{-3}$ in sample SW04, with mean value of 985.26 $Bq.m^{-3}$. While highest value of radon concentration in soil samples was in location SS10 with value of 2237.77 $Bq.m^{-3}$ and the lowest value was in location SS16 with value of 61.18 $Bq.m^{-3}$ with mean value of 1215.16 $Bq.m^{-3}$. The mean value of radon level in both samples is 1337.55$Bq.m^{-3}$. The obtained results in comparison with the recommended value given by International Commission of Radiation Protection (ICRP) of radon concentration in soil and sediment, which is in the range of 200 to 800 $Bq.m^{-3}$ [12], show that most sites of study area are higher than these limits.

Figure 1: Map of the investigated area

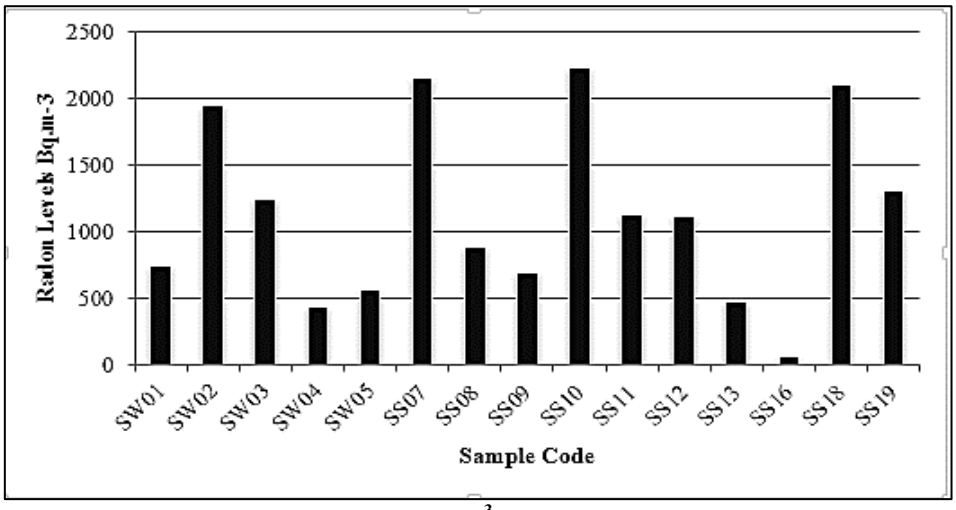

Figure 2: Radon levels ($Bq.m^{-3}$) in the investigated samples

Figure 3 shows the results of radium content in sediment and soil samples. The results indicate that radium content in sediment samples has maximum value of 9.75 $Bq.kg^{-1}$ in location SW02 and the minimum value is 1.96 $Bq.kg^{-1}$ in location SW04 with mean value of 4.45 $Bq.kg^{-1}$. While in the soil samples, the maximum value is 10.11 $Bq.kg^{-1}$ in location SS10 and the minimum value is 0.28 $Bqkg^{-1}$ in location SS16 with mean value of 5.49 $Bqkg^{-}1$. The mean value of radium content in both samples is 5.15 $Bq.kg^{-1}$. All values are below than the international value (30 $Bqkg^{-1}$) as recommended by UNSCEAR [1].

Uranium concentrations measured in (µgm/gm) and (ppm) in the investigated sediment and soil samples vary noticeably from one location to another as tabulated in Tables 1 & 2, respectively. Uranium concentration vary from the minimum value 2.54 ppm to the maximum value 11.38 ppm with mean value of 5.76 ppm for sediment samples while uranium concentration in soil samples range from 0.36 ppm to 13.07 ppm with mean value of 7.10 ppm. The mean value of uranium concentrations in all samples is 6.65 ppm. The results are comparable with different places around the world (Table 3). About 80% of the samples are above the reported world average value of 2.8ppm [1].

Exhalation rates for both terms (mass and area) are shown in the Figures 4 and 5, respectively. It is clear from Figure 4 that the mass exhalation rate of radon varies from 0.08 $Bqkg^{-1}h^{-1}$ to 2.88 $Bqkg^{-1}h^{-1}$ with a mean value of 1.41 $Bqkg^{-1}h^{-1}$, while, the surface exhalation rate of radon varies from 1.37 $Bqm^{-2}h^{-1}$ to 49.98 $Bqm^{-2}h^{-1}$ with a mean value of 24.47 $Bqm^{-2}h^{-1}$. It is evident from Figures 4 and 5 that the radon exhalation rates also vary noticeably from one site to another. This variety might be because of the distinctions in the amount of radium and porosity of the soil [20]. Descriptive statistics for all properties examined in the investigated samples are shown in the Table 4.

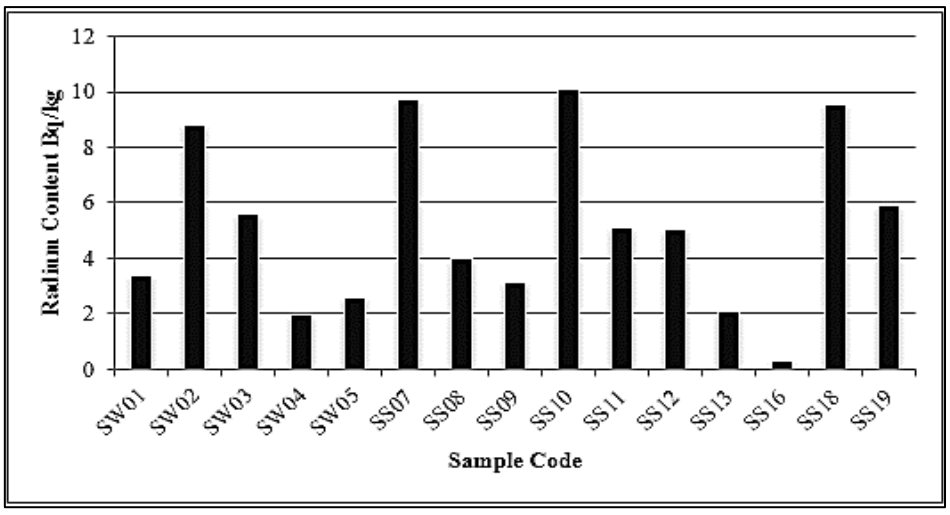

Figure 3: Radon content ($Bq.Kg^{-1}$) in the investigated samples

Table 1: Uranium concentration in (µgm/gm) and in (ppm) in the sediment samples

Sample	W_U (µgm/gm)	C_U (ppm)
SW01	129.80	4.33
SW02	341.44	11.38
SW03	217.28	7.24
SW04	76.19	2.54
SW05	98.76	3.29
Mean	172.69	5.76
Range	٧٦.١٩-341.4	2.54-11.38

Table 2: Uranium concentration (µgm/gm) and in (ppm) in the soil samples

Sample	W_U (µgm/gm)	C (ppm)
SS07	378.12	12.60
SS08	155.20	5.17
SS09	121.34	4.04
SS10	392.23	13.07
SS11	197.52	6.58
SS12	194.70	6.49
SS13	81.83	2.73
SS16	10.72	0.36
SS18	369.65	12.32
SS19	228.56	7.62
Mean	212.99	7.10
Range	10.72-392.23	0.36-13.07

Table 3: The comparison of U concentrations in soil samples of the present study with other places around the world

Location	U (ppm) Minimum	Maximum	Mean	Reference
Albania*	0.48	7.68	1.84	[1]
Australia	1.6	3.8	2.2	[13]
Bulgaria*	0.64	15.2	3.2	[1]
Cyprus*	0.08	7.2	1.2	[14]
Italy*	0.16	5.6	-----	[15]
Egypt*	0.48	9.6	2.96	[1]
Jordan*	1.76	8.32	6.72	[16]
Serbia & Montenegro*	1.2	6.24	2.76	[17]
USA*	0.32	11.2	-----	[18]
Nigeria*	1.2	4.1	2.7	[19]
Present work	0.36	13.07	6.65	-
World Average			2.64	[19]

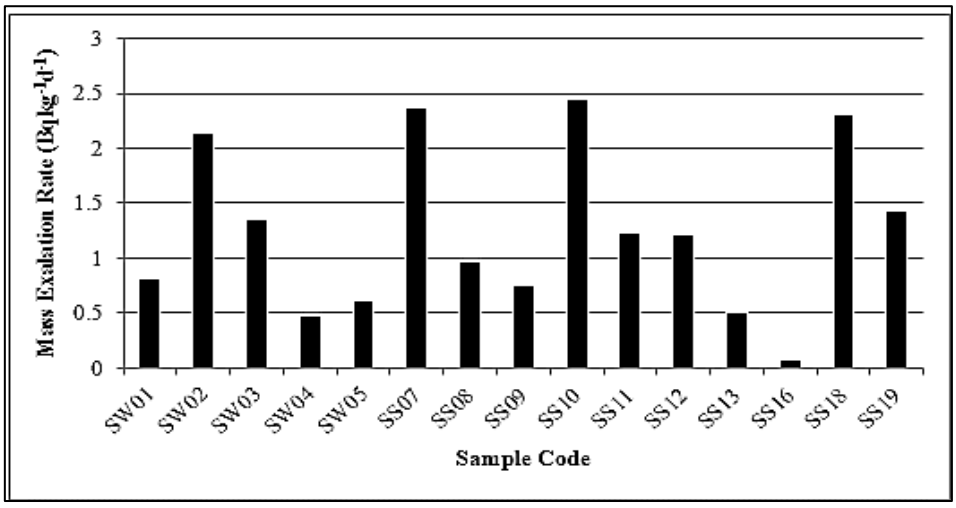

Figure 4: Mass exhalation rates of the investigated samples

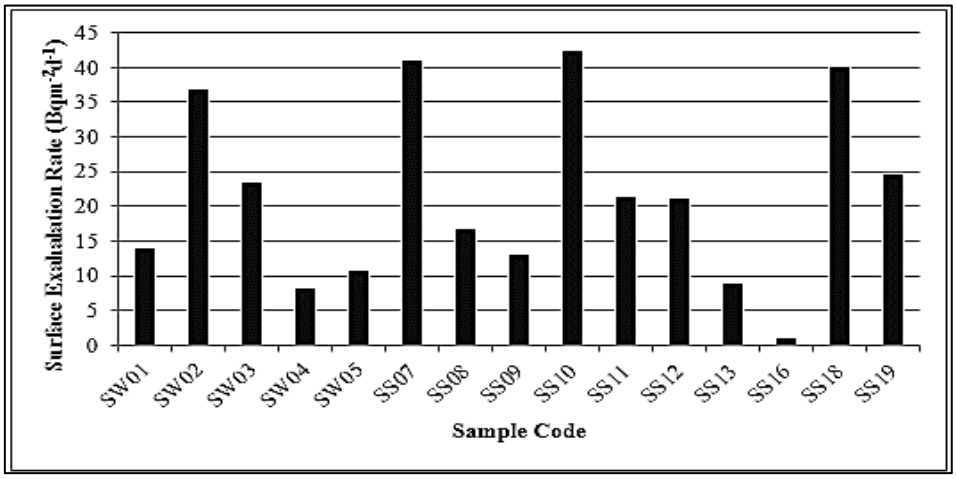

Figure 5: Surface exhalation rates of the investigated samples

Table 4: Statistical summary of radon level, radium content, E_A and E_M for the investigated samples

Descriptive	Radon level Bq/m^3	Radium content Bq/kg	E_A (Bq/m^2/d)	E_M (Bq/m^2/kg)	C_U (ppm)
Mean	1337.55	6.05	25.43	1.47	6.65
Minimum	71.87	0.32	1.37	0.08	0.36
Maximum	2628.96	11.88	49.98	2.88	13.07
STDEV.	670.4	3.03	12.75	0.73	4.05

The variations of uranium concentration, EA, and E_M vs. radium content are given in Figure 6 and 7, respectively, which shows a positive correlation between them. For health safety, the extreme allowable value of radium activity in soil and rocks must be below 370 Bq.Kg^{-1} [21]. In this manner, the obtained results indicate that the study region is unharmed as far as risk impacts to health and environment of radium is attentive.

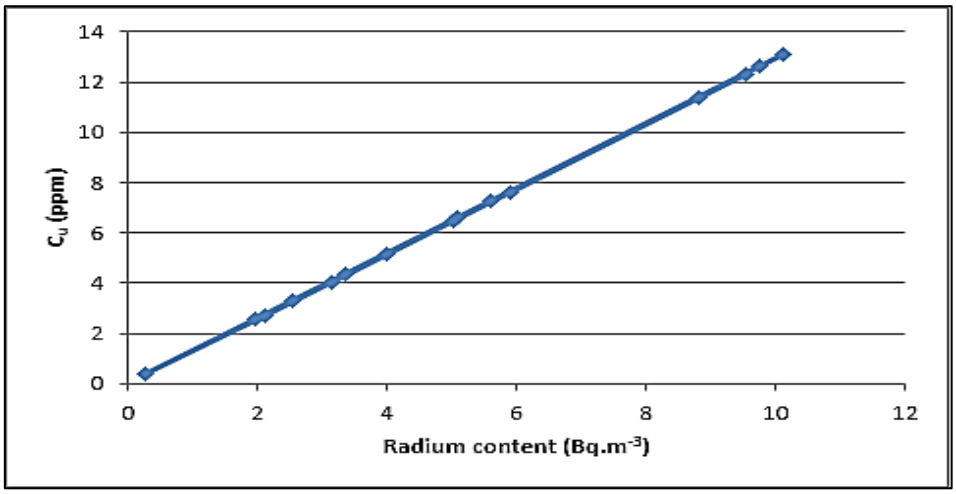

Figure 6: Positive correlation between uranium concentration and radium content

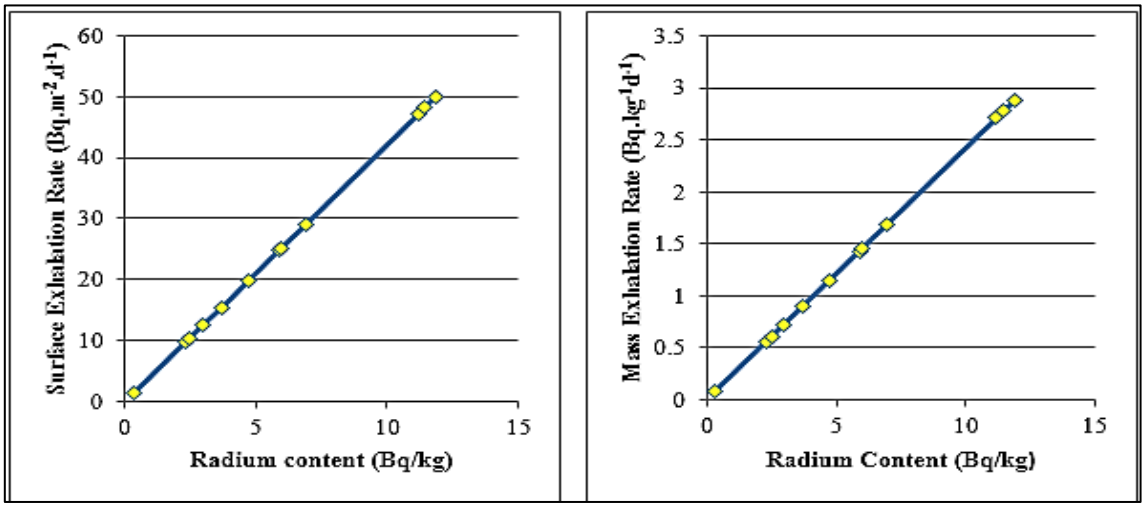

Figure 7: Variation of surface and mass exhalation rates with radium content

4. Conclusions

- In the present work, radon-222 has been measured in 15 different locations in one of the biggest oil fields situated in southern Iraq.
- The results indicate that the study area has different radon levels ranged from (71.87-2628.96) Bq.m^{-3}. The mean value of radon level is 1337.55Bq.m^{-3}. Radon concentration in most of the samples is higher than the recommended value given by ICRP [12].
- Radium content in the study sites is lower than the allowable limit and the global limit (30 Bqkg^{-1}) as recommended by UNSCEAR [1].
- The results of uranium concentration show that most of the samples have greater values than the recommended world value. Uranium concentration ranged from 0.36 ppm to 13.07 ppm with mean value of 6.65 ppm.
- Positive correlation between radium content, E_A, and E_M in the investigated samples.
- The obtained results indicate that the study region is unharmed as far as the risk impacts to human life due to radium are attentive.

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