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Assessment of Radon Gas Concentrations and Radon Exhalation Rates in Soil Samples of Oil Fields in Kirkuk City - Northern Iraq

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Abstract -**Used Nuclear track detectors (CR-39 detector) to assessment radon concentration and the exhalation rate in soil sample in depth (15-30-45-60) cm for four oil fields (Jumbor, Khabaz, Bai Hassan, Avanah) in Kirkuk Governorate, Iraq . The mean of Radon concentration is 67.216$Bq.m^{-3}$in soil sample with range (30.62-122.5$Bq.m^{-3}$) and the study showed that the radon concentration increases with increasing depth, all the concentration of radon is below the action level (200-600$Bq.m^{-3}$) as recommended by ICRP (1993). The mean of surface emission from the soil sample is (15.1264 $mBq.m^{-2}.h^{-1}$) and range (6.890-27.562 $mBq.m^{-2}.h^{-1}$) , while the mean of mass emission is (0.368 $mBq.Kg^{-1}.h^{-1}$) and its range is (0.160-0.643 $mBq.Kg^{-1}.h^{-1}$) . All results measured are within the safe limit.**

Keywords **-Radon , Soil , CR-39 , Oil fields , radon exhalation rates.**

I. INTRODUCTION

Radon is the heaviest of all noble gases, It has a half-life of 3.82 days, and considered as a one of inert gases and have low reactivity and discovered by Dorn 1900 [1]. Radon^{222}Rn has an atomic number of 86 and a mass number of about 222, its boiling point 61.8 ℃, its solidification degree -71 and the solid density thereof is 9.7 $kgcm^{-3}$ [2]. It is considered to be the only metal that is in a gaseous state in the chain of uranium decomposition, and its behavior is similar to other gases. This gas can spread and influence from small openings and cracks because it is about seven times heavier than air and therefore tends to stay close to the ground [3].

Radon reaches the atmosphere through soil. The exhalation rate dependent on weather conditions (air pressure, humidity, and temperature) and the soil permeability [4] .

CR-39 is an organic detector that was discovered by Cartwright and Shirk in 1978 [5]. It consists of a polymeric material, which is prepared through a polymerization process of Poly Ally Diglycol Carbonate, which is an amorphous hydrocarbon structure, and the molecular formula of the reagent is $O_7H_{18}C_{12}$ [6]. This organic detector contains 48.6% hydrogen, 32.4% carbon, 18.9% oxygen and does not contain nitrogen [7].

Oil production in the Kirkuk field began in 1934, and its daily production capacity is 470000 barrels , Within the Kirkuk governorate, there are 6 oil fields, as 4 of these fields are productive and 2 of them are non-productive and are awaiting development [8]. Jambour oil field contain 56 wells, The South Jumbor field includes 43 wells while the North Jumbor field includes 13 wells [9]. Khabaz oil field located 23 km to the west to northwestern of Kirkuk city in north Iraq and contains 37 oil wells [10]. Bai hassan field was discovered in 1953 by the Iraq Petroleum Company (IPC). Production began in 1960 [11].

II. STUDY AREA

The four oil fields (Jumbor, Khabaz, Bai Hassan, Avanah) in the study area are located within the oil fields of Kirkuk Governorate - northern Iraq and the areas studied are located in the southeast and northwest part of the city of Kirkuk as shown in Fig.1

Fig.1 The selected oil fields in the study area.

Well 96 in the Bai Hassan field is considered a high-productivity well, while well 3 in the same field has stopped producing oil for many years and is approximately (500) m away from well 96.

All samples were taken at a distance of 30 m from the oil well, because the places near the well contain chemicals used in drilling the well and the soil around the well is contaminated with these materials, and Table I shows the coordinates of the fields of oil wells in the study area

Table I
The coordinates of the fields of oil wells in the study area.

Field(well no.)	longitudes	latitudes
Jumbor (15)	44°24'58.92"	35°15'18.84"
Khabbaz (5)	44° 8'9.49"	35°29'48.80"
Bai Hassan (96)	44° 1'24.67"	35°38'2.79"
Avanah (93)	44° 2'23.38"	35°43'28.12"

III. SAMPLE COLLECTION

Samples were collected for the purpose of finding the radon concentration using CR-39 detector.20 samples of soil were collected in the four oil fields for five wells to the depths (15-30-45-60) cm. The samples were placed in plastic bags and coded. We dried the samples from the moisture in them and subsequently crushed them with a plastic mortar and the samples were placed in the irradiation tube at a height of 3 cm and the weight of the samples was taken in (gm) unite as shown in table II.

Table II
Oil fields and sample code and weight of soil samples

No.	Field (well No.)	Depth (cm)	Sample Code
1	Jumbor (15)	15	SS1
2		30	SS2
3		45	SS3
4		60	SS4
5	Khabaz (5)	15	SS5
6		30	SS6
7		45	SS7
8		60	SS8
9	Bai Hassan (96)	15	SS9
10		30	SS10
11		45	SS11
12		60	SS12
13	Bai Hassan (3)	15	SS13
14		30	SS14
15		45	SS15
16		60	SS16
17	Avanah (93)	15	SS17
18		30	SS18
19		45	SS19
20		60	SS20

IV. EXPERIMENTAL METHOD

The CR-39 detector with a thickness of (500μ) British origin from the British company Tasl was used in this study $(2 \times 1)\,cm^2$ for the purpose of recording the effects of the charged alpha rays emitted from the soil samples .The soil samples were placed in the irradiation tubes for 60 days For the purpose of recording traces on the surface of the detector. These tubes are designed from plastic tubes with a diameter of (7 cm) and a height of (30 cm). These tubes are closed at the bottom and open at the top. The samples that have been collected and prepared are placed in these tubes at a height of (3 cm), and CR-39 detector is placed at a height of (25 cm) from the surface of the sample, and in this technique it must be closed tightly and tightly. Fig.2 illustrates the irradiation tube used and the irradiation tube technology diagram **.**

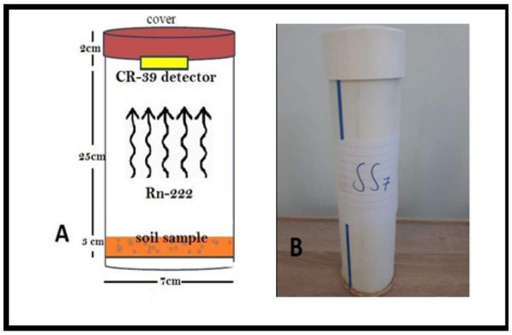


Fig.2 A: Irradiation tube technique diagram.
B: An example of one of the tubes used in research.

Using NaOH with purity of 99% as an abrasive to show the effect of the ionizing charges to calculate the number of tracks formed to find the concentration of radon gas through them, and the plastic detectors of the CR-39 detector were etched into their solution and the plastic detectors were placed in the NaOH (N=6.25) and placed in a water bath at a temperature of 70 □ for a period of three continuous hours The detectors are well washed by water to remove impurities and the abrasive solution from it. An optical microscope (10X.40X) was used to measure the number of tracks formed on the detector. To find the radon concentration in air space. using the following diffusion constant relationship [12]:

$$K = \frac{1}{4} r(2\cos\theta c - \frac{r}{R\alpha}) \qquad (1)$$

r : the radius of the irradiation tube which is (3.5 cm).
θ_c: the critical angle for the detector and is about 35□.
Rα: range of alpha particles produced from radon in air of (4cm). After substituting the values in the above equation, we notice that the propagation constant K is equal to K= 0.67 $\mathrm{Tr.cm^{-2}d^{-1}/Bq.m^{-3}}$.
The radon concentration in the air space found by using the following equation [13].

$$C_{Rn} = \frac{\rho}{KT} \qquad (2)$$

$C_{Rn}$is Radon concentration in the air space, measured in $Bq.m^{-3}$. ρ is the density of the resulting effects, measured in $\mathrm{Tr.cm^{-2}}$and T is The irradiation time is about 60 days.

The Radon emission rate is measured from the sample surface area E_A in unit $\mathrm{Bq.}m^{-2}\mathrm{h}^{-1}$. From the following relationship [14]:

$$\mathrm{E_A} = \frac{\rho\lambda V}{\mathrm{KAT_e}} \qquad (3)$$

While the exposure time to radiation T_e is found from the following relationship [16]:

$$T_e = \frac{T-1}{\lambda(1-e^{-\lambda t})} \qquad (4)$$

The radon rate emitted in terms of mass E_M in unit $\mathrm{Bq.}Kg^{-1}\mathrm{h}^{-1}$, calculated from the following law [17]:

$$\mathrm{E_M} = \frac{\rho\lambda V}{\mathrm{KMT_e}} \qquad (5)$$

V. RESULTS

A. Radon Concentration for Soil Sample

Table III shows the values of radon gas concentrations for different depths in the soil, starting from the surface of the earth, reaching the depth (60cm), with an increase of (15cm) each time using the CR-39 detector. The rate of radon gas concentrations in the selected oil fields, the extent of gas concentration in each field, and the total rate of gas concentration in the study area are shown in Table IV, and the rate of radon gas concentration in the soil of the study area using CR-39 detector reached (67.216) $Bq\,.m^{-3}$ with a range (122.5-30.62) $Bq\,.m^{-3}$.

Table III
Radon gas concentrations for different depths in the Soil.

Field	well no.	Radon Concentration ($Bq\ .m^{-3}$)			
		(0-15)cm	(15-30)cm	(30-45)cm	(45-60) cm
Jumbor	15	44.34	50.11	66.81	86.30
Khabaz	5	30.62	36.08	64.03	66.82
Bai Hassan	96	75.17	77.95	108.57	122.5
Bai Hassan	3	41.76	47.33	50.11	52.89
Avanah	93	58.47	83.52	86.30	94.65

Table IV
Mean and Range of radon gas concentration in the soil of the study area**.**

Field	Well no.	Mean ($Bq\ .m^{-3}$)	Range ($Bq\ .m^{-3}$)
Jumbor	15	61.89	44.34 - 86.30
Khabaz	5	49.38	30.62 - 66.82
Bai Hassan	96	96.04	75.17 - 122.5
Bai Hassan	3	48.02	41.76 - 52.89
Avanah	93	80.73	58.47 - 94.65
		Overall mean : 67.216	Total range:122.5 – 30.62

Fig.3 shows the radon gas concentrations measured by the CR-39 detector for soil samples for a depth of 15cm, the highest concentration was (75.17 $Bq\ .m^{-3}$)for the sample SS9 in the Bai Hassan oil field well 96 and it was found that the lowest concentration of gas reached (30.62 $Bq\ .m^{-3}$) for sample SS5 at Khabaz oil field, Well 5**.**

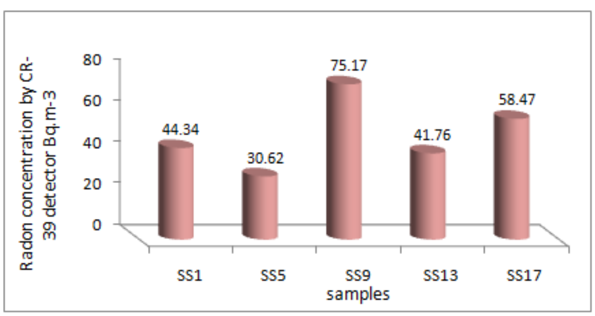


Fig.3 radon concentrations measured by the CR-39 detector for soil samples for a depth of 15cm.

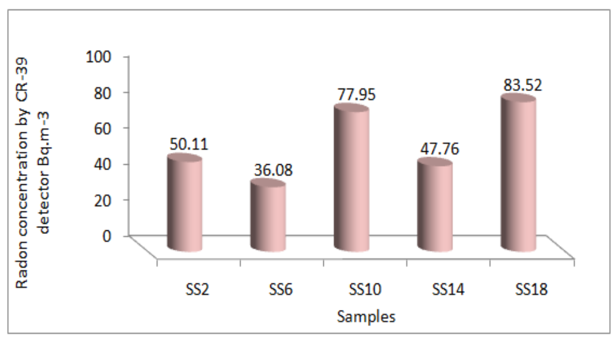


Fig.4 radon concentrations measured by the CR-39 detector and samples to a depth of 30cm.

Fig.4 shows the radon gas concentrations measured by the CR-39 detector and samples to a depth of 30cm. The highest concentration of radon was (83.52 $Bq\ .m^{-3}$for the sample SS18 in the Avanah field, Saralu pumping station, and the lowest concentration was (36.08 $Bq\ .m^{-3}$) for sample SS6 in the Khabaz field.

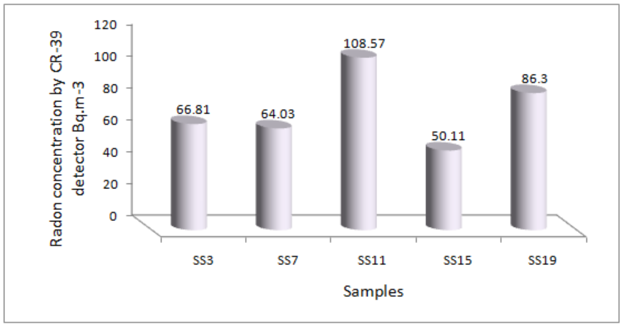


Fig.5 radon concentrations measured by the CR-39 detector and samples to a depth of 45cm.

Fig.5 shows radon concentrations measured by the CR-39 detector and samples to a depth of 45cm, where the highest gas concentration reached (108.57 $Bq\,.m^{-3}$) for the sample SS11 for well 96 in the Bai Hassan field, while the lowest concentration was about (50.11 $Bq\,.m^{-3}$) for sample SS15 of Well 3 in the Bai Hassan field

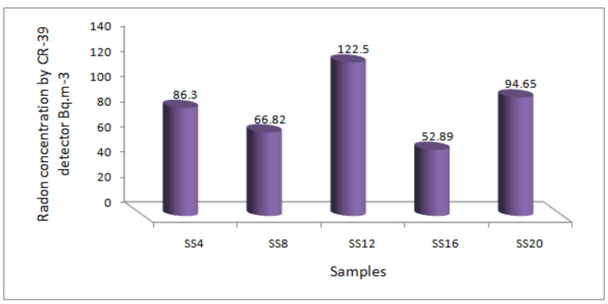


Fig.6 the radon concentrations measured by the CR-39 detector and samples to a depth of 60cm.

Fig.6 shows the radon concentrations measured by the CR-39 detector and samples to a depth of 60cm, the highest concentration was (122.5 $Bq\,.m^{-3}$) for the SS12 sample in the Bai Hassan well field 96, and it was found that the lowest concentration of gas reached (52.89 $Bq\,.m^{-3}$) for sample SS16 in Well 3 of the Bai Hassan field. We conclude with this that the concentration of radon gas increases with increasing depth because the main source of radon is underground and it exits through cracks and pores. Radon concentrations decrease as the path length decreases below ground level.

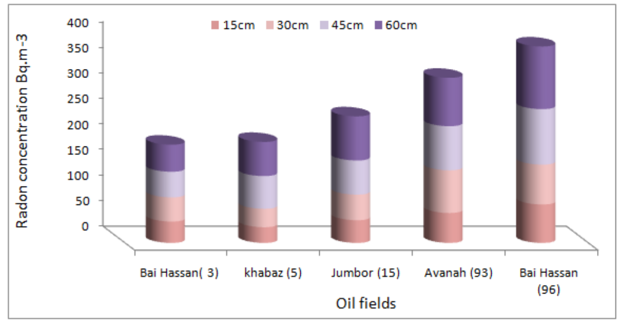


Fig.7 radon concentration measured by the CR-39 detector and the selected oil field.

Fig.7 shows the radon gas concentration measured by the CR-39 detector and the selected oil field.

Table V

Comparison between radon concentrations in Soil sample for present study with those elsewhere

Country	mean	Range	Used detector	Ref.
Brazil	69	4-404	HPGe	[16]
Malaysia	198.442	67.219-295.068	CR-39	[17]
Al-Diwaniyah-Iraq	350.64	163.58-689.89	CR-39	[18]
Kirkuk-Iraq	162.29	-	CR-39	[19]
Al-Qadisiyah, Iraq	6.48 ±0.77	0.12-13.02	CR-39	[20]
Oil field - Kirkuk- Iraq	67.216	30.62-122.5	CR-39	Present study

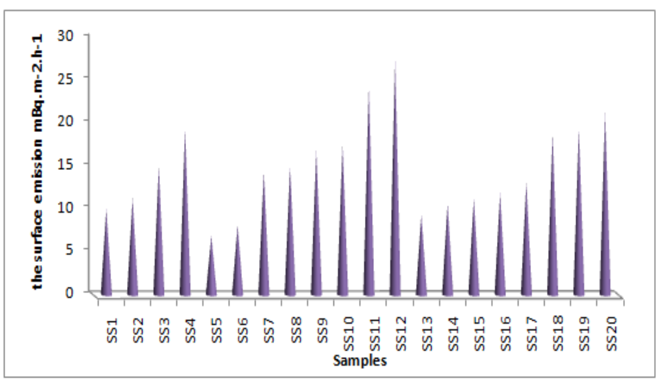
B. Exhalation Rate

Table VI shows the surface emission E_A ($mBq.m^{-2}.\mathrm{h}^{-1}$) and mass emission E_M in unit ($mBq.Kg^{-1}.\mathrm{h}^{-1}$) for radon ^{222}Rn measured by CR-39 detector. From Fig.8 it can be seen that the highest surface emission value was about (27.562 $mBq\,.m^{-2}.\mathrm{h}^{-1}$ in the sample SS12 Bai Hassan field well 96 of depth 60 cm . The lowest surface emission of radon gas in the sample SS5 with a depth of 15cm was (6.890 $mBq\,.m^{-2}.\text{h}^{-1}$) with a rate of (15.1264 $mBq\,.m^{-2}.\text{h}^{-1}$and the range (6.890-27.562 $mBq\,.m^{-2}.\text{h}^{-1}$.

Table VI

Surface emissionE_{A}($mBq.m^{-2}.\text{h}^{-1}$) and mass emission E_{M} ($mBq.Kg^{-1}.\text{h}^{-1}$) for soil sample

Sample code	$E_{\text{A}}(mBq.m^{-2}.\text{h}^{-1})$	$E_{\text{M}}(mBq.Kg^{-1}.\text{h}^{-1})$
SS1	10.022	0.183
SS2	11.275	0.233
SS3	15.034	0.321
SS4	19.419	0.465
SS5	6.890	0.160
SS6	8.118	0.190
SS7	14.407	0.361
SS8	15.034	0.368
SS9	16.913	0.433
SS10	17.539	0.423
SS11	24.430	0.587
SS12	27.562	0.643
SS13	9.396	0.254
SS14	10.649	0.284
SS15	11.275	0.293
SS16	11.901	0.337
SS17	13.154	0.319
SS18	18.792	0.493
SS19	19.419	0.491
SS20	21.298	0.521
Mean	15.1264	0.368
Range	6.890 - 27.562	0.160 –0.643



.Fig.8 Surface emission E_{A} in $mBq.m^{-2}.\text{h}^{-1}$

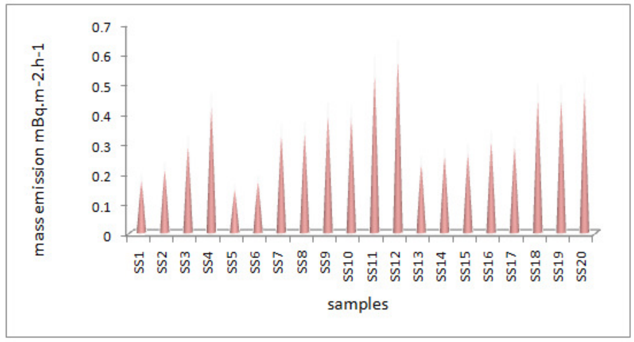


Fig.9 Mass emission E_{M} in $mBq.Kg^{-1}.\text{h}^{-1}$.

From Fig.9 we note that the highest value of mass emission E_{M} for radon ^{222}Rn was about (0.643 $mBq.Kg^{-1}.h^{-1}$)for the sample SS12 was in the Bai Hassan field well 96 in depth 60cm and the lowest mass emission value was (0.160 $mBq.Kg^{-1}.h^{-1}$) for sample SS5 and 15cm depth in Khabaz field well 5, Mass emission (0.190 $mBq.Kg^{-1}.h^{-1}$)for sample SS6 and 30cm depth in Khabaz field for the same well and the mass emission mean of radon gas in soil samples is (0.368 $mBq.Kg^{-1}.h^{-1}$) and its range is (0.160-0.643 $mBq.Kg^{-1}.h^{-1}$) . Table (7) shows the comparison between radon exhalation rate($mBq.m^{-2}.\text{h}^{-1}$) in Soil sample for present study with those elsewhere.

Table VII

Comparison between radon exhalation rate ($mBq.m^{-2}.\text{h}^{-1}$) in Soil sample for present study with those elsewhere.

Country	Mean ($mBq.m^{-2}.\text{h}^{-1}$)	Range (($mBq.m^{-2}.\text{h}^{-1}$)	Reference
Canda	-	30 - 42	[21]
India	-	0.0174 - 0.348	[22]
Turkey	0.3736	-	[23]
Egypt	-	1.27 – 15.56	[24]
Al-Qadisiyah, Iraq	1.04	-	[20]
Egypt	1.83	-	[25]
Ghana	32.18	-	[26]
Oil field - Kirkuk-Iraq	15.1264	6.890 - 27.562	Present study

VI COUCLUSION

The mean of Radon concentration is $67.216 Bq.m^{-3}$in soil sample with different depth in for the four oil field (Jumbor, Khabaz, Bai Hassan, Avanah) with range (30.62-122.5$Bq.m^{-3}$) all the concentration of radon is below the action level (200-600$Bq.m^{-3}$) as recommended by ICRP (1993)[27]. The mean of surface emission from the soil sample is (15.1264 $mBq\,.m^{-2}.h^{-1}$) and range (6.890-27.562 $mBq\,.m^{-2}.h^{-1}$) , while the mean of mass emission is (0.368 $mBq.Kg^{-1}.h^{-1}$) and its range is (0.160-0.643 $mBq.Kg^{-1}.h^{-1}$) . All results measured are within the safe limit.

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