Surface and Deep Soil ^{222}Rn Gas Exhalation Comparison

A Case Study in Tawke, Duhok, Northern Iraq

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***Abstract*— In this study, 13 different surface locations and 20 mud samples were collected during drilling, from one of the oil wells in the Kurdistan region of Iraq. The samples were taken at different well depths. RAD7 technique was used for finding the radon concentration. The smallest values in soil and surface were 14.12±8.59 and 16±4.24Bq/m3 and the highest were 93.25+21.72 and 137±8.76Bq/m3 respectively. The difference in the depth and surface formation shows the surface formation over depth ratio. The exhalation rate recorded value of the surface was generally higher than that of the depth formations. The exhalation results were finally compared with the recommended values of the International Atomic Energy Agency (IAEA) levels. The data show that it was less than the standards of IAEA.**

Keywords-NORM; surface geological formation; oil well; ^{222}Radon gas; exhalation rate; RAD7

I. INTRODUCTION

Natural radioactivity is more than the background radiation in oil drilling. Since the '80s some regulatory agencies paid attention to the Naturally Occurring Radioactive Material (NORM) issues related to hydrocarbon production [1]. Gamma radiation that comes from waste has an extremely wide range [2, 3]. Activities relative to uncontrolled releasing and enhanced NORM levels cause environment contamination. These kinds of risks can be reduced by the adoption of checks to recognize the NORM source, controlling NORM waste and polluted equipment, and protecting workers. The ^{238}U and ^{232}Th are radioactive materials situated into rock formations and soil. Unstable radioactive chemical elements of this kind create other radionuclides, which bring on certain conditions (temperature, pressure, acidity, etc.) into the surface layer and subsurface environment. They are mobile with a probability of transmitting from the reservoir to the surface during the extraction of crude oil products. This research aims to study radon gas and its exhalation in terms of area and mass ratio, considering depth. More than one samples come from the same formation, although their distance is of the order of hundreds of meters. Samples were collected from different locations that have a spatial geological formation. In Saudi Arabia, radon concentration in the soil ranges from 75 to 220Bq/m^3 [3], with a reported mean value of 4561Bq/m^3 [4]. In India, the radon gas in soil is 7.46±0.69kBq/m^3 [5]. The radon exhalation rate in Syria was measured as 9Bq.m^{-2}.s^{-1} [6]. The aim of the current study is to find the radon concentration by using the RAD7 technique. A total of 13 formation samples and 20 mud samples were collected in the North of Duhok Governorate during drilling. Sampling was conducted at different depths, the purpose was to calculate the surface and mass exhalation rate of radon and to compare them with the findings of other studies.

II. STUDY AREA

The study area is located in Iraq, Northwest and in the North of Duhok Governorate, about 60km from the center of the city, in 37.161985 latitude, 43.016341 longitude. It is one of the 51 well locations that extract crude oil. The depth to reach the layer of crude oil is 2200m, so during the excavation, we can find different geological formations.

III. EXPERIMENTAL PREPARATION

Twenty samples of drilling mud from assorted depths (assorted formations) were gathered from the T-49 well, located in the Tawke oil field. The radon concentrations and relative depths from the collected samples are listed in Table I and the surface formation measurements are shown in Table II. The collected samples were dried in an oven at 110°C for one day for eliminating moisture, then milled to fine powder, and finally garbled with 0.2mm mesh. This study used active mod as a solid-state determination to find the activity concentration of radon gas. The setup of the experiment is shown in Figure 1 as an active method to find radon concentration. It consisted of a plastic tube of about 1L volume made from polyvinyl chloride (PVC) as a chamber to accumulate radon. The PVC-tube was joined with a vinyl tube that contained desiccant ($CaSO_4$) for drying the gas from humidity, and a radon monitor device. Soil samples were put in the bottom of the tube as radon exposure source, with closing sides by the PVC cover. Then the plastic-tube container was isolated via two valves adjusted at the sides of the container. The concentration was measured after putting

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the samples and leaving them in room temperature for about one month. This time was sufficient for the samples to reach radium-radon, and radon decay equilibrium. When connected to the closed loop both valves were open. The device pooled air from the container, passing it through the desiccant to the inlet filter and then to the RAD7 device into the measuring tube chamber. The air was discarded from the outlet of the RAD7 device. The radioactive element decays in the interior of the chamber, creating detected alpha (α) particles that emit progeny, especially polonium isotopes. There is a high voltage of about 2218V on the chamber walls. The RAD7 detector converts alpha radiation to electrical signal by utilizing the alpha technique and is able to separate the different electrical pulses produced from ^{214}Po and ^{218}Po with energies of 7MeV and 6MeV correspondingly. The humidity is between 4%-8%, in room temperature ranging from 20^{o}C to 31^{o}C.

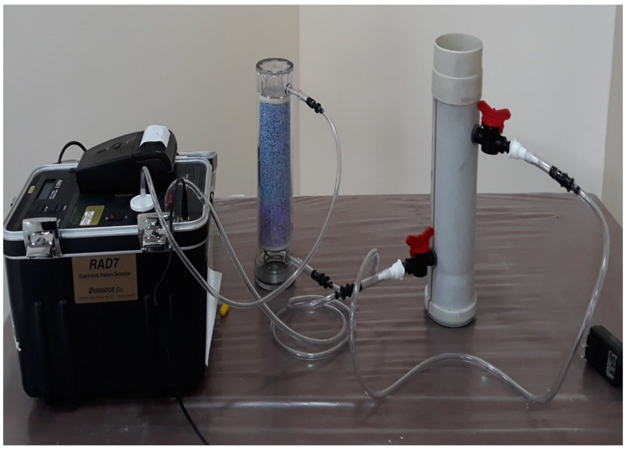

Fig. 1. Method of radon concentration measurement.

At equilibrium state, the flux (exhalation) of radon from the sample inside the can in terms of area and mass can be measured by [7]:

$$EA=\frac{(C_{Rn}.V.\lambda)/S}{T+(e^{-\lambda T}-1)/\lambda} \quad (1)$$

$$EM=\frac{(C_{Rn}.V.\lambda)/M}{T+(e^{-\lambda T}-1)/\lambda} \quad (2)$$

where EA is the exhalation rate in terms of area (Bq.m^{-2}.d^{-1}) and EM is the exhalation rate in terms of mass (Bq.kg-1.h-1), C_{Rn} is the radon concentration calculated by the RAD7 detector in a Bq/m^3, λ=7.56×10^{-3} h^{-1} is the constant of radon decay, T is the exposure time in hours, V is the volume of the can, equal to 0.001192m^3 and S is the surface area of the sample in the can, equal to 0.003847m^2. The RAD7 works on a four-cycle mode, the data are stored in an internal memory via using the starting protocol of 2-days test. The saved value depends on the average gas concentration of radon during each break time.

IV. RESULTS AND DISCUSSION

The statistics of the concentration of radon into different depths and formations of Tawke area and the soil from different locations show that different depths have different concentrations of radioactive radon gas and the results are compared with the ones from the surface samples. The surface formation in general was recorded to have higher concentrations than the depth locations. The highest rate was recorded in the depth of 1100m (Euphrates formation and Khormala Formation), and the lowest ratio was recorded in the depth of 1900m (Kolosh formation and Jurbi formation), with values of 93.25±19.72, 137±8.76 and 14.12±8.59, 16±4.24Bq.m^{-3} respectively. The results of radon concentration vs formation and depth measurement are displayed in Figure 2. There are many factors affecting radon release from soil and rocks, such as permeability, moisture, porosity, CO_2 soil concentration, temperature, and pressure. Maybe each location includes specific distinctive soil and rock properties, so the evaluation must be held accordingly [3].

TABLE I. RADON CONCENTRATIONS AND EXHALATION IN DIFFERENT DEPTHS

Depth (m)	Layer name	Weight (g)	Rn Std division (Bq/m^3)	Radon area (mBq.m^{-2}.h^{-1})	Radon mass (mBq.kg^{-1}.h^{-1})
Surface	Surface area	126.34	62±15.25	177.8±43.73	5.41±1.33
400	Upper Faris	129.96	85.25±7.2	244.48±20.59	7.24±0.61
500	Sandston-clayston-Upper Faris	136.02	66.25±3.8	189.99±10.81	5.37±0.31
600	Sandston-clyston- Upper Faris	132.5	40.75±21.7	116.86±62.29	3.39±1.81
700	Sandston-clyston- Upper Faris	145.12	52.25±10.17	149.84±29.17	3.97±0.77
800	Lower Faris clayston	136.34	57.5±10.87	164.9±31.17	4.65±0.88
900	Euphrates	145.1	40±16.79	114.71±48.15	3.04±1.28
1000	Euphrates	129	47±11.46	134.79±32.86	4.02±0.98
1100	Euphrates	137.8	93.25±19.72	267.42±56.55	7.46±1.58
1200	Pelaspi	126.8	69±8.98	197.88±25.75	6±0.78
1300	Pelaspi	142.2	63.5±12.15	182.1±34.84	4.93±0.94
1400	Jurkes	138	24±3.36	68.83±9.64	1.92±0.27
1500	Jurkes	126.04	29±8.44	83.17±24.2	2.54±0.74
1600	Jurkes	149.69	24.25±7.93	69.54±22.74	1.79±0.58
1700	Jurkes	150.6	23.75±5.85	68.11±16.78	1.74±0.43
1800	Kolosh	153.34	27.05±4.71	77.6±13.51	1.95±0.34
1900	Kolosh	129	14.12±8.59	40.52±24.63	1.21±0.73
2000	Kolosh	137.58	18.23±7.21	52.3±20.68	1.46±0.58
2100	Kolosh	137.15	23.01±1.32	65.98±3.79	1.85±0.11
2200	Kolosh	140.34	30.50±5	87.47±14.34	2.4±0.39
		Max	**93.25±21.72**	**267.42±62.29**	**7.46±1.81**
		Min	**14.12±8.59**	**40.52±3.79**	**1.21±0.11**
		Average	**44.53±9.52**	**125.0±26.45**	**3.52±0.74**

In the underground, there is radon movement depending on compaction, brittle, lithology, porosity, etc. [8, 9]. The raises of Radon gas emission were caused by soil moisture, but if there is a saturation of soil pores, the emission will be inhibited. The CO_2 behaves as a radon carrier gas into the soil, enhancing the ^{222}Rn concentration into the soil atmosphere [10]. Note that the studied samples' maximum radon concentration level is acceptable [11]. Table III shows the comparison of this study results with the results of other works regarding radon concentration and exhalation. The present study shows that the radon rate was higher than the study done in Iraq-Kurdistan, Egypt, Pakistan and India, while it was lower than in Iraq-Baghdad and Iraq-Erbil. Anyhow, this value is lower than the acceptable level which should be less than 300Bq.m^{-3} [12]. Comparing with the mass exhalation rate in India, Osaka-Japan and Catania- Italy, the value of the average exhalation rate of this study was lower. In general the results were less than the mean world value which is 57600mBq.m^{-2}.h^{-1} [13]. In term of mass, this study results were near to India and Erbil-Iraq.

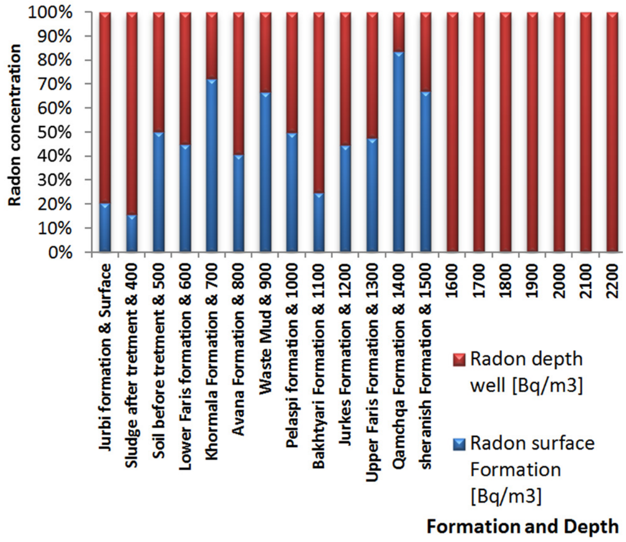

Fig. 2. Radon concentration in different depths and soil formations

TABLE II. ^{222}RADON CONCENTRATION AND EXHALATION IN DIFFERENT SURFACE FORMATIONS

Formation Name	Weight (g)	Rn Std division (Bq/m^3)	Radon area (mBq.m^{-2}.h^{-1})	Radon mass (mBq.kg^{-1}.h^{-1})
Jurbi formation	156.15	16±4.24	45.88±12.16	1.13±0.3
Sludge after treatment	165.85	16±5.66	45.88±16.23	1.06±0.37
Soil before treatment	165.35	66.5±11.27	190.71±32.32	4.43±0.75
Lower Faris formation	100.89	33.25±2.06	95.35±5.91	3.63±0.22
Khormala formation	170.56	137±8.76	392.88±25.12	8.86±0.57
Avana formation	128.07	39.5±13.87	113.28±39.77	3.4±1.19
Waste Mud	130.25	80±13.44	229.42±38.54	6.77±1.14
Pelaspi formation	160.1	47±4.24	134.78±12.16	3.24±0.29
Bakhtyari formation	142	31±8.49	88.9±24.35	2.41±0.66
Jurkes formation	134.27	55.5±6.81	159.16±19.53	4.56±0.56
Upper Faris formation	154	57.5±7.14	164.89±20.47	4.12±0.51
Qamchqa formation	161.25	123.25±17.34	353.45±49.73	8.43±1.18
Sheranish formation	133.21	59.35±18.11	170.2±51.93	4.91±1.5
	Max	**137±8.76**	**392.88±25.12**	**8.86±0.57**
	Min	**16±4.24**	**45.88±12.16**	**1.13±0.3**
	Average	**58.60±9.34**	**168.06±26.78**	**4.38±0.71**

TABLE III. RADON EXHALATION RATE IN TERMS OF AREA AND MASS

Location	^{222}Rn concentration (Bq/m^3)	^{222}Rn (mBq.m^{-2}.h^{-1})	^{222}Rn (mBq.kg^{-1}.h^{-1})	Reference
Tawky-T49. Various well depths and formations	44.53+9.52 58.60±9.34	125.08±26.45 168.06±26.78	3.52±0.74 4.38±0.7	Present study
India	7.46±0.69	246.63–1100	7.17–31.98	[5, 14]
Turkey		1476	-	[15]
Erbil-Iraq	361.77±3.79	67.962-515.167	1.882- 12.630	[16]
Iraq-Kurdistan	15.638±7.38	5670-14020	536.09-1324.12	[17]
Osaka-Japan	-	10.8	-	[18]
Hawaii	-	9.0±226	-	[19]
Japan		1260	-	[20]
Germany	-	7200-63000	-	[21]
Catania-Italy		43.1±6.7	-	[22]
Baghdad-Iraq	1337.55	1059.5	61.25	[23]
Alexandria-Egypt	7	464.4	-	[24]
Saudi-Arabia	75–220			[3]
Pakistan	666±55	5860±1200	-	[25]
Bengaluru-India	497±173	78588±27576		[26]
Mean world value	<300	57600	-	[12, 13]

V. CONCLUSION

There are differences on the amount of radon gas and its exhalation rate, depending on the depth and the surface formation soil. The overall surface exhalation rate area and mass average was greater than the depth soil's. The natural decay of uranium produces radon gas. RAD7 was the easiest way to find the radon concentration in the soil. The results show that the rates are less than the mean world value.

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