Determination of radon gas concentration $^{222}\text{Rn}$ from rock models of selected oil wells from Basra oil fields - Iraq

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**Abstract**

In this study, 56 rocks samples were taken from 8 welled oil wells from the oil fields in Basra Governorate - southern Iraq at deep depths of up to 3500m from the surface of the earth, to determine radon gas concentrations $^{222}\text{Rn}$ emitted from the models of oil wells rocks. The Rational Application Developer (RAD7), an active measurement method, used rapid electronic technology. The results of this study showed that the largest concentration of radon gas in oil well rock (Rocks) is $53861\text{Bq.m}^{-3}$ in a rock sample at a depth of 3500 m from the Ru-205 well in the southern Rumaila oil field and the lowest concentration is $248\text{Bq.m}^{-3}$ in the rock sample. From WQ-94 well in West Qurna field. The effective annual dose that oil workers can be exposed to upon contact has been calculated to the highest concentration of radon gas $107.772\text{µSvh}^{-1}$ which is higher than the permitted dose level $50\text{µSv.h}^{-1}$ proposed by the EPA in the United States, and may pose risks to the health of workers in Oil Fields, and therefore, measures must be taken to preserve the health and safety of workers. The possibility of developing cancer as a result of exposure to radon gas per million people was found to be high compared to the permissible limits (170-230) per million people previously.

**Key words**: rocks, oil wells, radon gas $^{222}\text{Rn}$, RAD7 device, effective annual dose, Cancer.

**1. Introduction**

Living organisms are exposed to various ionizing and non-ionizing radiative effects, part of which is due to the natural radioactive chain, including natural radioactive elements that are concentrated by some industries such as the phosphate fertilizer industry and the oil and gas industry and there are elements used for research or exploration [1]. The oil industry is Gas is one of the industries in which
workers are exposed to the danger of natural occurring radioactive materials (NORM), which are concentrated in large quantities due to that industry. Natural radioactive materials are found in oil and gas formation tanks like other elements, with different concentrations, accompanying the oil extracted from the depths Underground, these natural radioactive materials come out with production fluids during the extraction and separation of crude oil, as these materials are deposited from one production line to another and from point to point within the same production line, and are often the highest concentration of radium–226 in Christmas trees which It is the point where the oil comes from the well to the surfaces of the oil equipment, as well as increasing its concentration in the deposits of the production pipelines and the transportation of oil and in the sites of bends and protrusions. The presence of natural radioactive materials in the sedimentary sediments and sludge leads to high levels of radiation due to the accumulation of natural radioactive materials of NORM, and the word NORM appears to distinguish between natural radioactive materials created from artificial radioactive sources. [2–6] Radon gas (Rn) is considered one of the most dangerous radioactive elements to be exposed to workers in the oil and gas industry, and it is an inert gas that is colorless, tasteless, odorless and non–flammable. About 7.7 times it has a high ability to liberate from soil to the atmosphere, so it is close to the surface of the Earth. Radon gas is released from the uranium–238 decomposition chain that dissolves into radium–226. Radium (Ra) is one of the most important radioactive elements that accompany residues of extraction and refining of crude oil. Barium Ba, Strontium Sr, and Ca are continuously shown to accompany them. Inhaling or contacting radon gas poses a risk to public health, as it is considered the largest contributor to the exposure of the general public to natural radiation sources, whereby radon dose alone contributes 50–55% of the total dose that a person is exposed to annually from all natural sources combined. Environmental and health problem. Numerous studies have demonstrated a direct correlation between radon gas exposure and lung cancer incidence [7–8]. This common effect on the health effects of radon gas and its offspring resulting from its degradation with short half–lives is the main cause of lung cancer, as the health effects of radon gas appear in
The $\alpha$-particles released by it and its breakdown products can radon and the products of its decomposition reach the body of the organism either by breathing or digestion, and radon gas with radionuclides resulting from its dissolution contribute about 75% of the equivalent annual effective dose equivalent to individuals and individually from Earth sources. The health effects of radon lie in its alpha particles and by its dissociation products, as these particles have enough energy to penetrate the tissue, reach the inner section of cells, and sabotage this tissue. There are two ways that radon and dissociation products can enter the human body are breathing and digestion, and it is believed that digestion is not dangerous because the presence of food in the stomach, even with a thickness not exceeding 1.5mm, can stop most of the alpha particles released by the radon disintegration and its offspring, and found that the half–life of the radon is 30 minutes When the stomach is empty and 70 minutes when the stomach is full, there are still no evidence linking the ingestion of radon and the increase in gastric cancer cases [9–12] In this study a method called active method was used through a fast electronic device called RAD7. This study aims to determine the concentrations of radioactive radon gas emitted from oil rock models in selected wells from the oil fields in Basra – Iraq. This study is also a future work program to map the radon gas in the oil fields in Iraq, where the study area is of economic importance as well as the presence of many international companies operating in it.

1.1 Study area description:

The study area is located in Basra Governorate – South of the Republic of Iraq between two latitudes (31 ° 20 '– 29 ° 50') in the north and Qawsi length (48.30 ° – 46.40 °) east, Figure (1) with an area of 19070Km$^2$ With a rate of 4.3% of Iraq’s total area of (4440,000) Km$^2$ inhabited by about 5 million people. Basra Governorate has 15 productive oil fields and more than 654 productive wells distributed over all fields. Rocks) These fields contain an oil reserve estimated at 67.8 billion The study areas included ((8 giant oil fields that include many oil wells, which are fields (North Rumaila, Southern Rumaila, Al–Zubair, West Qurna–1, Al–Lahis, Artawi, Nahr Bin Omar, Al–Tuba).
2. Materials and methods of work

To determine radon gas concentrations in oil well rocks, 56 Oil Rocks samples were collected from different depths of the underground surface of selected oil wells from different areas of oil fields in Basra Governorate – southern Iraq in January 2020. The samples were placed in boxes prepared for this purpose, after this collection process, the studied samples were grinded as a very fine powder with a grinder and dried at a temperature of 110 ° C for 24 hours using a thermal oven and sifted with a 2µm sieve to get rid of impurities and foreign bodies and prepared the samples with scientifically approved specifications to determine Radon gas concentrations (Figure 2). RAD7 technology was adopted through a rapid electronic device (Figure 3) used for continuous monitoring of radon in the air and soil to determine the concentration of radon gas in rock models brought from the study area in Basra Governorate – southern Iraq. The work of this device is based on measuring radon gas concentrations emitted directly from the samples under study, as it pulls a quantity of the generated gas Grab from the top of the model and sends it to the LOCAS cell to determine radon gas concentrations in the rock samples that were crushed as a fine powder, after To ensure that there is no water vapor associated with the gases, this pumping process extends for a period of 5 minutes and then the
device starts for another 5 minutes, and this counting process is to determine the concentration of the two elements Polonium $^{218}$Po– ($3.05$ min) and Polonium $^{212}$Po ($164$ μs), this means that the process takes place after $(15-9)$ minutes, and RAD7 is characterized by its ability to determine the energy of a massive alpha electronically, which can distinguish between radon isotopes Element Polonium $^{218}$Po and Polonium $^{214}$Po and between Radon $^{222}$Rn and Thoron $^{220}$Rn, where (purging) the RAD7 detector is dried with fresh air for 10 minutes by connecting the drying unit in a closed loop with the RAD7 device, the outside air passes through the Desiccant and returns to the interior, and it is always noted that the process of air flow is in the same way through the Desiccant, when the humidity level is less than 6%, then we start testing where The pump starts to work for 5 minutes during which radon is withdrawn from the sample and sent to the measurement room in RAD7, after which the RAD7 device stops for a period of more than 5 minutes during which it reaches equilibrium status, then the process is repeated for four cycles and at 5 minutes per session. Then the total test duration becomes 30 minutes and at the end of each operation, RAD7 prints information related to the average radon gas concentration, standard deviation, humidity, temperature inside the device, date and time of the test, as well as the operating number and number of cycles, and then provides us with a graph of four cycles With the accumulated spectrum.

Figure (2) picture of the oil rocks model used in this study before and after grinding.
3. Results and Discussion

In this study, samples of rocks were used for areas of oil wells in Basra Governorate – southern Iraq to determine radon gas concentrations in these rocks that were taken from different depths of the earth surface using a sophisticated rapid measurement technology. Tables 1–7 show radon gas concentrations measured in models of rocks in oil wells in Basra Governorate – southern Iraq, where it is noticed that the lowest concentration of radon gas in rocks is 248 Bq.m$^{-3}$ in a sample of rocks from a well WQ−94 West Qurna field, and the largest radon concentration is 53861Bq.m$^{-3}$ from a sample of the Ru−205 well rocks from the southern Rumaila oil field within the study area, and Figure (4) illustrates the relationship between radon gas concentration emitted from the oil rocks samples of the Ru−205 well in the southern Rumaila field from the study area in the oil fields in Basra Governorate – Southern Iraq. The concentration range for all samples is 5700.857Bq / m$^{-3}$. Figure (5) shows the relationship between the radon gas concentration rate emitted from oil rock samples for eight oil wells from the study area in the oil fields in Basra Governorate – southern Iraq. The results of the current study were compared with previous studies conducted by [13] and it was found that they are higher or close to the results of those studies, and we believe that the reason behind the increase in radon gas concentrations in the rock samples chosen from oil wells in the fields of
the study area is the fact that those rocks are extracted from deep depths from the underground and contain large quantities of Natural Occurring Radioactive Material. Also, the reasons for the emergence of different concentrations from one well to another may be due to the nature of the geological formation of the oil fields in their different locations. The effective dose experienced by the two laborers upon contact, as 1Bq / m3 equals 0.00025mSv·y⁻¹, according to EPA CEC, given that 1Bq / m³ = 2.854x10⁻³µSv h⁻¹, and from this we conclude that the greatest radon concentration is 53861Bq.m⁻³ in well rock samples. The oil under study is equivalent to an effective dose of 107.722 ± 10.92 vSvh⁻¹ upon contact, which is a dose higher than the permissible dose level 50µ Svh⁻¹ proposed by EPA in the United States [14–15].

Figure (6) illustrates the relationship between radon gas concentration and the effective dose of eight rock models Oil wells Elected from the study area. The likelihood of developing cancer as a result of exposure to radon gas per million people was estimated by multiplying the annual effective dose in mS.y) (18 × 10⁻⁶). The probability of infection in this study when taking the highest concentration dose in this study was 107.722 ± 10.92 vSvh⁻¹ giving a value High per million people This is a high value compared to the permissible limits (170–230) per million people by ICRP [16–19].

Table 1. Concentration of radon gas (Bq.m⁻³) ²²²R in rock models in a well ((Ru–205) South Rumaila field in the study area.

| Sample No | Depth (m) | Radon Concentration(²²²Rn) in Bq/m³ | Effective Dose µSv h⁻¹ | Lung Cancer ×10⁻⁶ |
|-----------|-----------|----------------------------------|------------------------|------------------|
| R1        | 500       | 4390                             | 8.78                   | 158.04           |
| R2        | 1000      | 8216                             | 16.43                  | 295.74           |
| R3        | 1500      | 8873                             | 17.74                  | 319.32           |
| R4        | 2000      | 10295                            | 20.59                  | 370.62           |
| R5        | 2500      | 12194                            | 24.38                  | 438.84           |
| R6        | 3000      | 15632                            | 31.26                  | 562.68           |
| R7        | 3500      | 53861                            | 107.722                | 8507             |
| Mean      | 16208.714 | 32.414                           |                        |                  |
Table 2. Concentration of radon gas (Bq.m$^{-3}$) $^{222}$R in rock models in a well (R-158) North Rumaila field in the study area.

| Sample No | Depth m (m) | Radon concentration ($^{222}$Rn in Bq/m$^3$) | Effective dose μSv h$^{-1}$ | Lung Cancer $\times 10^{-6}$ |
|-----------|-------------|---------------------------------------------|-----------------------------|-----------------------------|
| R1        | 500         | 2965                                        | 5.93                        | 106.74                      |
| R2        | 1000        | 6341                                        | 12.68                       | 228.24                      |
| R3        | 2000        | 6935                                        | 13.87                       | 249.66                      |
| R4        | 2500        | 7849                                        | 15.69                       | 282.42                      |
| R5        | 2750        | 9305                                        | 18.61                       | 334.98                      |
| R6        | 3000        | 11276                                       | 22.55                       | 405.9                       |
| R7        | 3250        | 13425                                       | 26.85                       | 483.3                       |
| Means     | 8299.428    |                                             | 16.59                       |                             |

Table 3. Concentration of radon gas (Bq.m$^{-3}$) $^{222}$R in rock models in a well (WQ-94) West Qurna –1 field in the study area.

| Sample No | Depth m (m) | Radon concentration ($^{222}$Rn in Bq/m$^3$) | Effective dose μSv h$^{-1}$ | Lung Cancer $\times 10^{-6}$ |
|-----------|-------------|---------------------------------------------|-----------------------------|-----------------------------|
| R1        | 500         | 248                                         | 0.49                        | 8.82                        |
| R2        | 1000        | 397                                         | 0.79                        | 14.22                       |
| R3        | 1500        | 463                                         | 0.92                        | 16.56                       |
| R4        | 2000        | 512                                         | 1.02                        | 18.36                       |
| R5        | 2500        | 605                                         | 1.21                        | 21.78                       |
| R6        | 2750        | 621                                         | 1.24                        | 22.32                       |
| R7        | 3000        | 836                                         | 1.67                        | 30.06                       |
| Means     | 526         |                                             | 1.048                       |                             |

Table 4. Concentration of radon gas (Bq.m$^{-3}$) $^{222}$R in rock models in (Lu–18) Lahis field in the study area.

| Sample No | Depth m (m) | Radon concentration ($^{222}$Rn in Bq/m$^3$) | Effective dose μSv h$^{-1}$ | Lung Cancer $\times 10^{-6}$ |
|-----------|-------------|---------------------------------------------|-----------------------------|-----------------------------|
| R1        | 250         | 1142                                        | 2.28                        | 41.04                       |
| R2        | 500         | 1276                                        | 2.55                        | 45.9                        |
| R3        | 1000        | 1981                                        | 3.96                        | 71.28                       |
| R4        | 1500        | 2190                                        | 4.38                        | 78.84                       |
| R5        | 1750        | 2735                                        | 5.47                        | 98.46                       |
| R6        | 2000        | 2926                                        | 5.85                        | 105.3                       |
| R7        | 2500        | 3001                                        | 6.00                        | 108                         |
| Means     | 2178.714    |                                             | 4.355                       |                             |
Table 5. Concentration of radon gas (Bq.m\(^{-3}\)) \(^{222}\)R in rock models in a (Tu-5) bricks field in the study area.

| Sample No | Depth (m) | Radon concentration\(^{222}\)Rn in Bq/m\(^3\) | Effective dose \(\mu\)Sv h\(^{-1}\) | Lung Cancer \(\times 10^{-6}\) |
|-----------|-----------|---------------------------------------------|--------------------------------|--------------------------|
| R1        | 200       | 864                                        | 1.72                           | 30.96                    |
| R2        | 400       | 1214                                       | 2.42                           | 43.56                    |
| R3        | 600       | 1387                                       | 2.77                           | 49.86                    |
| R4        | 800       | 1615                                       | 3.23                           | 58.41                    |
| R5        | 1000      | 1879                                       | 3.75                           | 67.5                     |
| R6        | 1200      | 2126                                       | 4.25                           | 76.5                     |
| R7        | 1500      | 2532                                       | 5.06                           | 91.08                    |
| Means     |           | 1659.571                                   | 3.314                          |                          |

Table 6. Concentration of radon gas (Bq.m\(^{-3}\)) \(^{222}\)R in rock models in a well (NR-18) Nahr Bin Omar field in the study area.

| Sample No | Depth (m) | Radon concentration\(^{222}\)Rn in Bq/m\(^3\) | Effective dose \(\mu\)Sv h\(^{-1}\) | Lung Cancer \(\times 10^{-6}\) |
|-----------|-----------|---------------------------------------------|--------------------------------|--------------------------|
| R1        | 200       | 921                                        | 1.84                           | 33.12                    |
| R2        | 500       | 1117                                       | 2.23                           | 40.14                    |
| R3        | 800       | 1422                                       | 2.84                           | 51.12                    |
| R4        | 1000      | 1483                                       | 2.96                           | 53.28                    |
| R5        | 1200      | 1716                                       | 3.43                           | 61.74                    |
| R6        | 1400      | 2215                                       | 4.43                           | 79.74                    |
| R7        | 1500      | 2510                                       | 5.02                           | 90.36                    |
| Means     |           | 1626.285                                   | 3.25                           |                          |

Table 7. Concentration of radon gas (Bq.m\(^{-3}\)) \(^{222}\)R in rock models in a well (Zu-171) Zubair oil field in the study area.

| Sample No | Depth (m) | Radon concentration\(^{222}\)Rn in Bq/m\(^3\) | Effective dose \(\mu\)Sv h\(^{-1}\) | Lung Cancer \(\times 10^{-6}\) |
|-----------|-----------|---------------------------------------------|--------------------------------|--------------------------|
| R1        | 500       | 3128                                        | 6.25                           | 112.56                   |
| R2        | 1000      | 5982                                        | 11.96                          | 215.28                   |
| R3        | 1500      | 7216                                        | 14.43                          | 259.74                   |
| R4        | 1800      | 8119                                        | 16.23                          | 292.14                   |
| R5        | 2000      | 10311                                       | 20.62                          | 371.16                   |
| R6        | 2200      | 10725                                       | 21.45                          | 386.1                    |
| R7        | 2500      | 10787                                       | 21.57                          | 388.26                   |
| Means     |           | 8038.285                                    | 16.072                         |                          |
Table 8. Concentration of radon gas ($\text{Bq}\cdot\text{m}^{-3}$) $^{222}\text{Rn}$ in rock models in a well (Rt–7) Artawi field in the study area.

| Sample No | Depth (m) | Radon concentration ($^{222}\text{Rn}$) in Bq/m$^3$ | Effective dose (µSv h$^{-1}$) | Lung Cancer ($\times 10^{-6}$) |
|-----------|-----------|-------------------------------------------------|-------------------------------|-------------------------------|
| R1        | 500       | 797                                             | 1.59                          | 28.62                         |
| R2        | 800       | 945                                             | 1.89                          | 34.02                         |
| R3        | 100       | 1347                                            | 2.69                          | 48.47                         |
| R4        | 1500      | 1473                                            | 2.94                          | 52.92                         |
| R5        | 1800      | 1480                                            | 2.96                          | 53.28                         |
| R6        | 2000      | 1566                                            | 3.13                          | 56.34                         |
| R7        | 2500      | 2005                                            | 4.01                          | 72.18                         |
| Means     |           | 1373.285                                        | 2.744                         |                               |

Figure 4. Radon concentration (Bq, M$^{-3}$) measured in the rock samples of the Ru–205 well for different depths.
4. Conclusion

The results of this study showed the determination of radon gas concentrations emitted from oil rocks at different depths of the earth's surface in selected oil wells from oil fields in Basra Governorate – southern Iraq by means of effective electronic technology through the RAD device.

1. The radon Average concentration for all models under study is 5700.857 Bq / m3, and the largest radon concentration in rocks is 53861 Bq.m⁻³. It appeared in a rock sample from the Ru–205 South Rumaila oil field, and radon concentration in the
rocks from well WQ–94 in West Qurna Field–1 is the least concentrated rock species (248 Bq.m⁻³).

2. It was found that the equivalent annual dose in rock samples (Rocks) in the oil wells in the southern Iraqi oilfields covered by the study was higher than the permitted dose level of 50 µSv.h⁻¹ recommended by EPA in the United States.

3. The possibility of lung cancer in this study is of high value compared to the permissible limits (170–230) per million people by ICRP.

4. These Concentrations and doses pose a confirmed risk to the health of workers in those fields if the necessary measures and measures are not taken to protect them.

5. The study provides an important database on the concentration of radon gas in oil wells rocks in oil fields in Basra Governorate – Iraq.

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