Advanced Physical Research
Vol.7, No.2, 2025, pp.204-211
https://doi.org/10.62476/apr.72204

URANIUM AND RADON CONCENTRATION IN SOIL SAMPLES FOR THE GAS-FIRED POWER PLANT IN BABIL GOVERNORATE - IRAQ

Mohammed Abdul Kadhim Hadi Al-Sadi*

Environment Pollution Department, College of Environment, Al-Qasim Green University, Babylon 51013, Iraq

Abstract. The present study used a nuclear trace detector CR-39 by using two techniques: firstly, a reaction chamber to obtain radon concentrations and secondly, neutron irradiation to estimate uranium levels. High levels of radon gas concentration were found in different locations in the environment of the gas-fired power plant, where high concentration rates were recorded in some soil samples exceeding the permissible exposure limit (400 Bq/m^3) (UNSCEAR, 1993). It was also found that the annual effective dose was greater than the 10 mSv recommended as an occupational dose (ICRP 1993). The current results showed that the uranium concentration in some surface soil samples was higher than the recommended value (11.7 ppm) provided by UNSCEAR (1993, 2000).

Keywords: Uranium concentration, radon gas, CR-39 detector, Am-Be neutron source, Soil samples, Nuclear track detectors, Gas-Fired Power Plant.

***Corresponding author:** Mohammed Abdul Kadhim Hadi Al-Sadi, Environment Pollution Department, College of Environment, Al-Qasim Green University, Babylon 51013, Iraq,
e-mail: *Mohammed1986@environ.uoqasim.edu.iq*

Received: 15 January 2025; Revised: 25 March 2025; Accepted: 8 April 2025; Published: 24 June 2025.

1 Introduction

Uranium is a radioactive element that occurs naturally. It is a silver-white, glossy, heavy, and radioactive element (Zhang et al., 2022). Naturally occurring uranium consists of three isotopes ^{234}U, ^{235}U, and ^{238}U, all of which decay via both alpha and gamma emissions (EFSA, 2009). The 235U and 234U isotopes make up around 0.72% and 0.0054% of the total, respectively; the 238U isotope is the most abundant by weight (99.28%) (Cui et al., 2023). Because of its utilization in both military and civilian applications, such as nuclear weapons, energy generation, and medicine, uranium metal and its compounds are of enormous interest to physicists and chemists (UNEP, 1985). Alpha particles emitted during uranium decay can cause harmful effects in humans through internal exposure by ingestion and inhalation. Uranium is also classified as both radioactive and toxic (Amin & Haleem, 2022; Zakariya & Kahn, 2014). Radon gas, emitted from uranium decay chains, is extremely dangerous and is present at unacceptably high levels sometimes. Several factors influence the risk of exposure to radon and uranium, including the duration and intensity of exposure, the rate of isotope dissolution, and the biological factors of the exposed individuals themselves (Tawfiq et al., 2016). Humans absorb more radiation than the artificial radiation used in oil exploration, nuclear reactors, power generation, medical applications, and nuclear weapons, increasing their radioactivity (Tawfiq et al., 2013; Dumazert et al., 2018). Platelets and lymphocyte cells are quickly affected by radioactive elements. Changes in

Table 1: Sample code, sites, coordinates for soil samples in the gas-fired power plant.

Latitude (N)	**Longitude (E)**	**Sites/Units**	**Sample code**
32.407	45.077	Gas Field	**SS1**
32.403	45.08	Oil store	**SS2**
32.404	45.082	Garage	**SS3**
32.403	45.083	Garden	**SS4**
32.401	45.084	Unit One	**SS5**
32.399	45.086	Unit two	**SS6**
32.397	45.087	Unit three	**SS7**
32.397	45.09	Unit four	**SS8**
32.394	45.091	Unit five	**SS9**
32.401	45.098	Unit Six	**SS10**
32.398	45.102	Unit Seven	**SS11**
32.399	45.108	Unit eight	**SS12**

the blood composition of the human body can lead to anemia, fatigue, and heightened vulnerability to infection, bleeding, or leukemia. Both natural and artificial sources of ionizing radiation can expose people to this type of radiation outside their bodies. Skin contact, ingestion, and inhalation are the three ways that radioactive materials can be absorbed. When radioactive elements enter the human body, they are carried throughout the body by the blood (Inaam et al., 2023).

The natural radioactive decay of uranium, found in rocks, soil, and water, produces radon gas, which is odorless, colorless, and tasteless. Soil releases radon into the atmosphere, where it decays, releasing more radioactive particles. These particles can damage DNA and, when inhaled, can cause lung cancer when they encounter cells lining the airways. Outdoor radon concentrations typically range between 5 and $15Bq/m^3$. Indoor radon concentrations, on the other hand, are higher the highest concentrations are found in caves, mines, power plants, and oil fields, reaching over $10,000Bq/m^3$ (Sweaf & Salman, 2019). Given the danger posed by uranium and radon gas to workers' lives due to the possibility of their presence at unacceptable levels in some industrial facilities, this work focused on estimating the concentration of uranium and radon gas and assessing radioactive hazard indicators in the soil of the gas-fired power plant.

2 Material and Method

2.1 Collection Samples

Each of the twelve samples collected from the gas-fired power plant in Babylon Governorate, Iraq, at a depth of 10 cm, included 100 grams of dirt that were manually sorted. The sample code, locations, and coordinates for soil samples taken at the gas-fired power plant are listed in Table 1. After being tagged with the date and place of collection, the soil samples were stored in plastic bags. To further distinguish one sample from the others, a unique code was also given to each one.

2.2 The CR-39 Detector and Preparation Samples

The CR-39 nuclear trace detector used is highly efficient and more sensitive in detecting alpha particles emitted by uranium and radon isotopes at low and high energies compared to other solid-state detectors, which is why it was chosen for our current work.. For two hours, the soil samples were dried in an electric oven set at 100 °C. After being finely pulverized with a manual grinder, the soil samples were sieved through a 2 mm fine mesh screen. 0.5 gm of soil powder and 0.1 gm of methyl cellulose ($C_6H_{10}O_5$) powder, which was utilized as a binder, were combined. Then, using a hydraulic press, the mixture was formed into a disc that measured 1.5

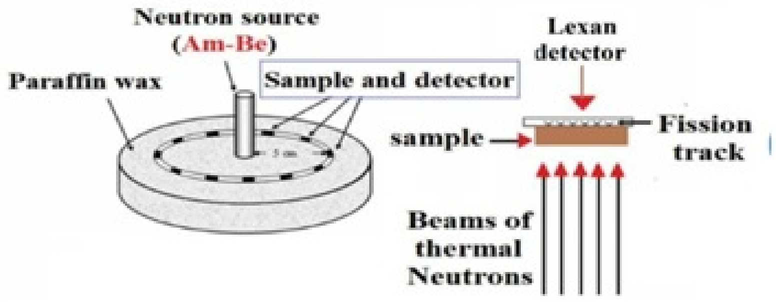

Figure 1: Neutron irradiation system

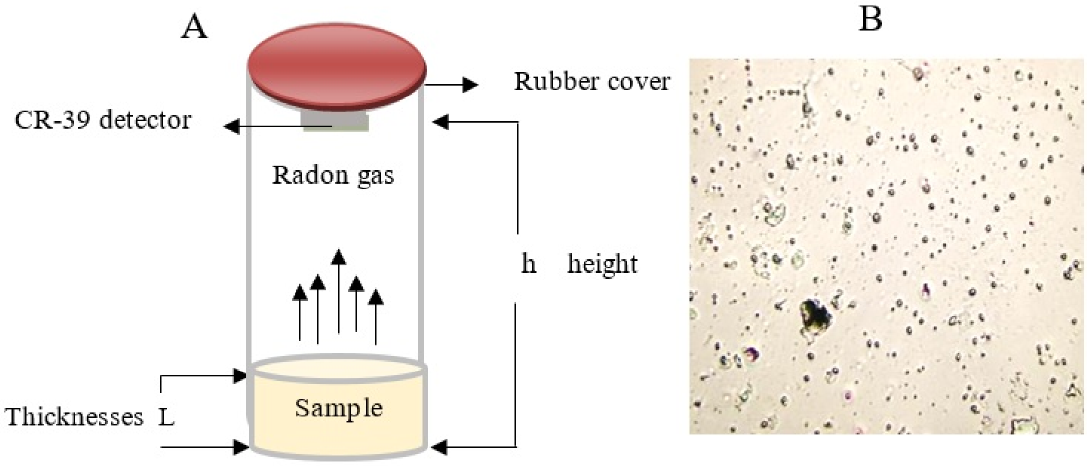

Figure 2: A: A schematic diagram of the sealed-cup technique; B: tracks density observed in the light microscope.

mm in thickness and 1 cm in diameter. The discs were coded after being covered with a CR-39 detector. The samples were exposed to $^{241}Am - ^{9}Be$ radiation for a week, with an activity of roughly 3×10^5 $n\ cm^{-2}\ s^{-1}$.

Twenty grams of soil samples were placed in a tightly sealed plastic reaction chamber that was seven centimeters high in order to evaluate the radon gas concentration. To prevent radiation imbalance inside the box, the plastic containers' lids were promptly raised after two days of radiation equilibrium. To stop radon gas from escaping, a CR-39 nuclear trace detector with a 1 cm^2 area was positioned and its lid was securely fastened. As illustrated in Figure 2, the sample height was 2 cm and the distance between the detector and the sample surface was 5 cm. For sixty days, the detectors were left (Mohammed & Ahmed, 2025). Following the exposure period, the detectors were raised in order to get them ready for the chemical scraping procedure and determine the impacts that would ensue. Figure 1 shows the method that was employed.

2.3 Chemical Etching

Following irradiation, a NaOH solution was used to chemically etch the CR-39 detector for five hours at 70 ± 1 °C in a water bath with Normality 6.25 N. The detectors were then cleaned and washed with distilled water (UNSCEAR, 1993). In a water bath, chemical etching was carried out. An optical microscope with a 40X magnification was used to calculate the track density (Sweaf & Salman, 2019). The background was subtracted from the recorded alpha track density in order to modify it.

3 Calculations

3.1 Uranium Concentration

By comparing the track densities recorded on the soil sample detector with those of the standard samples using Equation 1, the uranium concentration in the soil samples was determined (Fares, 2023).

$$C_x = \rho_x \left(\frac{C_s}{\rho_S} \right) \tag{1}$$

$$C_x \;=\; \rho_x / \; slope \tag{2}$$

C_x and C_s represent the uranium content for the unknown sample and the standard sample in (ppb), whereas ρ_x and ρ_S represent the induced fission track density for the unknown sample and the standard sample in (tracks/mm^2). For the standard sample, the slope of the linear relationship between track density and uranium content is equal to y=411.2x.

3.2 Radon Concentration

The amount of radon gas ^{222} Rn in the tube's air gap was calculated using equations 3 and 4. Where ρ is the irradiation detector's track density (Tr/cm^2), K is the calibration factor, and t is the exposure time (62 day), K factor can be calculated by using the formula below (Hashim et al., 2016; Al-Sadi & Kadhim, 2023).

$$C_{Rn} \left(\frac{Bq}{m^3} \right) = K \frac{\rho}{T} \tag{3}$$

$$K = \; 0.25r(2cos\theta c - \; r_\alpha \tag{4}$$

where r stands for the tube's radius ($r = 0.75cm$), θc for the CR 39 detector's critical angle (θc = 40°), and rα for the alpha particle range in the air ($r\_\alpha = 4.15cm$). Thus, it was determined that the blood calibration factor was 0.022 $Tr./cm^2.dy \; per \; Bq/m^3$ (Al-Sultani & Al-Sadi, 2023; Hadi Al-Sadi & Altbtbiey, 2021). The following formula was used to determine occupational workers' annual exposure.

$$1 \; Bq/m^3 = 0.00445 \; WLM = 1.72 \times 10^{-2} \; mSv \tag{5}$$

4 Result and Discussion

In the gas-fired power plant, the radon concentrations varied from 651.08Bq/m^3 to 251.39Bq/m^3 with an average of 512.75Bq/m^3, and the workers' yearly effective dosage ranged from 11.068 mSv to 4.274 mSv with an average of 8.717μSv. The mean yearly inhaled radon exposure for workers was 2.282 WLM, with a range of 2.897 WLM to 1.119 WLM.. According to UNSCEAR (2000), the average yearly inhalation dose from gas-fired power plants is far greater than the global average. According to the current study's findings, the radon gas concentration rates in a few soil samples from the gas-fired power plant are significantly greater than the acceptable exposure level of 400Bq/m^3 (Al-Sadi & Kadhim, 2019; UNSCEAR, 1993). The existence of a gas field, which causes the gasses to seep deeply into the soil and pollute the surrounding environment. Additionally, radon gas builds up inside the soil when it is covered with cement, asphalt, and gravel since these materials do not alter the soil layers.

Contrast, it was discovered that the average uranium concentration in soil samples from the gas-fired power plant was 17.99 ppm, with the highest concentration being 25.35 ppm, the lowest

Table 2: The levels of radon, uranium, annual exposure (WLM), and annual effective dosage (mSv) in soil samples from the gas-fired power plant.

U (ppm)	Annual exposure (WLM)	Annual effective dose (mSv)	C_{Rn} (Bq/m^3)	Sample code
23.88	2.539	9.698	570.46	**SS1**
22.19	2.679	10.234	601.99	**SS2**
13.089	1.775	6.780	398.84	**SS3**
11.73	1.896	7.244	426.09	**SS4**
7.621	1.708	6.527	383.92	**SS5**
23.29	2.614	9.985	587.38	**SS6**
17.412	2.024	7.732	454.82	**SS7**
22.711	2.532	9.672	568.95	**SS8**
6.823	1.119	4.274	251.39	**SS9**
25.35	2.826	10.794	634.96	**SS10**
19.69	2.897	11.068	651.08	**SS11**
22.18	2.773	10.593	623.12	**SS12**
17.997	2.282	8.717	512.75	**Mean ± SD**
25.35 - 6.823	2.897- 1.119	11.068- 4.274	651.08- 251.39	**Range**

being 6.823 ppm, and the average falling between these three values. According to current findings, some surface soil samples had uranium levels above the UNSCEAR (1993)-recommended threshold of 11.7 ppm (UNSCEAR, 2000). Levels of radon and uranium are hazardous and detrimental to people. Due to a variety of human industrial operations that release radiation into the environment, exposure to these high amounts of radiation has an adverse effect on human health as well as the health of living things and ecosystem components. In addition to the high temperatures that significantly influence the rise and fall of concentrations, the high levels of uranium and radon in certain sections of the gas-fired power plant station are caused by the high amounts of gases that are discharged into the air from the plant itself.

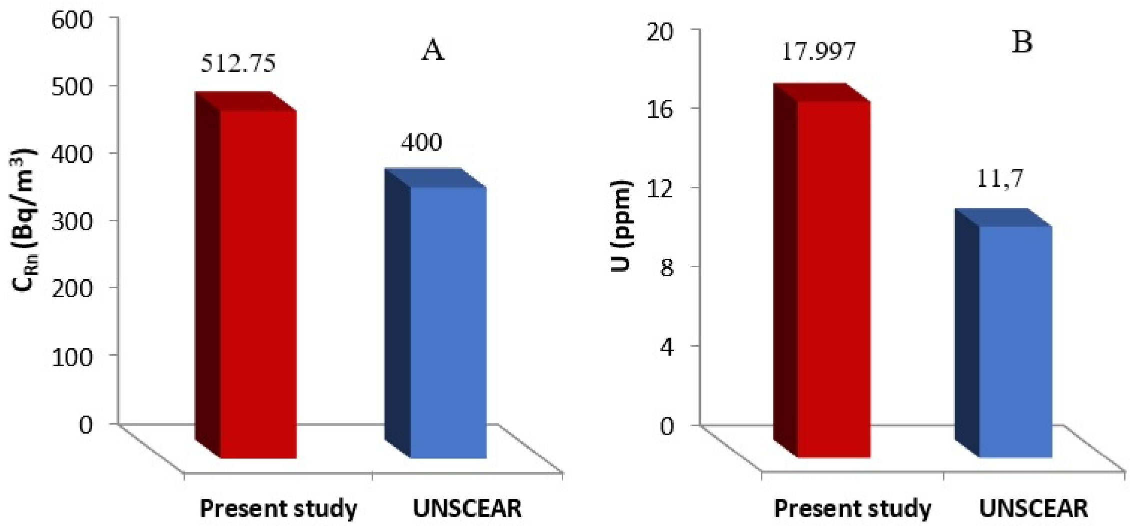

Figure 3: Mean values in the current study compared to the permissible limits. A: Radon concentrations; B: Uranium concentration

5 Conclusions

High levels of radon gas concentration were found in different locations in the environment of the gas-fired power plant, where high concentration rates were recorded in some soil samples exceeding the permissible exposure limit $400 Bq/m^3$ (UNSCEAR,1993). The annual effective dose was also found to be greater than the recommended 10 micro Sieverts as an occupational dose (ICRP 1993). The present results showed that the concentration of uranium in some surface soil samples was higher than the recommended value (11.7 ppm) provided by UNSCEAR (2000,1993). In addition to the high temperatures that significantly influence the rise and fall of concentrations, the high levels of gases released from the plant, which contain naturally occurring and artificially enhanced radioactive materials, are the cause of the elevated uranium and radon levels in certain sections of the gas-fired power plant.

6 Recommendations for Future Work

1. Improving ventilation in the gas-fired power plant buildings, continuing to provide information on indoor radon and uranium concentrations and their associated health risks through periodic site surveys.

2. Implementing a national radon mitigation program aimed at establishing a national average radon concentration of 100 Bq/m^3 per year. If this level cannot be achieved due to the prevailing emission conditions at the gas-fired power plant, a reference level of 300 Bq/m Bq/m^3 should be established.

3. Establish protocols for measuring radon concentrations to help ensure the quality of radon testing. Integrate radon prevention measures into the gas-fired power plant building codes, implement radon and uranium elimination programs, and ensure their levels are reduced to below national reference levels. Enhance the education of building professionals and provide financial support for radon removal from existing buildings.

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