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Research Note

# Measurements of Radioactive Pollution in the Soil near the Power Generators

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*A B S T R A C T*

The aim of present work was to assess the impact of diesel power generators wastes on radon levels using solid state nuclear track detector CR-39. Forty eight soil samples were collected from area around four power generators located in Al-Ghazalia region in Baghdad, Iraq. Twelve samples at depths of 10-30cm around each generator were taken, three in each direction (N, S, E and W) at different distances (0, 5, and 10m). The value of radon concentrations ranged from 358.3Bq.m$^{-3}$ at distance 5.0m from G2N to 1258.6Bq.m$^{-3}$ at distance 10.0m for G2S. The mean values of radon concentrations varied from the lowest value of 604.6 Bq.m$^{-3}$ to the highest value of 694.7Bq.m$^{-3}$ in the soil samples around G1 and G4, respectively. The mean value was 636.6 Bq.m$^{-3}$. The values of radon level are higher than the international recommended value. Surface and mass exhalation rates were also calculated with average values of (0.35) Bq.m$^{-2}$.h$^{-1}$ and (0.15) Bq.kg$^{-1}$.h$^{-1}$, respectively. These values are found to be below the limit of the recommended values.

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## INTRODUCTION

Radon, which is a topic of public health concern, is a progeny of Uranium-238 formed from the radioactive decay of $^{226}$Ra. It is a colorless, odorless, electrically uncharged noble but hazardous gas which is radioactive, emits alpha radiation and decays with a half-life of 3.824 days.

Radon concentration in the soil depending on several factors such as the type of soil physical and chemical properties, location, the surrounding buildings and human activities in the regions [1]. Soil is considered the primary source of radon; hence many researchers studied the concentration of radon in the soil because of its negative impact on human health at the high proportion of natural border.

Vaupotic et al. [2] studied the radiation level in soil for different regions near the elevated seismic activity at the Italian-Slovene border, they found the elevated seismic activity effected on radiation concentration in the soil.

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Bistra and his coworkers [3] studied radon concentration in soil gas at 64 locations within 13 urban areas of Bulgaria. Radon concentration in soil gas was found to be log-normally distributed within the range of 3–97 kBq.m$^{-3}$, with arithmetic mean of 26 kBq.m$^{-3}$; this range of radiation depending on human activities in each location [3]. Soil and building materials found to cause a high level of radon indoor of buildings in Romania [4].

Seasonal variation of the radon concentration was investigated in Turkey, the highest radon concentration observed in summer and the lowest concentration measured in winter [5].

Vikas and his research team [6] studied depth dependence on the soil-gas radon concentration levels; the results showed increasing of soil-gas radon concentration levels with depth.

Researches on soil gas radon concentration were also conducted in different provinces in Iraq. Hasan et al. [7] measured radon concentration in 15 locations in Al-Najaf Al-Ashraf city, four different depths were taken in each location starting from the ground surface, the results showed that the largest concentration obtained at 60cm depth, while the lowest concentrations were at depth 5cm. This study agreed with Al-

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Hamidawi et al. [8] studied conducted in Al-Kufa city. The investigation was made at three depths for 20 locations [8]. Other study was made in South of Iraq, radon concentrations in 72 oil well fields were assessed and the investigation showed great variability of radon concentration in each well due to different geological environments in Iraq [9].

The aim of present study was to measure radon concentrations in the soil samples collected from the sites affected by the local power generators in Al-Ghazalia region in Baghdad city.

## MATERIALS AND METHODS

Forty-eight soil samples were collected from the area around four generators located in Al-Ghazalia region in Baghdad at depths between 10 to 30cm. Twelve soil samples were collected around each generator, three in each direction (North, South, East and West) at three different distances away from the generator (0.0m, 5.0m and 10.0m). Table 1 summarized the environmental description around each generator.

**TABLE 1**. Environmental description for the four generators

| Generator Code | North | South | East | West |
|---|---|---|---|---|
| G1 | Uninhabited area | Two main streets Schools Markets Residential area | Power station Main street Heavy residential area | Effect of G2 Playground with high lighting |
| G2 | Effect of G4 Popular market, Car park | Bakery By-road Residential area | Effect of G1 Playground | Effect of G3 Popular market Car park |
| G3 | Car park | Residential area | Effect of G2 Playground Car park | Main street Popular market, Car park |
| G4 | Residential area | Effect of G2 Playground | Residential area | Residential area |

The collected soil samples were dried, crushed and sieved with a 2mesh size sieve. The samples were investigated by means of sealed can technique using solid state nuclear track detector CR-39. Thirty grams of each sample were placed at the bottom of a plastic can (size 6.5cm height and 4cm diameter) with a piece of (1.5x1.5 cm2) of CR-39 detector placed at the top of the container 4 cm above the sample (Figure 1). Tracks of alpha particles emitted from 222Rn are recorded in the detector. The detectors were left for a period of 2 months, this long time of irradiation is necessary to accumulate considerable number of tracks of α-particles that emitted from radon, and their progenies. After the irradiation, CR-39 plastics were developed in NaOH solution with chemical etching conditions 6.25 N at 80oC for 4 hours [10]. Then, the detectors were examined for α-tracks using an optical microscope with 10×40 magnification. Equations (1 and 2) were used to calculate radon concentrations CRn (Bq.m-3) and the effective radium content CRa in (Bq.kg-1) in the soil samples, respectively [11]:

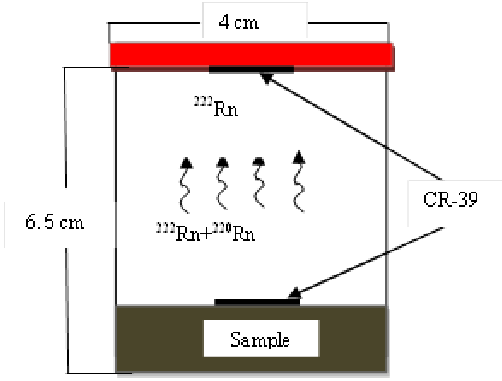


**Figure1**. Sealed can technique

$$C_{Rn} = \frac{\rho}{C_F\,T} \tag{1}$$

$$C_{Ra} = \frac{\rho\,h\,A}{C_F\,T\,M} \tag{2}$$

Where, $\rho$ is the measured alpha track density in unit Track.cm$^{-2}$, $h$ is the distance between CR-39 detector and the sample measured in cm, $A$ is the area of CR-39 in cm$^2$, $T$ is the exposure time in hours, $M$ is the mass of the sample in kg and $C_F$ =0.04891 Tr.cm$^{-2}$.d$^{-1}$/Bq.m$^{-3}$ is the calibration factor which is calculated using equation (3) [12]:

$$C_F = \frac{1}{4} r \left[2 cos\theta_c - \frac{r}{R_\alpha}\right] \tag{3}$$

Where, r is the radius of the container in cm, $\theta_c$ =35$^0$ is the critical angle of CR-39 and $R_\alpha$= 4.15cm is the range of α particle emitted from $^{222}$Rn.

Equations (4 and 5) were used to calculate the surface and mass exhalation rates of the samples for radon emission $E_A$ in Bq m$^{-2}$ h$^{-1}$ and $E_M$ in Bq kg$^{-}$1 h$^{-1}$, respectively [13]:

$$E_A = \frac{C\,V\,\lambda}{A[T + \lambda^{-1}\{e^{-\lambda T} - 1\}]} \tag{4}$$

$$E_M = \frac{C\,V\,\lambda}{M[T + \lambda^{-1}\{e^{-\lambda T} - 1\}]} \tag{5}$$

Here, C is the integrated radon exposure in Bq m$^{-3}$ h, V is volume of the container cm$^3$, and λ is the decay constant of radon in h$^{-1}$.

## RESULT AND DISCUSSION

Figure 2 shows radon concentrations for soil samples collected from the sites of the 4 generators in 4 different directions and 3 different distances (0.0m, 5.0m, and 10.0m) in each direction away from the generators. The calculated radon concentrations are ranged from

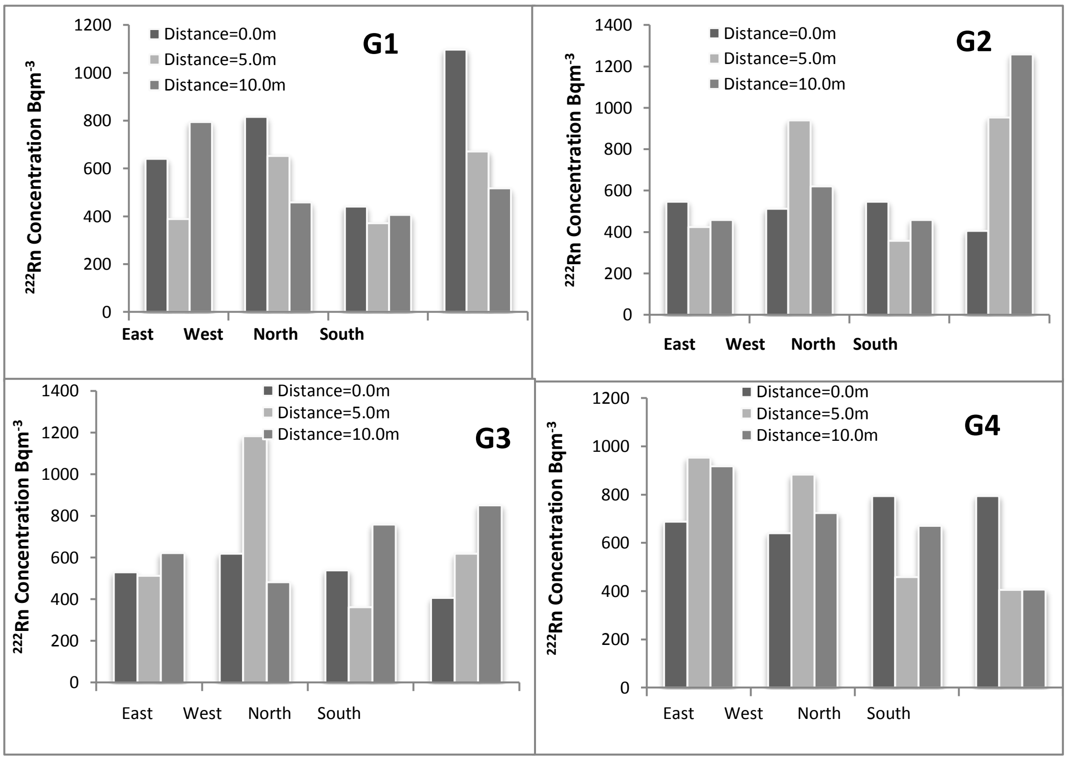


**Figure 2**. Radon concentrations in soil samples taken from the area around the 4 generators

358.3Bq.m$^{-3}$ at distance 5.0m from G2N to 1258.6Bq.m$^{-3}$ at distance 10.0m for G2S with average value of 636.6Bq.m$^{-3}$.

The mean values of radon level for each generator are given in Figure 3. The histogram shows that the highest value of radon level is obtained at G4. Radon levels in all samples are higher than the permissible limit of exposure to radon for the population to be (200 Bq.m$^{-3}$) [14].

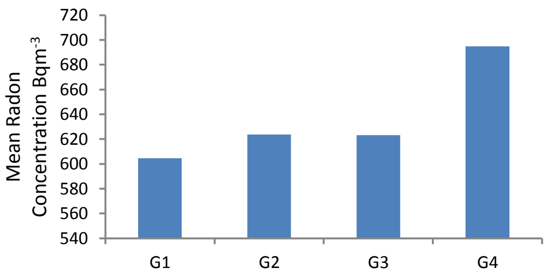


**Figure 3**. Mean values of radon level Bq.m$^{-3}$ for the samples of four generators

Table 2 lists average, minimum and maximum values of radon concentrations at distances (0.0m, 5.0m and 10.0m) away from the generators.

Radium content for the studied soil samples is shown in Figure 4. The values of radium content are ranged from the lowest value of 5.42Bq.kg$^{-1}$ in G2N sample at 5.0m away from the generator to the highest value of 19.03Bq.kg$^{-1}$ in G2S sample at distance 10.0m away from the generator with mean value of 9.58 Bq.kg$^{-1}$.

**TABLE 2**. Average, minimum and maximum values of radon at three different distances for the four generators

| Distance (m) | Average(Bq.m$^{-3}$) | Min (Bq.m$^{-3}$) | Max (Bq.m$^{-3}$) |
|---|---|---|---|
| 0.0 | 626.1 | 406.0 | 1097.9 |
| 5.0 | 633.2 | 358.3 | 1182.7 |
| 10.0 | 650.4 | 406.0 | 1258.6 |

The variation of radium content may be due to the different radioactive content of the material, emanation factor and diffusion coefficient of radon in that material, porosity and density of the material [10]. The acceptable value of radium activity in soil for safe use should not exceed 370 Bq/kg [15]. Thus, as far as the health hazard effects are concerned, the results reveal that the studied area are secure and safe. Figures 5 and 6 show that the surface and mass exhalation rates vary from 0.20 Bq.m$^{-2}$.h$^{-1}$ in G2N at 0.0m distance from the generator to 0.69 Bq.m$^{-2}$.h$^{-1}$ in G2S at distance 10.0m away from the generator with mean value of 0.35 Bq.m$^{-2}$.h$^{-1}$ and from 0.07Bq.kg$^{-1}$.h$^{-1}$ in G2N at distance 0.0m from the generator to 0.95Bq.kg$^{-1}$.h$^{-1}$ in G1W at 10.0m away from the generator with mean value of 0.15Bq.kg$^{-1}$.h$^{-1}$, respectively. The general trend of the figures shows that increasing radium concentration enhances the radon exhalation rate.

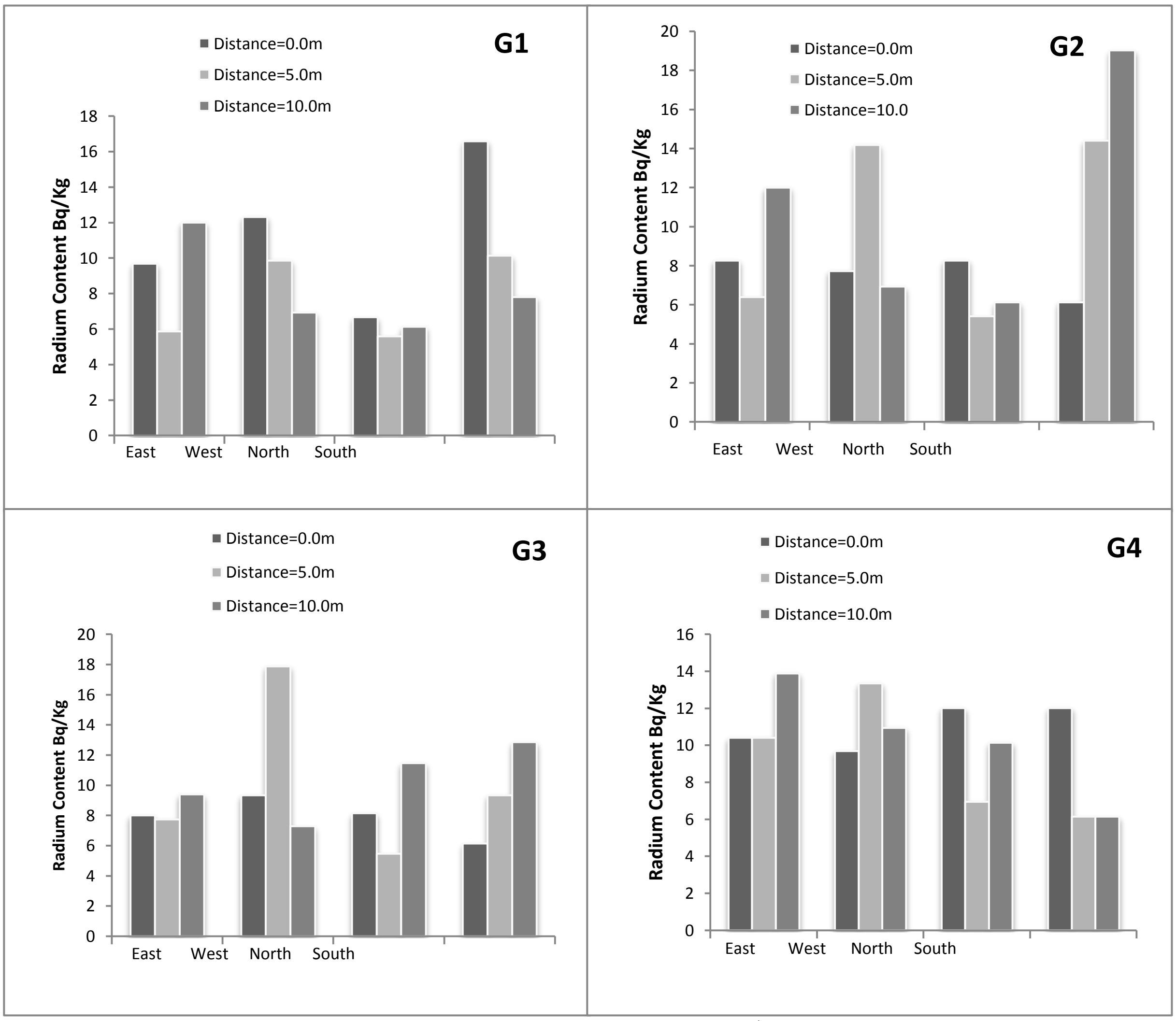


**Figure 4**. Radium content in $Bq.kg^{-1}$

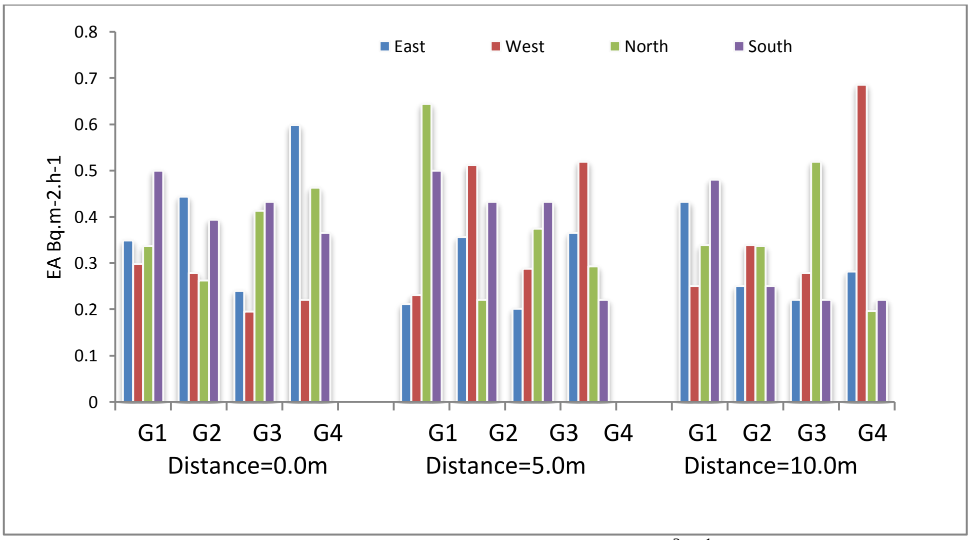


**Figure 5**. Surface exhalation rate in $Bq.m^{-2}.h^{-1}$

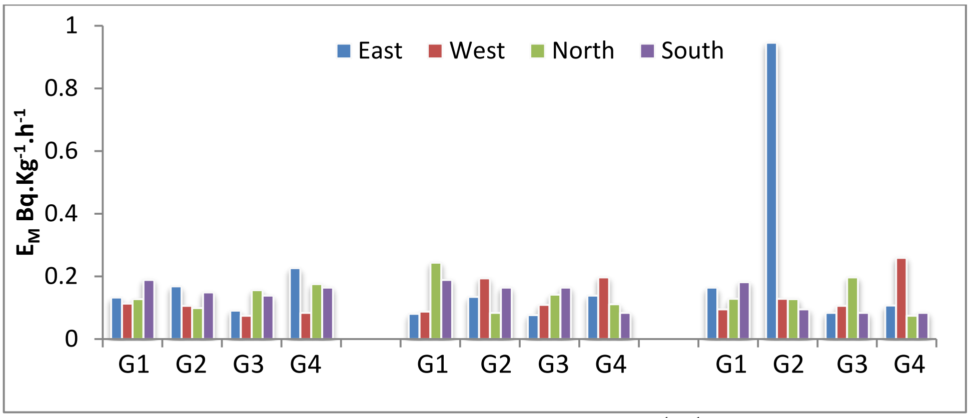


**Figure 6**. Mass exhalation rate in $Bq.kg^{-1}.h^{-1}$

## CONCLUSION

The goal of the present study is to assess the contribution of diesel Power generators, which are used heavily in Baghdad, to the total radon exposure and its effect to the inhabitants in Iraq.

In general, the results indicate that the radon exhalation rates from the investigated soil samples are low and below the recommended value given by ICRP, show that the Power generators does not pose any significant radiation hazard.

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**Persian Abstract**

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**چکیده**

هدف از مطالعه حاضر، ارزیابی تاثیر ضایعات ژنراتورهای دیزلی بر سطح رادون با استفاده از آشکار سازهای مسیر هسته ای CR-39 حالت جامد است. چهل و هشت نمونه خاک از مناطق اطراف چهار ژنراتور واقع در منطقه الغزالیه در بغداد عراق جمع آوری شد. دوازده نمونه در عمق های ۱۰- ۳۰سانتی متر در اطراف هر ژنراتور گرفته شد، هر سری سه نمونه در جهت های شمال، جنوب، شرق، غرب وفواصل مختلف (۰ و ۵ و ۱۰ متر). مقدار غلظت رادون در فاصله ۵ متری شرقی-غربی با مقدار $358.3 Bq.m^{-3}$ تا $1258.6 Bq.m^{-3}$ در فاصله ۱۰ متری شرقی-غربی دسته بندی شده است. مقادیر میانگین غلظت رادون از کمترین مقدار $604.6 Bq.m^{-3}$ به بالاترین مقدار $694.7 Bq.m^{-3}$ در نمونه خاک اطراف G1 و G4، متغیر است و مقدار متوسط $636.6 Bq.m^{-3}$ بوده است. مقادیر سطح رادون بالاتر از مقدار توصیه می شود بین المللی است. نرخ دود شدن سطحی وجرمی به ترتیب با ارزش های $(0.35) Bq.m^{-2}.h^{-1}$ و $(0.15) Bq.kg^{-1}.h^{-1}$ محاسبه شد. مقادیر بدست آمده زیر حد مجاز توصیه شده است.