Measurement of outdoor Radon Concentrations in Soil Samples collected from Karabuk University in Turkey by using CR-39 Detector

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Abstract. In this work, radon gas concentration in (35) samples of soil collected from Karabuk University in Turkey was measured by using nuclear track detector (CR-39). The content of radium, the rate of surface exhalation and the rate of mass exhalation have been assessed. The concentrations of radon were varied from (16.348 Bq.m\(^{-3}\)) to (196.988 Bq.m\(^{-3}\)). Results indicate that the equivalent content of radium varied from (0.386245 Bq.kg\(^{-1}\)) to (4.654255 Bq.kg\(^{-1}\)). The exhalation rate for surface varied from (0.002007 Bq.m\(^{-1}\).h\(^{-1}\)) to (0.023031 Bq.m\(^{-1}\).h\(^{-1}\)). The exhalation rate for mass varied from (0.000319 Bq.kg\(^{-1}\).h\(^{-1}\)) to (0.00366 Bq.kg\(^{-1}\).h\(^{-1}\)). All the obtained results found to be less than the corresponding limits for the world. Thus, based on the radon gas concentration and radiation, the equivalent content of radium (C\(_{Ra}\)), exhalation rate for the area (E\(_{Area}\)) and exhalation rate for the mass (E\(_{Mass}\)) in this area have no risk to the human’s health.

Keywords: Radon gas, nuclear track detector CR-39, soil, equivalent content of radium, exhalation rate for surface, exhalation rate for mass.

1. Introduction

Radon gas (\(^{222}\text{Rn}\)) is the most variable and largest radiation that contributed to public exposure. It was found that the ratio of radon and it’s daughters dose per year about (55%) of natural public exposure by inhalation of air, which the high levels of it can cause lung cancer [1] because Radon is a radioactive gas (alpha particle emitter) has a decay constant of (0.1812 day\(^{-1}\)) with t\(_{1/2}\) of (3.825 days) [2]. When radon exposure increased, the risk of lung cancer will increases, which has a linear relation with doses, it has been found that the risk of lung cancer increases (16%) per every (100 Bq/m\(^3\)) increase in radon concentration[3]. The \(^{238}\text{U}\) series generate radon (\(^{222}\text{Rn}\)) as a daughter of radium(\(^{226}\text{Ra}\)), which has another isotopes are the thoron (\(^{220}\text{Rn}\)) and actinon (\(^{219}\text{Rn}\)) which are daughters of \(^{232}\text{Th}\) and \(^{235}\text{U}\) series, respectively[4]. Radon is an inert gas heavier than the air, without any color and smell or taste, which is usually stay close to the ground floors [5]. Two different methods were used to measure the radon concentration. The first one is the passive method by integrative sampling for long time exposure using a suitable detector (like CR-39 in this work) and the second method is the continuous active radon sampling (like continuous radon monitor), the first
method requires no electrical power as in the case of the second [6]. There are many studies about radionuclides and radon concentration emitted from soil samples in Turkey, which starts in 1983[7] by using Gamma spectroscopy and CR-39 detectors (for indoor and outdoor radon), there are two studies for Karabuk Governorate[8,9], but for Karabuk University area, this is the first study about radon concentration outdoor in it.

2. Experimental Part

2.1. Calculation of Radon gas concentrations

Thirty-five soil samples were collected from Karabuk University as shown in table-1 and Figure-1. These samples were dried by the oven (at a temperature of 80°C for 2h) and grinded into a powder with size of (200 µm) by using a sieve, then 10 gm was taken for exposure. The sealed-cup technique was used in this work, the sample a weight of put in a small cup, then covered with a large cup that contain CR-39 detector with a thickness of (250 μm). And an area of (1cm²) at the top of it, as shown in Figure-2, the exposure time was (60) days to attained secular equilibrium. Then the chemical etching for the detectors was current by using (NaOH) solution with the normality of (6.25N) at(60°C) for five hours. The tracks in CR-39 of alpha particles concentration emitted from Radongas from soil samples were measured using an optical microscope (Nikon type 168 Japan made) with a magnification of (400X). The numbers of the tracks were measured to get track density (ρ), which is given as[3]:

\[
\rho = \frac{N_{ave}}{A}
\]

(1)

Where \(N_{ave}\) is an average number of total tracks and A is an area of field view. The Radon gas concentration in the soil samples was obtained by the comparison between track densities registered on the detectors of the samples and that of the standard soil samples which are shown in Figure (3), using the following relation [10]:

\[
C_X = \frac{C_s \rho_s}{\rho_x}
\]

(2)

\[
C_x = \frac{\rho_s}{\text{slope}}
\]

(3)

Where \(C_X\) is alpha particles concentration in the unknown sample, \(C_s\) is the alpha particles concentration in the standard sample, \(\rho_s\) is track density of the unknown sample (track/mm²) and \(\rho_x\) is track density of the standard sample (track/mm²).

2.2 Calculation of Radiation indices

The equivalent content of radium in the soil sample in the unit (Bq/kg) is given as[11]

\[
C_{Ra} (\text{Bq.kg}^{-1}) = \frac{\rho \cdot h \cdot A}{K \cdot T_e \cdot M}
\]

(4)

where, \(\rho\) is track density (track/mm²), A is the area of the surface sample (0.001589 m²), K (calibration constant) equal to the slope/exposure time(7.026/60=0.117), h is the distance from the surface of the sample to the detector(13.5 cm), M is sample mass of (0.01kg), \(T_e\) is the effective exposure time(h), which given as[11]:

\[
T_e = T - \frac{1}{\lambda (1-e^{-\lambda T})}
\]

(5)

Where \(\lambda\) is the decay constant of radon (0.1814 day⁻¹) and \(T\) is exposure time.

The area surface exhalation rate and the mass exhalation rate are given as[11,12]

\[
E_{Area} = \frac{C \cdot V \cdot \lambda}{A(T+\lambda^{-1}(e^{-\lambda T-1}))} \text{ (Bq.m}^{-2}. \text{h}^{-1})
\]

(6)
\[ E_{\text{Mass}} = \frac{C \cdot V \cdot \lambda}{M[T+\lambda^{-1}(e^{-\lambda T}-1)]} \text{ (Bq.kg}^{-1} \cdot \text{h}^{-1}) \] (7)

Where \(C\) is the radon activity or integrated radon exposure (Bqm\(^{-3}\)h), \(V\) is volume of cup (m\(^3\)), \(T\) is Time of exposure (hrs), \(M\) is Mass (kg) of the sample in cup, \(\lambda\) is the decay constant for radon (h\(^{-1}\)).

**Figure 1.** Map Satellite for Karabuk University sites.

**Table 1.** Locations, codes and radon concentration of soil samples taken from some points of Karabük University.

| No | x-coordinate | y-coordinate | Location and Sample code | Tracks density(track/mm\(^2\)) | Radon concentration (Bq/m\(^3\)) |
|----|--------------|--------------|--------------------------|-------------------------------|---------------------------------|
| 1  | 32.654611    | 41.213097    | Science Faculty (TCFB1)  | 1210.718                      | 172.467                         |
| 2  | -            | -            | Fertilizer (CRL2)        | 1001.281                      | 142.633                         |
| 3  | 32.655861    | 41.208527    | Central Research Labs.   | 697.167                       | 99.312                          |
| 4  | 32.657718    | 41.206220    | Stadium (ST1)            | 1382.752                      | 196.988                         |
| 5  | 32.652134    | 41.216106    | Rector Office (RO2)      | 596.752                       | 85.007                          |
| 6  | 32.655796    | 41.210864    | Literature Faculty (LF2) | 530.765                       | 75.608                          |
| 7  | 32.652001    | 41.214480    | Medicine Faculty (MF1)   | 734.464                       | 104.625                         |
| 8  | 32.654999    | 41.214022    | Technology Faculty (TCFC1)| 963.984                       | 137.320                         |
| 9  | 32.657936    | 41.210555    | Original soil (1)        | 748.809                       | 106.668                         |
| 10 | 32.654755    | 41.214170    | Technology Faculty (TCFA2)| 611.097                       | 87.051                          |
| 11 | 32.651310    | 41.214005    | Original soil (2)        | 774.630                       | 110.346                         |
| 12 | 32.655366    | 41.212142    | Social Centre (SC)       | 1196.373                      | 170.424                         |
| 13 | 32.656388    | 41.210405    | Technology Centre (TCC1) | 875.045                       | 124.650                         |
| 14 | 32.657159    | 41.208329    | Library (L1)             | 872.172                       | 124.242                         |
| 15 | 32.652694    | 41.214406    | Medicine Faculty (MF2)   | 493.468                       | 70.295                          |
| 16 | 32.659887    | 41.205894    | Engineering Faculty      | 533.634                       | 76.016                          |
Figure 2. The sealed-cup technique for radon exposure.
Figure 3. The relation of track density and radon concentration for standard soil samples.

3. Results and Discussion

The results of radon concentrations emitted from soil samples selected from Karabuk University, was obtained by using the equation (3) are presented in table (1). From this table, it can be noticed that the highest radon concentration was found in a Stadium soil sample (196.988 Bq/m\(^3\)), while the lowest value was found in TOKI-1(The residential complex) equal to (16.348Bq/m\(^3\)).We also find that there are some values of radon concentrations close to the highest value, which is in the Science Faculty (TCFB1) and Social Centre (SC) soil samples (172.467Bq/m\(^3\)) and (170.424Bq/m\(^3\)) respectively, that means they are the same soil, although that the radon concentration in fertilizer sample was (142.329 Bq/m\(^3\)) and for the original soil samples (106.441 Bq/m\(^3\)), which is in agreement with other studies that done by other researchers like Ereeset al in 2006 for Western Turkey[13],Kamand Bozkurt in 2007 for Kastamonu[14], Kam et.al., in 2010 for Çanakkale[15],Kurnazet. al., in 2011 for Trabzon[16], Tabaret. al., in 2013 for Dikili[17], Sogukpinaret., al., in 2014 for Eskisehir[18],Ozen et. al., in 2018 for Rize[19] and Asliet. al., in 2019 for Karabuk[9].However, all results of radon concentrations in this work were less than the recommended value of (200 Bq/m\(^3\)) and certified by (ICRP, 1993)[20]. Table 2, presents results for radiation induces like the equivalent content of radium ranged from (0.386245) to (4.654255) Bq/m\(^2\).h,which were to be less than the permissible value of (370 Bq/kg) as recommended by the Organization for Economic Cooperation and Development[21], the exhalation rates for the area were varied from (0.002007Bq/m\(^2\).h) to (0.023031Bq/m\(^2\).h) and exhalation rates for mass varied from (0.000319) to (0.00366)Bq/kg.h.It should be mentioned thatthe observed values of the radon exhalation rate in thepresent work were below the world average of (2.5 Bq/m\(^2\).h)[22].

Table 2. The effective radium content, area surface exhalation rate and mass exhalation rate.

| No | Radon concentration (Bq/m\(^3\)) | Equivalent content of Radium (Bq/kg) | Area exhalation rate (Bq/m\(^2\).h) | Mass exhalation rate (Bq/kg.h) |
|----|----------------------------------|-------------------------------------|-------------------------------------|--------------------------------|
| 1  | 172.467                          | 4.074887                            | 0.020164                            | 0.003204                       |
| 2  | 142.633                          | 3.369990                            | 0.016676                            | 0.002650                       |
| 3  | 99.312                           | 2.346440                            | 0.011611                            | 0.001845                       |
| 4  | 196.988                          | 4.654255                            | 0.023031                            | 0.003660                       |
| 5  | 85.007                           | 2.008475                            | 0.009939                            | 0.001579                       |
4. Conclusions

Radon concentration, radium content, exhalation rates for the area (surface) and mass were obtained for selected soil samples collected from different locations in Karabuk University in Turkey. The results were found to be less than their corresponding permissible and certified world values. Thus, the present results revealed that the area is safe as far as the health effect is concerned, except the highest values which within the statistical ranges, the approximate values of the radon concentration refer to the soil of one source, which is transferred from another place for the purposes of agriculture, especially since the concentration values of the radon emitted from the original mountain the soil was far from it,which in agreement with other studies. From this, we conclude that we must know the sources of these soils and examine them radiographically before using them in agriculture or construction material and conduct other tests, such as X-rays fluorescent for these soils to find out their composition, which is an evident through the shape and the color forthem,that they are transported soils.

Acknowledgment:
N. Çakmak would like to acknowledge the support of the Karabuk University, Scientific research project's Unit with project code No.: FDT-2020-2348.
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