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Research Article

# Measurement of Effective Radium Content and Radon Exhalation Rates in Soil Samples of Adigrat, Tigrai Region, Ethiopia

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## Abstract

The predominant source of radiation exposure for the global population is natural radiation, originating from radioactive elements present in the Earth's soil, air, and water. These elements, such as uranium, radium, and radon, have existed since the planet's formation. Prolonged exposure, particularly in specific geographic locations, significantly contributes to radiation risks for populations. Exposure routes include inhaling radon gas, ingesting radioactive substances in food and water, and direct exposure to terrestrial gamma radiation. While natural radiation exposure generally remains within safe limits, certain factors can elevate risks, such as geological formations rich in radioactive minerals or proximity to nuclear facilities. Environmental conditions and geological factors can also influence radiation levels, leading to fluctuations in exposure risks. Monitoring and regulating radiation exposure are crucial to prevent surpassing permissible levels, which can result in health hazards like an increased risk of cancer. Effective management requires ongoing research, stringent regulations, and public awareness efforts to mitigate the risks associated with natural radiation exposure and protect public health. Effective radium content and radon exhalation rates in soil samples collected from Adigrat in Tigrai state of Ethiopia were experimentally measured by ‘‘Sealed Can Technique’’ using LR-115 type II plastic track detectors. The values of effective radium content were found to vary from16.11 Bq/kg to 34.24 Bq/kg with an average value of 25.93 Bq/kg and a standard deviation of 6.10. The mass and surface exhalation rate has been found to vary from $1.61x10^{-6}$ Bq $kg^{-1}$ $d^{-1}$ to 3.42 $x10^{-6}$ Bq $kg^{-1}$ $d^{-1}$ and $0.81x10^{-4}$ Bq $m^{-2}$ $d^{-1}$ to $1.71x10^{-4}$Bq $m^{-2}$ $d^{-1}$, respectively. The radium content in soil in the study area is below the permissible value of 370 Bq/kg as recommended by Organization for Economic Cooperation and Development.

## Keywords

LR-115 Track Detector, Radium Content, Radon Exhalation Rate, Soil Samples

## 1. Introduction

Natural radioactivity is the primary source of ionizing radiation exposure for the population, found in varying concentrations within us and our surroundings. Uranium serves as the primary origin of radium and radon within the soil and rocks. Radium, a stable radioactive element at standard temperature and pressure, undergoes decay to radon, releasing α-particles and subsequent γ-radiations. The quantity of radium concentration determines the production of radon atoms

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[1]. Soil, in particular, serves as a significant source of continuous radiation exposure for humans, acting as a pathway for the transfer of radioactive materials into the environment. Therefore, soil is considered a key indicator of radiological contamination [2]. Radium is a byproduct of the uranium series decay process. As radium undergoes decay within soil particles, the radon isotopes produced must initially break free from the mineral grains and move into air-filled spaces [3]. Several recent studies have investigated radon, examining its behavior in the atmosphere under various weather conditions and its potential impact on human health due to its cancer causing properties. Understanding the natural radioactivity of building materials is crucial for assessing radiation exposure for the population, given that a majority of people spend a significant portion of their time indoors. Building materials add to the natural radiation exposure through the release of radon gas, which leads to internal radiation exposure as radon decay products accumulate in the human respiratory system[4]. This paper focuses on analyzing radium on soil samples from specific areas in Adigrat, considering the potential health risks associated with radium in the environment. The study also includes determining the rate of radon exhalation from these soil samples.

## 2. Geography of Study Area


***Figure 1.*** *Map showing the location of study area.*

Adigrat is located in East Tigrai, Ethiopia. It is known for its historical and cultural significance. The town and its surroundings are home to ancient churches, monasteries, and historical sites, reflecting the region's deep-rooted history. The town is located in a region with diverse landscapes, ranging from mountains to valleys. The population of Adigrat includes various ethnic groups, with Tigrayans being one of the predominant communities. Its geographical coordinates are 14°16' 37" North, 39°27' 39" East with an elevation of 2,457 meters above sea level and below a high ridge to the west. Adigrat serves as the capital of the Eastern Tigray zone.

## 3. Experimental Details

The closed Can technique was used to assess the radium content, radon concentration and the radon exhalation rate of soil samples. In this setup, the exhalation rate is influenced by the quantity of the samples and size of the Can. A total of sixteen representative soil samples were collected by grab sampling from the districts of Adigrat, Tigrai region. In the laboratory, the collected soil samples were pulverized, homogenized and sieved through 2 mm mesh. Soil samples were dried in an oven at a temperature of 110 ℃ for three hours to remove all the moisture content. Then 250 g of each sample was placed in a plastic cylindrical container (diameter 8.0 cm and height 10 cm) of area $5x10^{-3}m^2$. The container was sealed with a cover and LR-115 type-II plastic track detectors (3 cm x 4 cm) were fixed at the top inner surface [4]. The detectors were exposed for a period of about four months to get equilibrium between radium and radon progeny. The detectors were retrieved and etched in 2.5 N NaOH solution at a temperature of 65 ± 1 ℃ for one hour and half in a constant temperature water bath to reveal the tracks. Then, the detectors were steeped in distilled water for 15 min and dried with fresh air. Resulting alpha tracks were scanned under an optical microscope at a magnification of 400X to determine the track density [5].

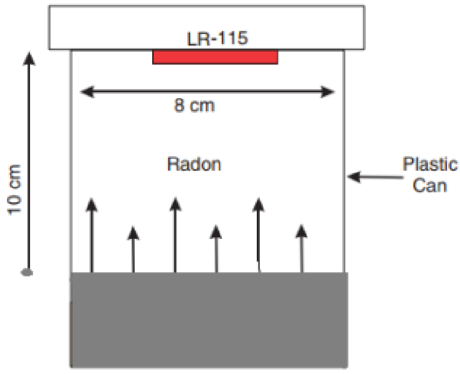


***Figure 2.*** *Experimental setup for measuring radium content and radon exhalation rates in soil samples.*

The effective radium content of the soil samples can be calculated in ($Bq.kg^{-1}$) using the relation [6].

$$C_{Ra}(Bq.Kg^{-1}) = \frac{\rho h A}{K T_e M}$$

Where: $C_{Ra}$ is the effective radium content of the sample in ($Bq\ kg^{-1}$), ρ is corrected track density, A is the surface area from which radon is exhaled ($m^2$) and M is the mass of the sample (kg), h is the distance between the top of the soil sample and the detector in meter, K (0.0245 tracks $cm^{-2}d^{-1}$ per $Bqm^{-3}$) is the sensitivity factor of the materialandTe is the effective exposure time [7].

The effective exposure time (Te) is given by the relation,

$$T_e = [T - \lambda^{-1}{}_{Rn}(1 - e^{-\lambda_{Rn}T})],$$

Where T is the exposure time and λ is the radon decay constant.

The mass exhalation rate and the surface exhalation rate of the soil sample for release of radon can be calculated by using the equation [6].

$$E_x(M)(Bq.Kg^{-1}.d^{-1}) = C_{Ra}\left(\frac{\lambda_{Ra}}{\lambda_{Rn}}\right)\frac{1}{T_e},$$

And $E_x(S)(Bq.m^{-2}.d^{-1}) = E_x(M)\left(\frac{M}{A}\right)$

Where $\lambda_{Ra}$ is decay constant for Radium ($^{226}Ra$) and $\lambda_{Rn}$ is decay constant for Radon ($^{222}Rn$).

## 4. Results and Discussion

The measured values of effective radium content and radon exhalation rates in soil samples collected from the study area are presented in the table below.

***Table 1****. The value of calculated track density (ρ), effective radium content, and radon exhalation rates in soil samples collected from selected districts in Adigrat.*

| DetectorCodes | Corrected trackden-sity ρ (tracks.cm$^{-2}$) | Effective Radium Content (Bq.kg$^{-1}$) | Radon Mass Exhalation rates (Bq.kg$^{-1}$d$^{-1}$) Ex (M) ×10$^{-6}$ | Radon Exhalation rate per unit area (Bq.m$^{-2}$d$^{-1}$) Ex (S) ×10$^{-4}$ |
|---|---|---|---|---|
| A-1 | 33,341.67 | 33.34 | 3.33 | 1.67 |
| A-2 | 32,333.33 | 32.33 | 3.23 | 1.62 |
| A-3 | 28,541.67 | 28.54 | 2.85 | 1.43 |
| A-4 | 32,686.67 | 32.69 | 3.27 | 1.64 |
| A-5 | 25,258.67 | 25.26 | 2.53 | 1.27 |
| A-6 | 24,536.67 | 24.54 | 2.45 | 1.23 |
| A-7 | 16,106.67 | 16.11 | 1.61 | 0.81 |
| A-8 | 25,458.33 | 25.49 | 2.55 | 1.28 |
| A-9 | 23,533.33 | 23.53 | 2.35 | 1.18 |
| A-10 | 34,240.67 | 34.24 | 3.42 | 1.71 |
| A-11 | 27,575.42 | 27.58 | 2.76 | 1.38 |
| A-12 | 21,672.17 | 21.67 | 2.17 | 1.09 |
| A-13 | 17,072.08 | 17.07 | 1.71 | 0.86 |
| A-14 | 20,855.17 | 20.86 | 2.09 | 1.05 |
| A-15 | 18,383.33 | 18.38 | 1.84 | 0.92 |
| A-16 | 33,300.67 | 33.30 | 3.33 | 1.67 |
| Min. | 16,106.67 | 16.11 | 1.61 | 0.81 |
| Max. | 34,240.67 | 34.24 | 3.42 | 1.71 |
| Mean | 25,930.78 | 25.93 | 2.59 | 1.30 |
| SD | 6102.81 | 6.10 | 0.61 | 0.30 |

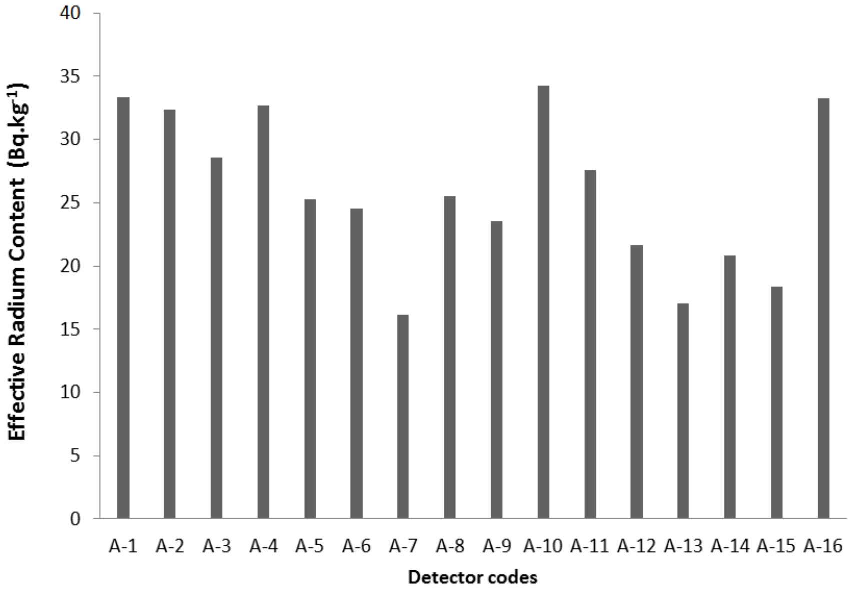


***Figure 3.*** *Radium concentration of the soil samples collected from the study area.*

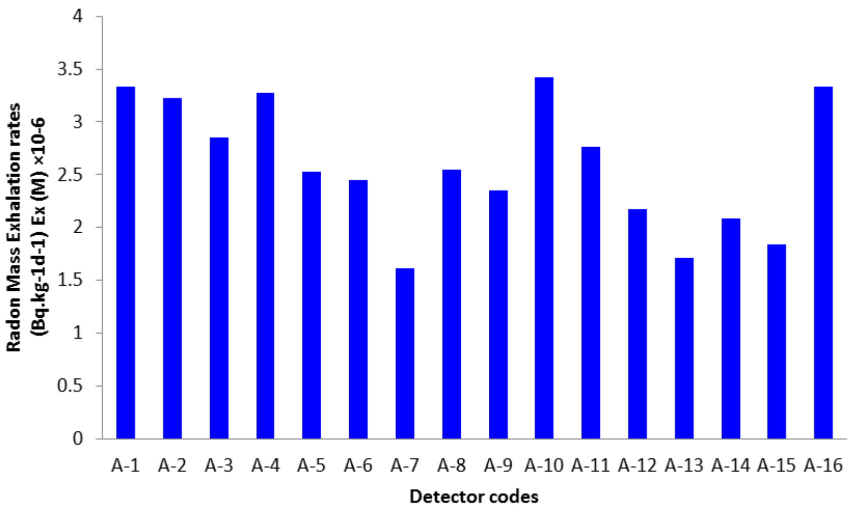


***Figure 4.*** *Radon Mass Exhalation rates of the study area.*

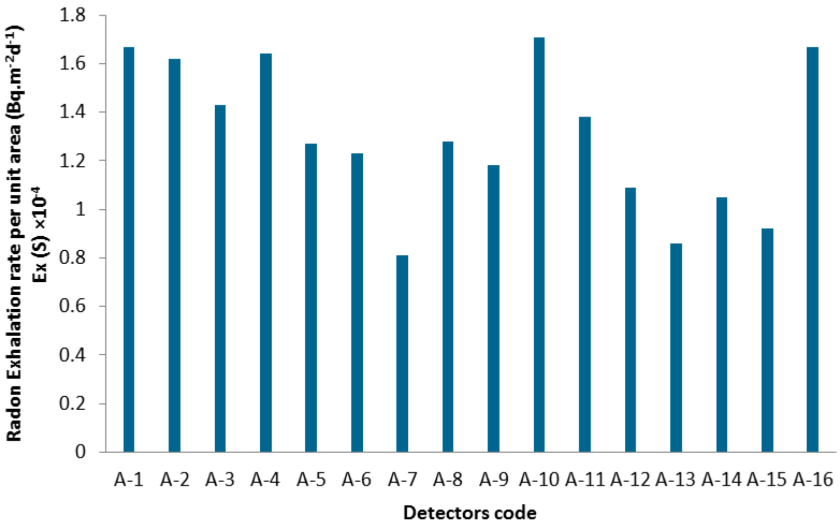


***Figure 5.*** *Radon Exhalation rates per unit area of the study area.*

The effective radium content in soil samples have been found to vary from from16.11Bq/kg to 34.24 Bq/kg with an average value of 25.93 Bq/kg and a standard deviation of 6.10. The mass exhalation rate has been found to vary from $1.61x10^{-6}$Bq $kg^{-1}$ $d^{-1}$ to 3.42 $x10^{-6}$Bq $kg^{-1}$ $d^{-1}$ with a mean value of 2.59 $x10^{-6}$Bq $kg^{-1}$ $d^{-1}$ and a standard deviation of 0.61 while the surface exhalation rate has been found to vary from $0.81x10^{-4}$Bq $m^{-2}$ $d^{-1}$ to $1.71x10^{-4}$Bq $m^{-2}$ $d^{-1}$ with a mean value of $1.3x10^{-4}$Bq $m^{-2}$ $d^{-1}$ and a standard deviation of 0.3. The values of radium content were found lower than the permissible value of 370 Bq/ kg recommended by Organization for Economic Cooperation and Development (OECD) [8] and UNSCEAR [9]. It has been observed that there are variations in the values of radon exhalation rates among the soil samples. This variation may be arisen due to the difference in the type of the soil samples and radium content of the samples as radium is present in varying amounts all over the world [10]. This research holds significance as it marks the first time that we have conducted measurements in this area to determine the radiation levels in the environment.

## 5. Conclusion

It is clear that, beyond the necessity for well-educated and trained individuals managing radiation sources, there is a need to educate the general public about the fundamental principles of radiation protection. This knowledge is crucial for people to accurately evaluate and understand the associated risks in comparison to other everyday risks encountered in both personal and professional settings. The results of the present study show that the effective radium content, radon exhalation rates varied significantly among the soil samples. The variations could be attributed to the high radium levels in the samples, as well as the geological features of the areas under study. The values of radium content and radon exhalation rate are found under the safe limit recommended by Organization for Economic Cooperation and Development. Hence, it can be concluded that the examined region is free from radium-related health hazards, given the negligible radon exhalation, which poses no significant risk. Additionally, a positive correlation has been identified among the radium content, area exhalation rate, and mass exhalation rate in the soil.

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This acknowledgment reflects the collaborative spirit fostered by both the community and the academic institution, highlighting the significance of collective efforts in advancing scientific inquiry and knowledge.

## Conflicts of Interest

The authors declare no conflicts of interests.

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