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Studying the Efficiency Dependence of CR-39 Detector on the Chamber Height

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Abstract:

The response of CR-39 plastic detector was computed practically taking into account the most significant parameter of chamber height that effect on efficiency of CR-39. The aim of this project is to calculate the sensitivity of a CR-39 detector in a diffusion chamber for radon measurements using various chamber heights like, (10, 15, 20, 25 and 30) cm. The obtained results revealed that the CR-39 detector's response for the chamber height of (10) cm is about 2 or 3 times higher than that of (15, 20, 25 and 30) cm, this is due to at the small height the concentrations of thoron (^{220}Rn) will be mixing with the concentration of ^{222}Rn.

Keywords:

Radon, CR-39, Plastic Detector, Efficiency, Chamber Height.

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INTRODUCTION

Radon consists of three isotopes, namely: ^{222}Rn (called radon, belongs to ^{238}U decay series) with half- life 3.82 days; ^{220}Rn (called thoron, belongs to ^{232}Th decay series) with 55.6 sec half-life and ^{219}Rn (called actinon, belongs to ^{235}U decay series) also with halflife 3.96 sec. ^{222}Rn has a much longer half-life than ^{220}Rn and ^{219}Rn [1]. As a result, environmental studies place less emphasis on ^{220}Rn and ^{219}Rn. The most common isotope of the element radon is ^{222}Rn, scientifically. Three types of alpha particles are released in the ^{222}Rn decay chain: namely, the alpha particles with energies of 5.49 MeV from ^{222}Rn, with energies of 6 MeV from ^{218}Po and those with energies of 7.69 MeV from ^{214}Po [2].

Radon (^{222}Rn), a noble gas, plays an important function in transmitting natural radioactivity from one location to another. It interrupts the natural decay cycle and, depending on the environment, transports its progenies to a new place. It does not diffuse to the upper atmospheric strata due to its high mass density. At high concentrations, radon radioactivity can be harmful to humans. It is thought to be the second cause of lung cancer [3,4].

Detectors are normally housed in a cup that is sealed with a permeable material, such as filter paper, to enable radon diffusion while preventing radon progeny, dust, and humidity from entering the chamber. A "diffusion chamber," "cup," or "radon dosimeter" are common names for such instruments [5-7].

Since the radon daughters are unable to escape the diffusion chamber, their activities become equal because the radioactive equilibrium occurs within the chamber, but their activities in the chamber air are not equal due to the plate-out effect. The accumulation of radon daughter atoms occurs on the chamber's inner wall surfaces as well as the detector itself. The detector exposure geometry changes because of the deposition, and the detector responses, as well as the track density and calibration factor, change [8].

The detectors and instruments used to calculate efficiencies are influenced by a variety of factors, including instrumentation characteristics, radiation types and energies, and sample properties. A good understanding of the properties of nuclear radiation, as well as the mechanisms of radiation interaction with matter, is needed for the radiation detector or method of radioactivity analysis, half-life, decay schemes, decay abundances, and energies of decay [9,10]

Experimental Method

The CR-39 (solid state nuclear track detector) is a polymer that detects energetic charged particles like alpha particles. The development of latent tracks is caused by the interaction of energetic particles with the polymer. Chemical etching of the polymer will create these latent tracks. The efficiency of etching CR-39 using alcohol/water solutions of sodium hydroxide was investigated in this study, and the five-dimensional height form of these dosimeters was calculated using this technique. CR-39 sheets with a surface area of (25 x 30) cm and a thickness of 0.5 mm were cut into small detectors with an area of 1 cm x 1.5 cm each. Each chamber was exposed for 60 days with a sample of soil as an alpha particle source. The CR-39 detectors were etched in 6.25 Normal NaOH at 70 C° for 6 hours after exposure, and the track density was measured with an optical microscope [10].

Radon concentration measurement:

This relationship can be used to measure the concentrations of ^{222}Rn in the air of tubes containing soil samples using CR-39 detector [11,12]:

$$C_a = \rho / \eta T \qquad \text{------------- (1)}$$

Where ρ is the track density (Tr/cm^2) on the exposed CR-39 detector

T is the duration of the samples' exposure (60 days) η is the diffusion factor (0.05774 $Tr/cm^2/d$ observed per Bq/m^3)

Then (η) is derived from this relationship using the tube's dimensions [10]:

$$\eta = \frac{1}{4} r \left(2 \cos \theta_t - \frac{r}{R_\alpha}\right) \qquad \text{--------------- (2)}$$

where r - The diffusion volume's tube radius (3.6 cm)

θ_t - The CR-39 detector's threshold angle (35°) [10] R_α - particle range in air from Rn

R_α can be derived from this relationship [13]:

$$R_\alpha = (0.005\, E_\alpha + 0.285)\, E_\alpha^{3/2} \qquad \text{----------------- (3)}$$

$= 4.019$ cm (for energy $E_\alpha = 5.49$ MeV)

According to the dimensions of the present system, the diffusion factor (η) equals (0.057744) $Tr.cm^{-2}.\ d^{-1} / Bq\ .\ m^{-3}$

The following equation can be used to measure ^{222}Rn concentration in samples: [12]:

$$C_s = \frac{\lambda_{Rn} C_a H T}{L} \qquad \text{------------------- (4)}$$

Where C_s - The concentration of ^{222}Rn in the samples (Bq\m^3)

C_a – ^{222}Rn concentration in air space inside the tube (Bq\m^3)

λ_{Rn} - Decay constant of ^{222}Rn (0.1814 day^{-1}) H – Height of air space in the tube.

L – Thickness of the sample in the tube (3cm).

T - Time of irradiation (60 days).

Result and Discussion:

The study of efficiency of CR-39 detector dependence on the chamber height, therefore, different height of the chambers was used in this study like (10, 15, 20, 25 and 30) cm, as shown in Fig. (1)

Fig. (1) Tubes at different height with their backgrounds.

by using equations (1) and (4) to calculate the concentrations of radon for the same soil samples and tabulated the results in Table (1):

Table (1) Radon concentrations for using different tubes

Length of Tube(cm)	ρ(Track/cm²)	Ca (Bq/m³)	Cs (Bq/m³)
10	18335.808	5292.635 ± 36.076	192016.797 ± 1417.944
15	6476.640	1869.483 ± 21.441	101737.24 ± 1264.081
20	4496.635	1297.954 ± 17.268	94179.542 ± 1121.431
25	3207.39	925.813 ± 14.459	83971.239 ± 924.368
30	2547.045	705.205 ± 12.086	80019.712 ± 815.038

Table 1 shows the effect of chamber height (h) on the CR-39's response to determine the radon concentrations of the same samples of soil. When the radius is constant, the response of the detector decreases as the chamber height increases from 10 cm to 30 cm, it's true for radon concentrations in side of the different tubes, this is due to the mixing of the concentration of thoron with the ^{222}Rn at the height of (10) cm but for the other height of the tube approximately are identical until 30 cm, after which the concentrations decrease as the height of the chambers increases and show the inversely proportional between them, as shown in these figures (2,3 and 4), which clarify the chart of height impact on track density and ^{222}Rn concentrations in the air within the chambers with ^{222}Rn concentrations in the soil samples.

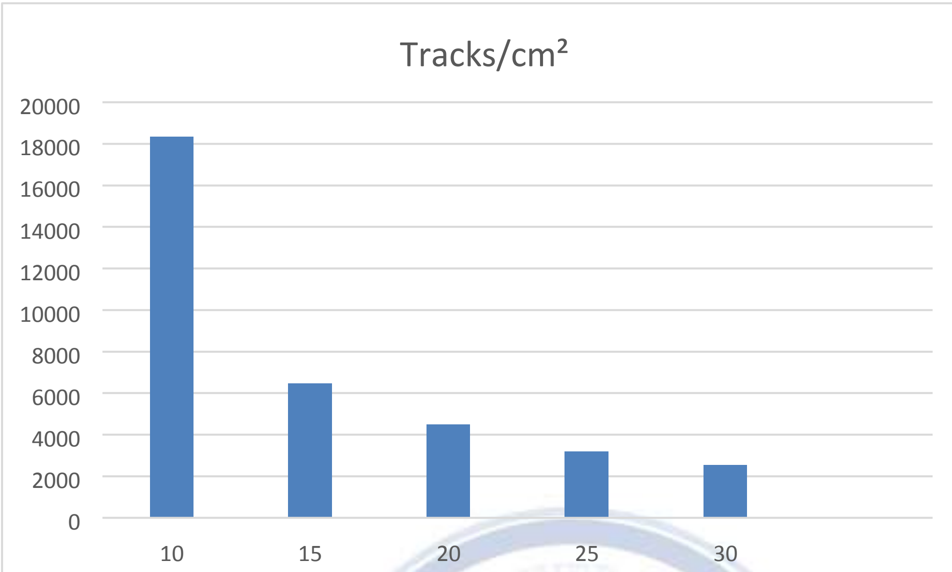

Fig. (2) The density of track/cm^2 on the CR-39 according to the height of chambers

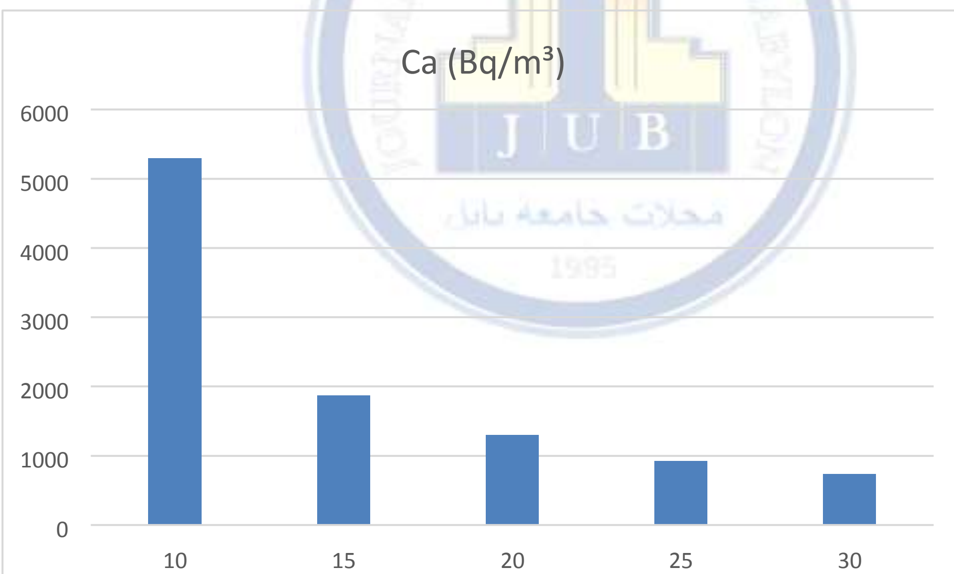

Fig. (3) The concentrations of ^{222}Rn inside the tube according to the height of chambers.

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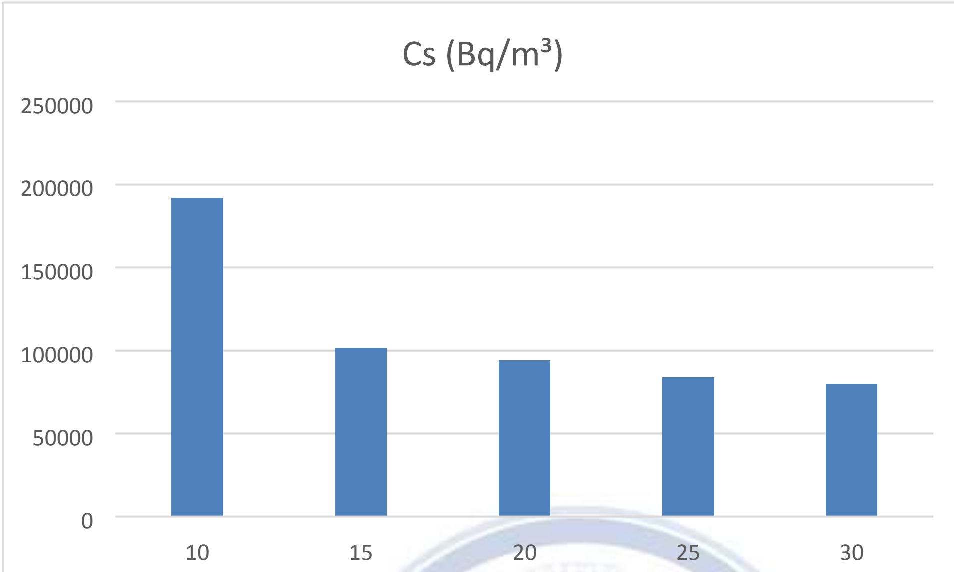

Fig. (4) The concentrations of ^{222}Rn in the soil samples according to the height of chambers.

The figures (2 and 3) are clearly identical because the radon atoms are present in the chamber air 100% of the time, but Fig.4 generally, has the same similarity with increasing of concentrations of radon this is due to the daughter atoms are partly deposited on the wall of the inner tube, as a result, the exposure geometry and detector reaction are change by this deposition which cause to change the track density and then the concentrations of radon increases by comparing with that of the air inside the tube of chambers, but generally we obtained that the chamber height at distance of 10 cm does not appropriate to measure the concentration of ^{222}Rn alone due to mixing with the concentration of thoron.

Conclusion:

In this study we conclude that the chamber height has an effect on response and efficiency of CR-39 (plastic detector) which was used to detecting radon concentration through measuring the track of the α-particles on the CR-39 film, specially at the height of 10 cm of the chamber the concentration of radon was higher than that of the other chamber height such (15, 20, 25 and 30) cm this is due to mixing the concentration of radon with the concentration of thoron at this distance and we conclude that the height of 30 cm is the most appropriate to measure the concentration of ^{222}Rn from the soil samples.

Conflict of interests.

There are non-conflicts of interest.

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