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Radon Emanation Coefficients of Some Egyptian Rocks

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Abstract: Thirty three samples were collected from four different areas at the Southeastern Desert of Egypt to estimate the values of the radon emanation coefficient of the rocks at these areas. The chosen areas are; Abu Dabbab, Abu Rusheid, Nuweibi and Um Naggat. CR-39 SSNTD fixed at the top of a radon chamber with the crushed sample at the bottom was employed to achieve this work. The results averaged the values of the emanation coefficient into two categories; one includes the rocks from Abu Dabbab and Nuweibi with a value of 0.027 and the other with a value of 0.008. The difference in the values of the emanation coefficient may be ascribed to the difference in the other properties of the rock grains. However, the isolation of these parameters may reveal experimentally a reciprocal relationship between the emanation coefficient and the radium activity in the rocks.
Keywords: Radon gas; Emanation Coefficient; SSNTDs.

1 Introduction

Not all of the radon atoms generated by the radium contained in a rock or soil grain are actually released into pore spaces and mobilized. One of three things canhappen to a radon atom after it is released by decay of a radium atom: (1) it may travel a short distance and remain embedded in the same grain; (2) it can travel across a pore space and become embedded in an adjacent grain; or (3) it is released into a pore space. The fraction of radon atoms released into a rock or soil pore space from a radium-bearing grain is termed the "radon emanation coefficient," emanating power", or "escape-to-production ratio" of the soil. The radon emanation coefficient of typical rocks and soils ranges from about 0.05 to 0.70 [1], and it has been suggested that an average value for most soils may be about 0.22 [2]. However, it is likely that soils derived from similar parent rocks in different regions may have significantly different emanation coefficients due to the effects of climate on the development of soils from their parent geologic materials. An understanding of these processes is essential to the development of accurate and useful predictive models for radon availability from rocks and soils.

The process of soil formation involves physical, chemical, and biological interactions with the air and water that pass through the soil, commonly resulting in the formation of different chemical compounds than those that existed in the parent material. Parent material composition (mineralogy and chemistry) determines not only the initial amount and distribution of radionuclides in the rock, but also the radon emanating power and transport characteristics. As a rock or a soil develops, it gets its characteristics including grain size and shape, the siting of radon parent nuclides within soil grains, and moisture conditions.

When a radium atom decays to radon, the energy generated is strong enough to send the radon atom a distance of about 40 nm-this is known as alpha recoil [3]. For a radon atom to escape a grain, then, the radium atom must be within the recoil distance of the grain surface (which varies somewhat depending on the density of the material) and the direction of recoil must send the radon atom toward the outside of the grain. Grain size and shape are two of the important factors that control the rock's emanation coefficient because they determine in part how much uranium and radium is near enough to the surface of the grain to allow the newly formed radon to escape into a pore space. The specific surface area (surface area-to-volume ratio) of the grains generally increases as grain size decreases, and it is also controlled by grain shape, so that a clay particle, with its small size and platy shape, would have a higher specific surface area, and thus, a higher emanation coefficient, than a larger or more spherical grain with the same radium content. If radium is uniformly distributed throughout the soil or mineral grains, the radon emanation coefficient is inversely proportional to the radius, i.e., grain size

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[4,5]Expressed in other terms, the radon emanation coefficient increases linearly with increasing specific surface area[6].
Radon chambers are employed to study the radon emanation and diffusion from different rocks. The principle is to enclose the studied rock in a suitable space with a calibrated radon monitor [7-10] Several Egyptian areas are subjected to many mineralogical and development studies. These areas are Um Naggat, Abu Dabbab, Nuweibi and Abu Rusheid at the Southeastern Desert[11,14], Fig. (1).

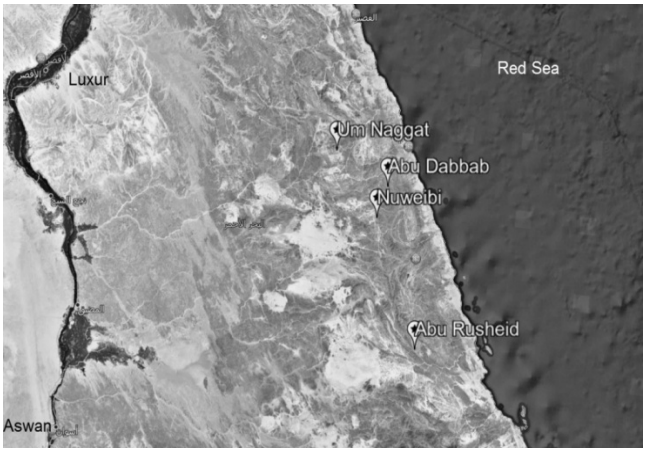

Fig.1: Locations of the chosen four areas at the Southeastern Desert, Egypt, Googleearth [15].

The high radium content in the rocks at the mentioned areas necessitates the evaluation of radon gas emanation and diffusion during the probable activities of the occupational individuals and public members[16]. In this study, it is intended to estimate the radon emanation coefficient of the rocks from the four areas Abu Dabbab, Abu Rusheid, Um Naggat and Nuweibi using can technique or radon chamber.

2 Experimental Methods

A number of rock samples were collected from each of the studied area which sums 33 samples. Previously, these samples were crushed and sieved to obtain samples of the grain size 300 µm while each sample was weighted and canned in a plastic container to measure the specific activity of the radionuclides; ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K using a HPGe spectrometer[16].
For this study, each sample, after investigated under HPGe spectrometer, was placed at the bottom of a cylindrical emanation chamber (3 liter plastic jar), which was then closed and sealed tightly with the inside surface of its cap was fixed a CR-39 plastic detector (1cmx1cm). This detector registers the α-particles emitted from the surrounding nuclides of radon gas and its decay products, Fig. (2). The height of the cap is enough to avoid registering α-particles emitted from thoron gas. The dimensions of the plastic jar assume that the mode of exposure of the CR-39 detector to radon gas is a bare one such that the radon decay products plated out on the inner surface of the jar cannot be detected. After one month, the detectors were taken out, etched (6.25 *N*NaOH at 70°C for 8h) and counted using an optical microscope at 400x magnification for alpha particle tracks under standard conditions [17].

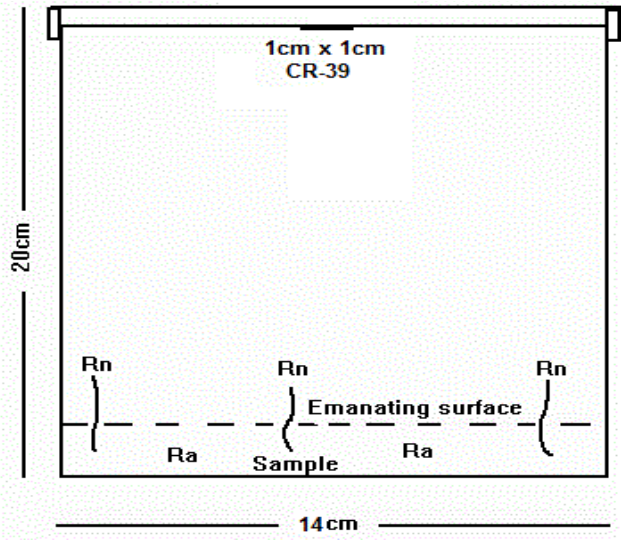

Fig. 2: Configuration of the radon emanation chamber.

The emanation coefficient f of the rock sample inside the jar is calculated as follows[18]:

$$f = VC/A_{Ra} \quad (1)$$

where

f= emanation coefficient, dimensionless,
V=volume of the jar (m^3),
C=radon concentration inside the jar (Bq/m^3),
A_{Ra}=radium activity in the sample (Bq)[16].

Radon concentration inside the jar is calculated according to the formula[19]:

$$C=\rho/(T_e \cdot K) \quad (2)$$

Accordingly, the emanation coefficient f is:

$$f=[V/(T_e \cdot K)] \cdot (\rho/A_{Ra}) \quad (3)$$

where
T_e=the effective exposure time (d),
K=calibration factor for the bare mode CR-39 detector (=0.5126 tracks.cm^{-2}.d^{-1}.(Bq.m^{-3})$^{-1}$)[17].
ρ =track density on the CR-39 detector (tracks.cm^{-2}).

The effective time T_e is calculated as follows[20] .

$$T_e=T-1/\lambda\,(1-e^{-\lambda T}) \quad (4)$$

where

T=the actual exposure time (=30d),

λ =decay constant of radon gas (d^{-1}).

3 Results and Discussion

The term in the rectangular brackets in Equation (3) includes three constants; V, T_e and K. So, in order to obtain the value of the emanation coefficient f for each of the studied sample, the relation between the track density ρ and the radium activity A_{Ra} should be studied.

Table (1) represents the values A_{Ra} and ρ for 33 samples collected from the rocks at Abu Dabbab, UmNaggat, Abu Rusheid and Nuweibi at the Southeastern Desert of Egypt. In general, Table (1) shows that the variation of the average values of the track density ρ responded well to the variation of the average values of the radium activity A_{Ra}. This proportionality is clarified in Fig. (3).

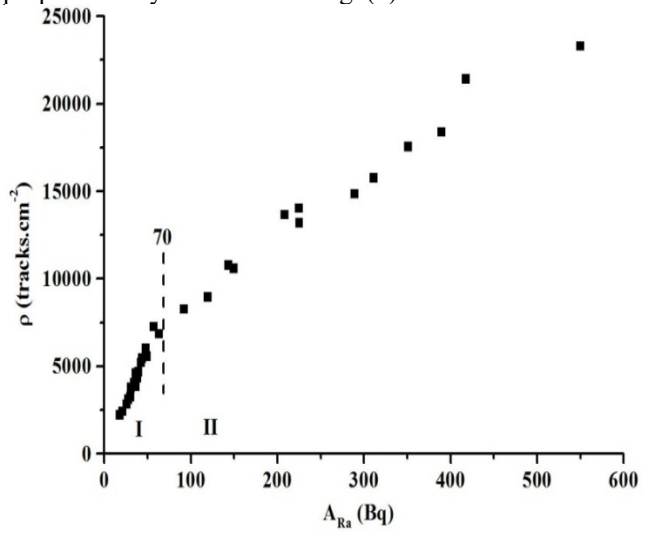

Fig. 3: Variation of the track density ρ on the CR-39 detectors with the radium activity A_{Ra} in the rock samples collected from four areas at the Southeastern Desert, Egypt,.

On the other hand, Fig. (3) shows that the data representing the relation between ρ and A_{Ra} are distributed over two distinct regions. The first region covers the radium activity up to 70 (Bq) which includes the samples collected from the areas at Abu Dabbab and Nuweibi. The second region covers the radium activity above 70 (Bq) which includes the samples collected from the areas at Um Naggat and Abu Rusheid.

Fig. (4) represents the relation between ρ and A_{Ra} for the samples collected from Abu Dabbab and Nuweibi. The figure fits the data in a straight line with a good correlation between ρ and A_{Ra}. The slope of the line equals the average value of (ρ/A_{Ra}). Substituting this value in Equation (3) yields the average value of the emanation coefficient f for the rocks at Abu Dabbab and Nuweibi to be 0.027±0.0015. Similarly, Fig. (5) shows the good correlation between ρ and A_{Ra} for the samples collected from Um Naggat and Abu Ruheid. The value of the slope of the straight line in the figure is substituted in Equation (3) to obtain the average value of the emanation coefficient f for the rocks at Um Naggat and Abu Rusheid to be 0.008±0.00035.

However, the value of the emanation coefficient is dependent on the distance travelled to the grain surface by the newly produced radon nucleus. This distance depends on the density of the bulk material of the grain and the hardness of this material[4,5]. Also, the emanation coefficient depends on the size (radius) of the grain[6]. All these factors may explain the tremendous variation in the values off as represented in Table (2). Table (2) indicates the difference in the values of the emanation coefficient for different rock types.

Equation (3) represents a clear inverse proportionality between the emanation coefficient f and the radium activity A_{Ra}. This trend is consistent with the results obtained by this study as shown in Table (2). Also, Table (2) shows that the minimum value of the radium specific activity, ^{226}Ra (~20Bq/kg), resulted in the maximum value of the emanation coefficient (> 25%). Indeed, this study estimated the values of the emanation coefficient f for the same grain size of all the studied rocks. This concludes that the isolation of the parameters that affect the emanation of radon gas from the rock grain may lead to an experimental concrete reciprocal relation between the emanation coefficient and the radium activity as described by Equation (3).

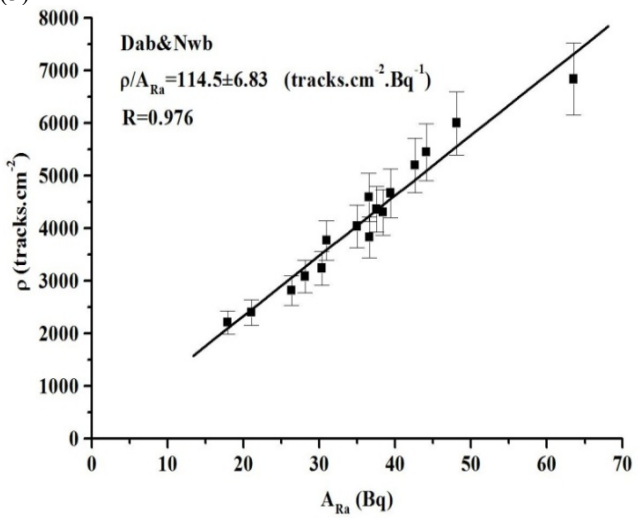

Fig. 4: Regression of the track density ρ on the radium activity A_{Ra} for the samples from Abu Dabbab and Nuweibi areas. Data are fitted as straight line with a good correlation.

Table 1: Radium activity A_{Ra} and the track density ρ for the rock samples collected from different four areas at the Southeastern Desert, Egypt.

No.	A_{Ra} (Bq)[16]	ρ (tracks.cm^{-2})	No.	A_{Ra} (Bq)[16]	ρ (tracks.cm^{-2})
Abu Dabbab			**Um Naggat**		
1	39.41	4.7E+03±7.1E+02	1	351.1	1.8E+04±2.2E+03
2	34.98	4.0E+03±5.3E+02	2	311.3	1.6E+04±2.0E+03
3	36.53	4.6E+03±7.3E+02	3	208.6	1.4E+04±1.4E+03
4	48.11	6.0E+03±8.4E+02	4	143.5	1.1E+04±1.4E+03
5	42.64	5.2E+03±7.7E+02	5	417.7	2.1E+04±1.8E+03
6	37.56	4.4E+03±6.7E+02	6	57.19	7.2E+03±1.0E+03
7	63.54	6.8E+03±9.6E+02	7	229.3	1.3E+04±1.3E+03
			8	49.24	5.5E+03±8.1E+02
Ave.	**43.25**	**5.1E+03±7.4E+02**	**Ave.**	**221.0**	**1.32E+4±1.5E+03**
Abu Rusheid			**Nuweibi**		
1	92.35	8.2E+03±9.2E+02	1	38.39	4.3E+03±6.8E+02
2	119.8	8.9E+03±1.1E+03	2	36.61	3.8E+03±5.7E+02
3	225.3	1.4E+04±1.8E+03	3	44.10	5.4E+03±7.6E+02
4	149.8	1.1E+04±1.5E+03	4	30.94	3.8E+03±5.5E+02
5	550.2	2.3E+04±3.1E+03	5	30.32	3.2E+03±4.8E+02
6	389.9	1.8E+04±2.2E+03	6	26.32	2.8E+03±3.6E+02
7	222.1	1.5E+04±1.6E+03	7	21.07	2.4E+03±3.7E+02
8	225.4	1.3E+04±9.0E+02	8	17.90	2.2E+03±2.8E+02
9	289.5	1.5E+04±1.9E+03	9	28.14	3.1E+03±4.3E+02
Ave.	**251.6**	**1.40E+4±1.7E+03**	**Ave.**	**30.42**	**3.44E+3±5.0E+02**

Table 2: Radium content and the emanation coefficient of different rocks.

Description (Ore/Rocks) Origin	**^{226}Ra (Bq/kg)**	**Emanation coefficient f**		**Reference**
		Fraction	**%**	
Italy ore	3500	0.0097	0.97	(21)
Al Missikat, Egypt	500	0.046±0.008	4.6	(22)
Al Aradiya, Egypt	495	0.023±0.004	2.3	(22)
Abu Dabbab, Egypt	105.8	0.027±0.015	2.7	This study
Nuweibi, Egypt	74.75	0.027±0.015	2.7	This study
Abu Rusheid, Egypt	578	0.008±0.0004	0.8	This study
Um Naggat, Egypt	520	0.008±0.0004	0.8	This study
Non-uranium ore	~20		>25	(21)
Precambrian rocks	~20		>25	(21)
Vermont schist rock	~20		>25	(21)
Matineda quartzite rock	~20		>25	(21)

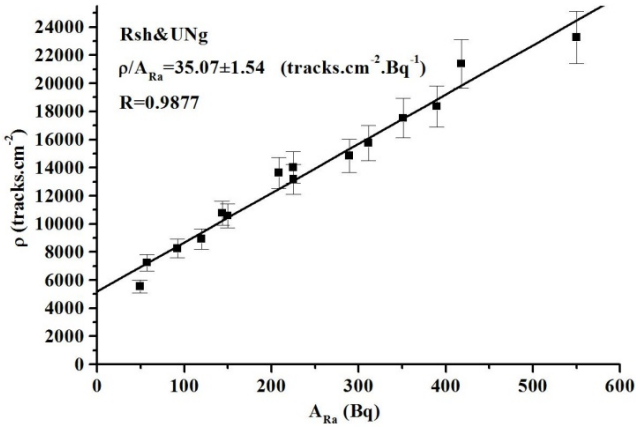

Fig. 5: Regression of the track density ρ on the radium activity A_{Ra} for the samples from Abu-Rusheid and Um Naggat areas. Data are fitted as straight line with a good correlation.

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