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Radon Emanation Coefficient of Some Egyptian Stream Sediments and Updating Radon Emanation Model

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Abstract: The emanation coefficient of radon gas from some Egyptian stream sediments was estimated using Can-Technique. Nineteen samples were collected from three areas at Egypt; Baltim at the Northern coast and Wadi Nugrus and Wadi Rimarim at the Southeastern Desert. The average value of the emanation coefficient of the studied sediments was 0.29±0.04. Previous data showed that the emanation coefficient of radon gas decreases with the increase in the activity concentration of radium. This study fitted the data in a formula containing the reciprocal of the radium activity concentration and accordingly updated the process model of radon emanation.

Keywords: Radon emanation, activity concentration. Can-Technique, radium, emanation process.

1 Introduction

In his 1556 textbook on mining, De Re Metallica (On Metal Matters), Gregorius Agricola described a wasting disease of miners in the Erzeberge (Ore Mountains) of Germany that “eats away the lungs … and plants consumption in the body.” Three centuries later, German scientists identified this miners' disease as lung cancer [1].
Radium was discovered by Marie and Pierre Curie in 1889; the following year, the German physicist Ernst Frederick Dorn demonstrated that radium emitted a radioactive gas, “radon emanation” (later, simply “radon”) [2]. Epidemiologic studies of radon and lung cancer conducted among miners in the 1950s confirmed Agricola's recognition of lung cancer as an occupational disease. The recognition that ra
don levels in some homes approximated those in mines led to epidemiologic studies of residential radon and lung cancer. These established radon as a cause of lung cancer in the general population, second in importance only to smoking, where it accounts for approximately 21,000 deaths per year in the U.S. [3].
We now know that radon is an odorless, invisible gas that results from the natural decay of uranium and thoron in soil and rock. The gas enters homes through cracks in the foundation, where it can be trapped inside, especially during winter months when homes are sealed.Because it is water soluble, well-water can be a source of residential radon; however, most of the exposure of the general population to radon is via soil gases [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 [7-12]. Several Egyptian areas are subjected to many mineralogical and development studies. These areas are Baltim at the Northern coast and Wadi Nugrus and Wadi Rimarim at the Southeastern Desert [13-15].

2 Materials and Methods

Locations of the chosen samples from the stream sediments are described elsewhere [13]. Also, the activity concentration of radium of each sample was determined previously [13]. To estimate the radon emanation coefficient from the studied samples, Can Technique was employed [16,17]. The dried samples from different locations were sieved through a 100 mesh sieve. The fine powder, about 400g of the sample was placed at the bottom of a cylindrical emanation chamber (7 liter plastic bucket), which was then closed for a period of one month in order to get equilibrium between the activity concentration of radium and that of radon. After 30d, CN-85 plastic detector (1cmx1cm) which was previously fixed by adhesive tape to the inside surface of the bucket cap and covered with a cardboard, is set free using a string passing through the cap to register α-particles emitted from the surrounding

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nuclides of radon gas and its decay products, Figure (1). The detector is hanged at a certain distance (about 15 cm) from the surface of the material to avoid registering α-particles emitted from thoron gas. The equilibrium inside the bucket had been kept and the detector is exposed for 30d. After the second month, the detectors were taken out, etched (2.5 N NaOH at 60°C for 3h) and counted using an optical microscope at 400x magnification for alpha particle tracks under standard conditZions [18].

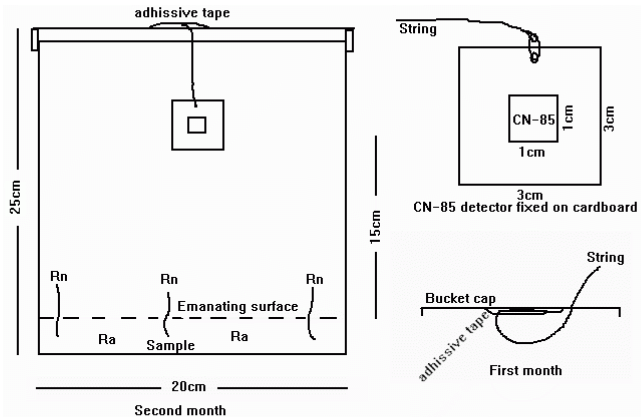

Fig. 1: Configuration of the radon emanation chamber [15].

The emanation coefficient f of each sample was calculated using the formula [19]:

$$f = V \cdot C / (M \cdot {}^{226}Ra) \quad (1)$$

where
f=emanation coefficient of radon (dimensionless),
V=effective volume of the air inside the bucket (m^3),
C=radon gas concentration inside the bucket (Bq/m^3),
M=mass of the sample (kg),
^{226}Ra=samX ple radium activity concentration (Bq/kg).
XC
While radon gas concentration C inside the bucket is
X+Z
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$$C = \rho / K \quad (2)$$

where
C=radon gas concentration inside the bucket (Bq/m^3),
ρ=track density per day on the surface of CN-85 detector ($tracks.cm^{-2}.d^{-1}$),
K=calibration factor of CN-85 detector (0.2838 $tracks.cm^{-2}.d^{-1}.(Bq.m^{-3})^{-1}$) [18].

3 Results and Discussion

3.1 Emanation Coefficient of the Studied Sediments

Radon emanation coefficient increases linearly with increasing specific surface area [6]. However, this study sieved the studied samples at 100mesh to obtain the grain size 300μm. On another hand emanation of radon depends on the radium activity concentration in the grain material as illustrated by Equation (1). Table (1) represents the values of the emanation coefficient f obtained for each sample from the studied areas at Baltim, Wadi Nugrus and Wadi Rimarim.

Table 1: Activity concentration ^{226}Ra, track density per day ρ and emanation coefficient f for nineteen samples collected from Baltim, Wadi Nugrus and Wadi Rimarim.

Sample code	^{226}Ra (Bq/kg)	ρ ($tracks.cm^{-2}.d^{-1}$)	f
Baltim			
1	44.4	164.03	0.23
5	11.1	46.11	0.26
7	11.1	58.93	0.34
8	22.2	123.04	0.35
9	22.2	87.14	0.25
18	11.1	52.28	0.30
Wadi Nugrus			
1	33.3	135.34	0.26
2	22.2	113.78	0.33
3	22.2	99.44	0.28
4	22.2	91.23	0.26
5	22.2	118.91	0.34
6	55.5	279.37	0.32
7	44.4	180.41	0.26
8	22.2	119.95	0.34
9	22.2	92.27	0.26
Wadi Rimarim			
R5	11.1	59.98	0.34
R6	11.1	44.59	0.26
R7	11.1	56.89	0.33
R8	22.2	78.93	0.23
Average	**23.37**	**108.4**	**0.29**

From the table, f for the studied sediments got values in the range 0.23-0.35 with an average of 0.29±0.04.

3.2 Fitting the Data about the Emanation Coefficient

Ishimori and others stressed that the emanation coefficient of each rock type should be measured experimentally due to the different physical properties of the rock materials like porosity and hardness apart from the radium content [19]. However, the author of this study believes that in many situations urgent knowledge about the physical properties of radon source should be available in order to intervene or take action. This necessitates the establishment of a mathematical relation between the emanation coefficient of material of radon source and the radium content at constant values of the other properties. Table 2 represents the value of the emanation coefficient resulted in this study along with the data from previous works carried out almost at grain size 300µm.

Table 2: Radium activity concentration ^{226}Ra and Emanation coefficient f of some rock types.

Rock description	**^{226}Ra (Bq/kg)**	**f**	**Ref.**
Al Missikat, Egypt #3	4730	0.0045 ±0.00076	20
Italy ore	3500	0.0097	20
Al Aradiya, Egypt Average	495	0.023 ±0.004	20
Abu Rusheid, Egypt	578	0.008 ±0.0004	21
Um Naggat, Egypt	520	0.008 ±0.0004	21
Abu Dabbab, Egypt	105.8	0.027 ±0.015	21
Nuweibi, Egypt	74.75	0.027 ±0.015	21
Stream Sediments	40	0.2	22
Stream sediments, Egypt	23.4	0.29 ±0.04	This study
Rock variety	~20	>0.25	20

Table 2 clarifies that the relation between the activity concentration of radium ^{226}Ra and the radon emanation coefficient f is inverse, f decreases with increasing ^{226}Ra. When this data is scattered as in Figure 2, a (1/x) like relation is revealed. By trial and error method the best fitting of the data about ^{226}Ra and f that shows the reciprocal relation between them is obtained as follows:

$$f=(4/{}^{226}Ra)+0.005 \quad (3)$$

The fitting relation between the emanation coefficient f and the radium activity concentration ^{226}Ra over the range 20-5000 (Bq/kg) is represented in Figure 2 as a continuous line.

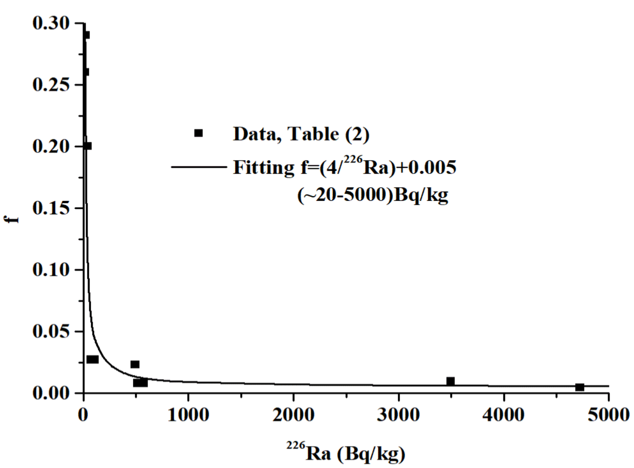

Fig. 2: Relation between ^{226}Ra and f over the range 20-5000 (Bq/kg).

The importance of the dimensionless constant 0.005 in Equation 3 is that it keeps the value of the emanation coefficient f non-zero at high values of ^{225}Ra while the adjusting constant 4 should have a unit of (Bq/kg) to keep f dimensionless.

3.3 Updating Radon Emanation Model

Equation 3 needs more physical explanation especially at high concentrations of radium. 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. Among many possibilities one of three things can happen to a radon atom after it is released by decay of a radium atom: (B) it may travel a short distance and remain embedded in the same grain; (E) it can travel across a pore space and become embedded in an adjacent grain; or (A) it is released into a pore sXCpace, Figure 3. That is the fraction of radon atoms released into a rock or soil pore space from a radium bearing grain which is termed the "radon emanation coefficient."

The concentration of radon gas in the pore spaces may reach saturation at high values of ^{226}Ra. Here this study suggests an additional possibility for the radon atom escaped from a grain to collide with another atom emanated from the same or another grain and turns back into any neighboring grain. This possibility is dominant at high radium content and pore radon saturation which permits only the constant fraction of 0.005 to diffuse through the pore spaces. This situation is represented by the possibility (H) in Figure 3.

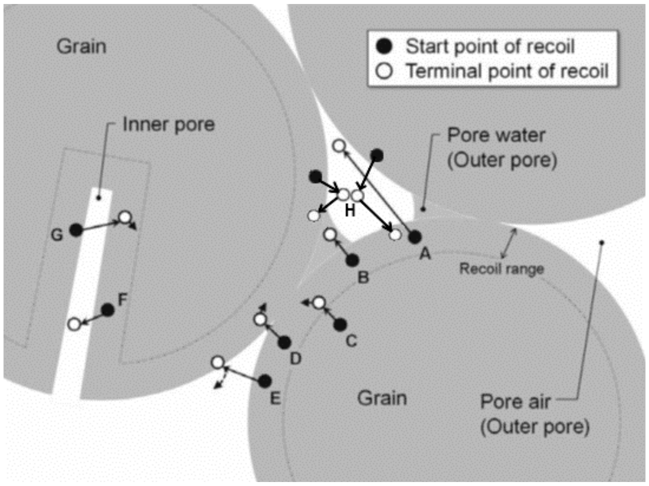

Fig.3: Radon emanation model. Modified after Ishimori and others [18].

4 ConclZ Usions

Can-Technique was employed to estimate the radon +emanation coefficient of some Egyptian stream sediments. The average value is 0.29±0.04. The Relation between the radium activity concentration in the rocks and the radon emanation coefficient was fitted to a reciprocal relation. A collision possibility between the emanating radon atoms is suggested to explain the low values of the emanation coefficient at high radium content and the process radon emanation model is updated,

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