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Radium Content and Radon Exhalation Rates in Beach Sand Samples Collected from Sea Coasts, Egypt using Sealed Cup Technique and LR-115 Detectors

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Abstract: In the present work, effective radium content and both area (surface) and mass exhalation rates in beach sand samples collected from eight sea costs locations (Red Sea and Mediterranean Sea)in Egypt have been measured using the sealed cup technique and LR-115 nuclear track detectors. The values of radium content have been found to vary from 20± to 84±18 Bq kg^{-1} with an average value of 37±20 Bq kg^{-1}. Area exhalation rate values were found to vary from 4x10^{-6} to 16.8x10^{-6} Bq m^{-2}h^{-1} with an average value of 7.4x10^{-6} Bq m^{-2}h^{-1}, whereas, mass exhalation rate values were found to vary from 60x10^{-9} to 252x10^{-6} Bq kg^{-1}h^{-1} with an average value of 111x10^{-9} Bq kg^{-1}h^{-1}. All the results obtained in the present work were found to be less than their corresponding world limits. Thus, the present results have revealed that, radium content and both area and mass exhalation rates in the studied beach sand samples do not pose risk to human health. The results were compared with national and some other countries.

Keywords: Radium content, Exhalation rates, Beach sand, Egypt, LR-115 detectors.

1 Introduction

Studies of natural radioactivity are necessary because of their radiological impact. Over the past five decades, growing attention has been devoted to the effect of natural radioactivity. Radon (^{222}Rn) is naturally occurring gas produced by the decay of radium (^{226}Ra), which is in turn a decay product in the uranium (^{238}U) series, which is found in all type of rocks, building materials, sand, soils, ground water and natural gas [1]. The dose due to inhaled radon and its progeny accounts for more than 50% of the total radiation dose to the public from natural sources [2,3].Radon is assumed to be an important cause of lung cancer after smoking [4,5]. Radium is present everywhere in the earth's crust so radon is found everywhere in varying quantity. The radium content of a sample also contributes to the level of environmental. Higher values of ^{226}Ra in sand contribute significantly in the enhancement of environmental ^{222}Rn [1].

Radon exhalation from beaches may enable the estimation of indoor level in case of using it in manufacturing of building materials. Radon exhalation is a complex phenomenon depending upon a number of parameters such as radium content in sand, sand morphology, sand moisture, sand grain size, temperature, atmospheric pressure and rainfall [6]. Exhalation designates the escape of radon from a material to the atmosphere. In the sand, radon molecules can escape from grain of sand by diffusion or recoil into the sand pores, this process is called emanation. The number of radon atoms released per unit area per unit time from the material is termed as exhalation rate [7, 8].

The importance of this study in determining the level of radium in the sand of Egyptian beaches is due to the presence of people for a long time on the beach, which may expose them to ratios of natural radiation. In addition to this importance, it may be in the near future, the use of beach sand as a building material and concrete production. Beach sand is not currently used in building materials as well as reinforced concrete because it contains chlorides and sulfates that lead to corrosion in ferrous materials used in concrete. Due to the availability of sandy beach sands in nature, many studies are conducted to the possibility of granting this sand the advantages that make it used in building materials and manufacturing reinforced concrete [9].

In the present study radium content and radon exhalation rate measurements from beach sand samples collected from the coastal parts along the Mediterranean sea(Alexandria, El-Dabaa and Marsa Matroh) and the Red sea(Marsa Alam, Al-Quseir, Safaga, Hurghada and Al-Sokna) in Egypt have been carried out.

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Fig. 1: Geographic location of the seacoast in Egypt where the beach sands were collected.

2 Material and Methods

In the present investigation, "sealed cup technique" [1, 6, 8, 10] was used to study the radium content and radon exhalation rates. Different beach sand samples were collected from five coastal locations on the Red Sea and three coastal locations from the Mediterranean Sea in Egypt as shown in Figure 1. The samples were dried at room temperature to 1mm grain size then placed for drying at 105 ºC for 24 h to ensure that moisture is completely removed , each sample divided into five equal volumes, weighed, and then placed in cylindrical containers made of aluminum. Each sample container was capped tightly to an inverted cylindrical cup of 3.5 cm radius and 11 cm high. A piece of LR-115 type II (Kodak Pathé, France) detector with area 1.5 cm2 is fixed at the top center of the inverted cup. The experimental arrangement is shown in Figure 2. The cups were left undisturbed at room temperature for three months exposure time. During this time α-particles from the decay of radon bombarded the LR-115 detector inside the inverted cup through the α-decay of radium contents of the samples. After the irradiation period the bombarded detectors were collected and chemically etched in 2.5 M NaOH solution at 60 ºC during 2 hours optical microscope.

The radon activity concentration (C_{Rn}) is calculated by using equation [10]

$$C_{Rn} = \rho / (\eta\ t) \tag{1}$$

where ρ the track density (tracks cm-^{2}) , η the sensitivity factor of LR-115 detector(tracks cm^{-2} d^{-1} / Bq m^{-3}) and t the exposure time (d).The value of η depends on the height and radius of the measuring cylinder cup[8] . An effective equilibrium (about 98%) for radon members of the decay series is reached in about 30 days [11]. Once the radioactive equilibrium is established, one may use the radon alpha analyses for the determination of steady-state activity of radium. The effective radium content (C_{Ra}) is calculated by using equation [10]:

$$C_{Ra} = C_{Rn} / (1 - e^{-\lambda_{Rn} t}) \tag{2}$$

The mass exhalation rate (E_M) of the sample release of the radon can be calculated by using the expression [6]:

$$E_M\ (\mathrm{Bq\ kg^{-1} d^{-1}}) = C_{Ra}\ (\lambda_{Ra}/(\lambda_{Rn})\ /T_e \tag{3}$$

where λ_{Ra} , λ_{Rn} and Te are radium decay constant, radon decay constant and the effective exposure time, respectively. The effective exposure time T_e given by:

$$T_e = [\ t - (1 - e^{(-\lambda_{Rn} t)}) / (\lambda_{Rn})] \tag{4}$$

The surface exhalation rate (E_A) of the sample for release of radon can be calculated by using the expression [6]:

$$E_A\ (\mathrm{Bq\ m^{-2}\ d^{-1}}) = E_M\ (M/A) \tag{5}$$

Where M is the mass of the sample in kg and A the area of cross section of the cylindrical cup in m^{2}.

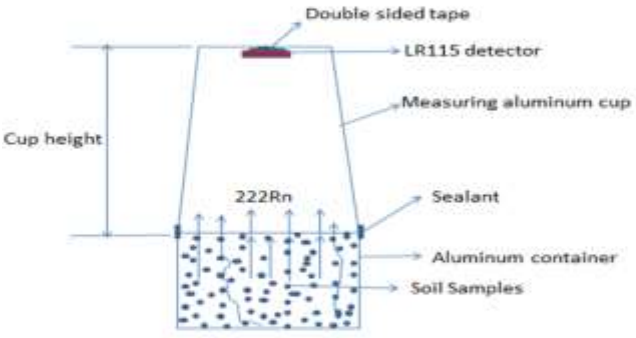

Fig. 2: Schematic diagram of the passive radon device.

3 Results and Discussion

Table 1 , represents the values of effective radium content and the mass and surface exhalation rates for beach sand samples collected from five coastal locations on the Red Sea . It is seen that the value of effective radium content in collected samples varies from 20±4 to 84±18 Bq kg^{-1} with a mean value of 38.6±23.15Bq kg^{-1}. The radon exhalation rates measured in terms of mass and area of beach sand samples are found to vary from 60 x 10^{-9} to 252 x 10^{-9} Bq kg^{-1}h^{-1} with a mean value of (115.8±69.44) x10^{-9} Bq kg^{-1}h^{-1} and 4 x 10^{-6} to 16.8 x 10^{-6} Bq m^{-2} h^{-1} with a mean value of (7.7±4.63) x 10^{-6} Bq m^{-2} h^{-1}.

Table 2 , represents the values of effective radium content and the mass and surface exhalation rates for beach sand samples collected from three coastal locations on the Mediterranean Sea . It is seen that the value of effective radium content in collected samples varies from 22±5 to 54±13 Bq kg^{-1} with a mean value of 34.33±14.06 Bq kg^{-1}. The radon exhalation rates measured in terms of mass and area of beach sand samples are found to vary from 66 x 10^{-9} to 162 x 10^{-9} Bq kg^{-1}h^{-1} with a mean value of (103±42.17) x10^{-9} Bq kg^{-1}h^{-1} and 4.4 x 10^{-6} to 10.8 x 10^{-6} Bq m^{-2} h^{-1} with a mean value of (6.87±2.81) x 10^{-6} Bq m^{-2} h^{-1} .

From Table 1 and Table 2 , the effective radium content and the radon exhalation rates from beach sand samples collected from all locations on the Red Sea and the Mediterranean Sea are 37±20.33 Bq kg^{-1} and 111±60.99 x10^{-9} Bq kg^{-1} h^{-2}, 7.39±4.07x10^{-6} Bq m^{-2} h^{-1}, respectively. It is seen that, there is a good correlation between mass and surface exhalation rates with radium content of beach sand samples.

It may be observed that the radon exhalation rates correspond to the estimated values of radium content. The average values of radium content obtained from this study are in a good agreement of the world value of 32 Bq kg^{-1} beach sand as reported in UNSCEAR 2000 [2] and much lower than the maximum permissible value of 370 Bq kg^{-1} for building materials recommended by the OECD 1979 [12]. Thus, results reveal that the beach sand samples analyzed radiologically safe and can be used as building materials without posing significant radiological threat to the population. The measured values of the radium content and the radon exhalation rates of beach sand samples from Safaga, the Red Sea region are the highest and this reflect that this location is suitable for climatotherapy [13].

Table1.Effective radium content (**C_{Ra}**), mass exaltation rate (**E_M**) and area exhalation rate (**E_A**) of radon in different beach samples along the Red Sea, Egypt.

Sample Location & Coordinates	C_{Ra} (Bq Kg^{-1})	E_M (Bq Kg $^{-1}$ h^{-1})x10^{-9}	E_A (Bq m^{-2} h^{-1})x10^{-6}
Marsa Alam 25.0676ºN ,34.8790ºE	20±4	60	4
Al-Quseir 26.1014ºN,34.2803ºE	26±6	78	5.2
Safaga 26.7500ºN,33.9360ºE	84±18	252	16.8
Hurgada 27.2579ºN,33.8116ºE	29.8	87	5.8
Al-Sokna 29.6725ºN,32.3370ºE	34±9	102	6.7
Average	**38.60±23.15**	**115.80±69.44**	**7.70±4.63**

Table 2. Effective radium content (**C_{Ra}**), mass exaltation rate (**E_M**) and area exhalation rate (**E_A**) of radon in different beach samples along the Mediterranean Sea, Egypt.

Sample location& Coordinates	**C_{Ra}** (Bq Kg^{-1})	**E_M** (Bq Kg^{-1} h^{-1})x10^{-9}	**E_A** (Bq m^{-2} h^{-1})x10^{-6}
Alexandria 31.2001ºN,29.9187ºE	54±13	162	10.8
El-Dabaa 31.0275ºN,28.4429ºE	22±5	66	4.4
Marsa Matroh 31.3543ºN,27.2373ºE	27±7	81	5.4
Average	**34.33±14.06**	**103±42.17**	**6.87±2.81**

Table 3 shows the comparison between the obtained results of effective radium content (C_{Ra}) in beach sand samples collected from different regions in Egypt using different techniques. The obtained values of radium content from this study were found to consistent with data obtained by other Egyptian investigators except for the values of beach sand samples collected from the Mediterranean Sea regions (Idku , East Rosetta Estuary and Rasheed). Because these regions are very rich with black sands that contain zircon and monazite minerals [15-16].

Table 3. The comparison between the obtained results of effective radium content **(C_{Ra})** in beach sand samples collected from different regions in Egypt using different techniques.

Region	**C_{Ra}(Bq Kg^{-1}) (Min.-Max.)Av.**	**Used techniques**	**References**
Coastal of The Red Sea (Safaga).	25	γ-Spectrometry (HPGe)	22

Coastal of The Red Sea(South part)	22	γ-Spectrometry (HPGe)	23
Coastal of The Red Sea (Safaga)	(163-221)190	γ-Spectrometry (HPGe	13
Coastal of The Red & Mediterranean Seas	(30-60)39	γ-Spectrometry (HPGe)	24
Coastal of The Mediterranean Sea (Idku)	(6.47-27.43)	γ-Spectrometry (HPGe)	14
Coastal of The Mediterranean Sea(East Resotta Estuary)	646.89	γ-Spectrometry (HPGe)	15
Coastal of The Mediterranean Sea (Rasheed)	256-3906	γ-Spectrometry (HPGe)	16
Coastal of The Red Sea (Sues Canal)	(4.3-18.5)11.63	γ-Spectrometry (HPGe)	25
Coastal of The Mediterranean Sea (Baltim)	(5.4-353.3)73.2	γ-Spectrometry (HPGe)	26
Coastal of The red Sea (South Marsa Alam)	(17-143)114	γ-Spectrometry (HPGe	27
Coastal of The Red Sea **Coastal of The Med. Sea**	**(20-84)38.6±23.15** **(22-54)34.3±14.06**	**α-Spectrometry** **Cup technique-LR-115**	**This Study**

It is also noted in Table 3 that most of the measurements in Egypt depend on the active technique using gamma spectroscopy with the HPGe detector because of the high accuracy of this detector in the environmental measurements. There is a dearth of measurements using passive technology using alpha spectroscopy and LR-115 and CR-39 nuclear track detectors, despite their ease of use and low cost. There is a dearth of measurements using passive technology using alpha spectroscopy and LR-115 and CR-39 nuclear trace detectors, despite their ease of use and low cost.

Table 4 shows Effective Radium Content (C_{Ra}) in beach sand samples from this study in comparison to these values in some countries using different techniques. The table shows the compatibility of the values from this study with the measured values in many regions of the world except in Brazil [17] and some regions of India [18-21,33]. The higher values of radium content in the beach samples collected from these studied areas may be attributed to presence of radiogenic heavy minerals in these samples [18].Some of these regions are characterized by a high level of natural background radiation[15-21].

4 Conclusions

Radium content and radon exhalation rates (both the mass and surface exhalation rates) have been measured successfully using LR-115 detectors by the sealed cup technique. The sealed cup technique is a passive and convenient useful tool for determining the radon exhalation rates as well as the radium contents in some sample of beach sands. The regions under study were eight locations for beach sand samples upon the coastal of the Red and the Mediterranean Seas in Egypt. It is observed that the studied regions are safe as for the health hazard effects of radium are concerned. It is possible to establish a national data base of beach sand samples from all coastal of the Red and the Mediterranean Seas in Egypt using this technique with low cost for a large-scale screening measurement. The measured values were compared with national and some other countries.

Table 4. Effective Radium Content (C_{Ra}) in beach sand samples in some countries using different techniques.

Country	**C_{Ra}(Bq Kg^{-1}) (Min.-Max.)Av.**	**Used Technique**	**References**
Bangladesh	(22.83-100.21)	γ-Spectrometry (HPGe)	28
Brazil	(6-4059)	γ-Spectrometry (HPGe)	17
China	(7.6-17.2)	γ-Spectrometry (HPGe)	29
China	(7.9-25.7)14.1	γ-Spectrometry (HPGe)	30
Ghana	(1.87-17.53)	γ-Spectrometry (HPGe)	31
India	(63.6-773)319	α-Spectrometry Cup technique-LR-115	18
India	(864-11471)3729	α-Spectrometry Cup technique-LR-115	19
India	(15.8-19.6) (14.3-18.4)	α-Spectrometry Cup technique-LR-115	32
India	(45.6-226.1)112	α-Spectrometry Cup technique-LR-115	33

India	(389-997)549	α-Spectrometry Cup technique-LR-115	20
India	(471-8896)2758	γ-Spectrometry (HPGe)	21
Libya	(4-13.5)7.5	γ-Spectrometry (HPGe)	34
Nigeria	12.93	γ-Spectrometry (HPGe)	35
Saudi Arabia	(19.5-22.4)	α-Spectrometry Cup technique-CR-39	36
Saudi Arabia	(12.1-36.3)22.7	γ-Spectrometry (HPGe)	37
Spain	(8.1-26.7)17.1	γ-Spectrometry (HPGe)	38
Thailand	(31.1-160.7)70.92	γ-Spectrometry (HPGe)	39
Turkey	(24.04-108.16)58.78	γ-Spectrometry (HPGe)	40
Egypt- Red Sea **Egypt- Med. Sea**	**(20-84)38.6±23.15** **(22-54)34.3±14.06**	**α-Spectrometry Cup technique-LR-115**	**This Study**

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