Indian Journal of Geo-Marine Sciences
Vol. 42(1), February 2013, pp. 35-41

Texture and environmental radioactivity measurements of Safaga sand dunes

*A. El-Taher[1] & H. A. Madkour [2]

[1]Physics Department, Al-Azher University, Assuit Branch, 71542 Assuit, Egypt

[2] National Institute of Oceanography and Fisheries, Red Sea Branch, Egypt
*[E-mail: Atef_Eltaher@hotmail.com]

Received 21 March 2011**; **revised 4 August 2011

The contents of natural radionuclides were measured in sand dunes samples collected from Safaga region in the Red Sea, Egypt by using low level gamma spectrometry. Based on the characteristic spectral peaks, the radionuclides ^{226}Ra, ^{232}Th and ^{40}K concentrations were determined. Average activity levels for these elements are 28.82, 14.03 and 558.39 Bq kg^{-1}. These values are lower than the global values reported in UNSCEAR publications. Results are discussed and compared with the levels in sand samples from different countries. Averages of radiation hazard parameters for the Safaga sand dunes samples are lower than the acceptable level 370 Bq kg^{-1} for radium equivalent Raeq, 1 for level index I γr, the external hazard index Hex ≤ 1 and 59 (nGy.h^{-1}) for absorbed dose rate. These data records the radioactivity background levels in Safaga sand dunes samples.

[Key words: Coastal sand dunes, Safaga area, Natural radionuclides, Red Sea, Egypt]

Introduction

The exposure of the public to natural sources of radiation has been estimated by the United Nations Scientific Committee on the Effect of Atomic Radiation[1] which concluded an effective average annual dose equivalent to 2.4 msv/yr per person. There are several publications deal with measuring low levels of naturally occurring radioactive isotopes [2-8.] Gamma-ray spectrometry has been applied in a wide range of investigations for qualifying and quantifying radionuclides in such materials since the development of NaI(TI) as a scintillator [9.]

The coastal sand dunes are widely distributed along the Egyptian coast of the Red Sea. Most of the large dune fields along the Egyptian coast of the Red Sea are formed at the mouth and adjacent to large wadies. Sand beaches also contribute to the dune sediments[10.]

Present study is an attempt to : a) to gain insight on the recent coastal dunes at Safaga area along the Red Sea coast. b) to evaluate the nature of surface textures of quartz grains which dominate the present day coastal sand dunes. c) assess natural radioactivity levels of (^{226}Ra, ^{232}Th and ^{40}K) in the sand dunes samples using γ-ray spectrometry. d) calculate the radiological parameters (radium equivalent activity Raeq, level index I γr, external hazard index Hex and absorbed dose rate) which is related to the external γ-dose rate. e) compare the activity concentrations for these natural radio-nuclides and radiation equivalent activities with similar studies carried out in other countries.

*Corresponding Author:

Materials and Methods

Safaga city is located at the northern part of the Egyptian Red Sea coast. Fifteen sand dunes samples have been collected from Safaga area (Fig. 1). Each sample about 1 kg were placed in plastic packets and transported to the laboratory. Grain size analyses were performed using the sieving technique according to[(11)]. Resulting data were processed on a personal computer using the "BASIC" program "SEDPAK [(12)]. Samples were dried in an oven at about 105 °C to ensure that moisture is completely removed. Weighted samples were placed in polyethylene beaker, of 350-cm^3. Beakers were completely sealed for 4 weeks to reach secular equilibrium where the rate of decay of the daughters becomes equal to that of the parent. It was assumed that ^{222}Rn and ^{220}Rn could not escape from the sealed containers after closure [(13-16)]. This step is necessary to ensure that radon gas confined within the volume and the daughters will also remain in the sample.

Activity measurements were performed by gamma ray spectrometer, employing a scintillation detector 3" × 3". It is hermetically sealed assembly, which includes a NaI (Tl) crystal, coupled to PC-MCA Canberra Accuspes. To reduce gamma ray

Fig. 1—Location map show Safaga area along the Egyptian Red Sea Coast.

background, a cylindrical lead shield (100 mm thick) with a fixed bottom and movable cover shielded the detector. The lead shield contained an inner concentric cylinder of copper (0.3 mm thick) to absorb x-rays generated in the lead. In order to determine the background distribution in the environment around the detector, an empty sealed beaker was counted in the same manner and in the same geometry as the samples. The measurement time of activity or background was 12 h. The background spectra were used to correct the net peak area of gamma rays of measured isotopes. A dedicated software program (Genie, 2000) from Canberra has carried out the online analysis of each measured γ-ray spectrum[13-16].

Calculations of count rates for each detected photo peak and radiological concentrations (activity per mass unit or specific activity) of detected radionuclides depend on the establishment of secular equilibrium in the samples. Concentration of ^{232}Th was determined from the average concentrations of ^{212}Pb (238.6 keV) and ^{228}Ac (911.1keV) in the samples, and that of ^{226}Ra was determined from the average concentrations of the ^{214}Pb (351.9keV) and ^{214}Bi (609.3 and 1764.5 keV) decay products[13-16].

Results and Discussion

The most common type of coastal dunes at Safaga area along the Red Sea coast is the incipient vegetated dune. Vegetated dunes are generally the form of ridges with flat upper surfaces and continuous crest. These ridges are usually parallel to each other. These dunes are usually formed by accumulation of sands behind vegetation or behind some obstacle. Pyramidal wind shadow dunes are very rare. This latter type of dunes forms via slip-face accretion in the lee of vegetation hummocks Sand surface of the dune slopes away from the crest of the dune shadow in two directions[17].

Coastal dune sands are mainly composed of quartz and feldspar grains. They constitute more than 80 precent of the sediment. However, the amount of biogenic fragments and shells, mostly soritides exeeds in the dunes at Safaga area. Therefore, quartz grains in the samples of the area between Safaga and Marsa Alam are relatively less than those in the northern areas and are mainly found in the fine and very fine sand fractions[10].

The purpose of the mechanical analysis for sediments is not only to obtain the nature of sediments but also to understand the physical characteristics of these sediments and to reveal the relation and the influence of grain size, source material and depositional environment. The areas under study receive sediments from the terrigenous rock fragments from the hinterland mountains. Also, the source sediments of the beach sands are mainly from the nearby coastal dunes and inland outcrops which are transported by occasional rain-torrents and wind actions to the beach. Distribution of gravel, sand and mud fractions is related to bottom topography and the type of source sediments. In the study area, sand is the main category among the three constituents (Table 1). The observed texture of the samples reflects a highly varied energy regime with strong ebbing and flooding intervened substantially by terrigenous flux from the opposite wadi.

During transportation by wind the entrained sediment is subject to sorting, rounding and etching of surface features, all of which impart distinctive characteristics on Aeolian sediments. Coastal dunes are mostly composed of medium and fine sands. These two size fractions constitute about 72% of the dune sediments (Table 1). Generally, the mean size (Mz) range from medium to fine sand. This is because the larger particles have a more tendency to roll down and less tendency to be moved up the dune by wind. Also standard deviation ($\boldsymbol{6_I}$) is moderately sorted (Table 1). Coastal dunes samples are mostly

Table 1—Grain size parameters of coastal dunes and mean roundness (rho) of quartz grains in the various size fractions at Safaga area and other areas of recent coastal sand dunes (after, Mansour, 1992b).

	Grain size parameters (Folk & Ward, 1957)			Size fractions (Ø)					
	Mz (Ø)	σ_I (Ø)	Sk_I (Ø)	-1 - 0	0 - 1	1 - 2	2 - 3	3 - 4	Mean
Mean	2.00	0.82	0.11	3.41	3.08	2.60	2.03	1.63	2.25
St. dev.	0.44	0.31	0.14	0.05	0.50	0.53	0.40	0.18	0.46
Mini	1.00	0.34	-0.14	3.35	2.01	1.66	1.53	1.23	1.51
Maxi.	3.02	1.73	0.58	3.47	3.72	3.42	2.77	1.94	2.90

σ_I = sorting , Sk_I = skewness, Stdev. = standard deviation, Mini. = minimum, Maxi. = maximum, Ø = phi

Table 2—Activity concentrations in Bq kg^{-1} for natural radionuclides in Safaga sand dunes

Sample Number	Activity in Bq kg^{-1}		
	^{40}K	^{232}Th	^{226}Ra
1	22.83±2.8	7.63±2.8	584.50±14
2	24.10±3.2	27.40±2.6	.46±12432
3	33.30±4.2	22.30 ±3.4	.32±18629
4	30.93±4.3	12.01±2.2	441.67±11
5	29.25±4.3	12.96±1.2	518.30±15
6	34.55±4.4	18.55±2.6	544.98±17
7	20.73±2.6	10.07±2.1	381.74±16
8	29.48±3.9	12.11±1.9	550.31±14
9	34.38±3.8	15.14±2.9	581.47±15
10	33.43±2.9	11.89±2.6	543.70±12
11	23.58±3.4	12.55±2.8	847.75±16
12	37.81±4.5	13.71±2.4	721.34±17
13	21.30 ±2.8	12.21±2.6	546.08±13
14	22.18±3.1	10.82±2.1	661.64±15
15	34.21±3.7	11.06±1.9	389.68±12
Minmium	21.30 ±2.8	7.63±2.8	381.74±16
Maximium	37.81±4.5	27.40±2.6	847.75±16
Average	28.82	14.03	558.39

positively skewed. All the studied sediments have a unimodel distribution with a model roundness class that varies from sub-rounded to angular depending mainly on the fraction size. Roundness modal class is subrounded in very coarse and coarse sand subangular in medium sand and angular in fine and very fine sand, subangular in medium sand and angular in fine and very fine sand fractions. However rounded grains decrease with increasing grain size. Quartz sand grains of recent coastal dunes are mainly characterized by adhering particle, low relief, rounded outline, medium relief and oriented and nonoriented, v-shaped pits are also recorded[10]. Most of these surface features were also obtained for costal dune sand grains by[18-19]. Quartz grain of coastal sand dunes reflect greater importance of mechanical features than chemical ones. Evaluation of roundness and assemblages of surface textures on quartz grains in recent coastal dune samples to be valuable when used in conjunction with other pertrological parameters in the study of coastal dune lithofacies[10].

The activity results of naturally occurring radionuclides ^{226}Ra, ^{232}Th and ^{40}K in Safaga sand dunes are given in Table 2. The activities of ^{226}Ra ranges from 21.30 to 37.81 Bq kg^{-1}, ^{232}Th content ranges from 7.63 to 27.40 Bq kg^{-1} and ^{40}K content ranges from 381.74 to 847.75 Bq kg^{-1}. Slight variation in the radioactivity content in sand can be observed due to type of sand, sand formation and the sand transport process and geomorphology. World averages for ^{226}Ra , ^{232}Th and ^{40}K are 35, 40 and 370 Bq kg^{-1}, respectively [(20)]. Thorium and uranium in sand are contained mainly in resistant heavy minerals such as monazite, zerecon and xenotime. Potassium is present in the light mineral fraction, such as potash – felspar, mica and glauconite, from which it is slowly converted into soluble forms by weathering processes. Heavy soils contain higher amounts of potassium than light soils. Uranium concentration in the sampling region is more dependent upon the climate, seasonal variability and the effects of evapotranspiration and the concentration of suitable complexing agents which can increase the solubility of uranium. Concentrations vary considerably spatially and temporally. Temporal variation may be seasonal, affecting changes in rainfall and run-off. Increased rainfall may result in more effective leaching and/or transport of uranium and lead to an increase in uranium concentration[21].

The concentration of ^{226}Ra, ^{232}Th and ^{40}K in study area is compared with the reported values of other environs as seen in Table 3. For ^{226}Ra and ^{232}Th it can be seen that the concentration is comparable with the value reported for most of the environs in Egypt and outside. The average values of these elements are smaller than the world values reported for UNSCEAR publications The concentration of ^{40}K is higher than most of the environs worldwide and the average value is higher than values reported for UNSCEAR publications.

Table 3—Concentrations of ^{232}Th, ^{226}Ra and ^{40}K (Bq kg^{-1}) in sand dunes from safaga beaches and other studies in different beaches of the world

Location	^{226}Ra	^{232}Th	^{40}K	Reference
Safaga sand dunes, Red sea, Egypt	21- 38 (29)	8 – 27 (14)	382- 848 (558)	Present work
Red sea shore sediment, Egypt.	95-106	2.3 - 222	98-1011	(22)
Mediterranean Sea, Egypt	3.0 -10.8	0.6 - 7.8	10 - 86	(23)
Nile Delta , Egypt.	32.2 - 63.7	44.3-95.6	96-102	(24)
Zaranik, North Sinai, Egypt	124.1	214	77.7	(25)
Preta beach Brazil	54 –180	128–349	47–283	(26)
Northeast Coast, Spain .	5 –19	5 – 44	136 -1087	(27)
Coastal Kamataka	249.2	489.6	55	(28)
Heavy sand , Bangladesh.	2582	4684	639	(29)
All India	7.8-1520	17.5-158.3	43 -766	(30)
Bombay	5.18-33.7	7.4-21.5	37-572	(31)
Mangalore	120.0-37.1	120.0-37.1	46.4-327.6	(32)
Greece	1-238	1-193	12-1586	(33)
Spain	13-165	7-204	48-1586	(34)
Italy	57-71	ND	580-760	(35)
Serbia	21-29	25-43	348-441	(36)
Canary Islands	7.3-104	11.6-110.5	141.6-1489	(37)
Greece	21-80	16-85	337-1380	(38)
Bulgaria	9-77	5-110	11-760)	(39)
France	9-62)	16-55	120-1026	(40)
Ireland	6-292	3-60	40-800	(41)
China	2.4-430	23.3-224	281-891	(42)
Namibia	45-48	3-38	42-1100	(43)
Taiwan	36	14.8-44.4	148-814	(44)
Japan	5-130	5-185	75-1400	(45)
USA	8.5-154.6	4-130	ND	(46)
Global average Soil	(7-50) 35	(10-50) 40	(100-700) 370	(20)
Global average Soil	(4-130) 32	(8- 160) 45	(100-700) 420	(1)

ND : not detected

The radiological parameters such as indices of radium equivalent activity, external hazard index, and indoor absorbed gamma dose rate were calculated to estimate the exposure risk from usage of safaga sand dunes and presented in Table 4.

Conversion factors to transform specific activities A_K, A_{Ra} and A_{Th} of K, Ra and Th, respectively, in absorbed dose rate at 1m above the ground (in Bq kg^{-1}) are calculated by Monte Carlo method as

$$D(n\,Gy\,h^{-1}) = 0.0417A_K + 0.462A_{Ra} + 0.604\,A_{Th} \quad \ldots(1)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}. From Table 4, the values of calculated absorbed dose rates in Safaga sand dunes samples ranged from 31.67 to 67.60 n Gy h^{-1} with average value are 46.1 n Gy h^{-1} and found to be comparable to the world average of 55 n Gy h^{-1} UNSCEAR 2000.

Table 4—Radiation hazard parameters for Safaga sand dunes

$I_{\gamma r}$	dose rate (nGyh^{-1})	Ra_{eq} (BqKg^{-1}	Sample Number
1	81.32	41.14	0.64
2	96.30	46.70	0.72
3	115.60	67.60	0.91
4	82.11	39.84	0.62
5	78.94	42.99	0.61
6	103.05	50.09	0.78
7	64.52	31.67	0.49
8	89.17	43.88	0.68
9	100.81	49.30	0.77
10	92.30	45.14	0.70
11	106.81	54.24	0.85
12	112.96	55.73	0.87
13	80.81	40.28	0.63
14	88.59	44.62	0.70
15	80.02	38.41	0.60
Minimium	64.52	31.67	0.49
Maximium	115.60	67.60	0.91
Average	91.57	46.10	0.70

The natural radioactivity of building materials is usually determined from ^{226}Ra, ^{232}Th and ^{40}K contents. As Ra and its daughter products produce 98.5% of the radiological effects of the U series, the contribution from the ^{238}U has been replaced with the decay product ^{226}Ra. Radium equivalent activity is an index that has been introduced to represent the specific activities of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them. This first index can be calculated according to

$$Raeq = A_{Ra} + 1.43A_{Th} + 0.077A_{K}, \qquad \ldots(2)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively. The Raeq is related to the external γ-dose and internal dose due to radon and its daughters. The radium equivalent activity (Raeq) values for the Safaga sand samples varied from 64.52 to 115.60 Bq kg^{-1} with average value are 91.57 Bq kg^{-1}. These values are less than 370 Bq kg^{-1}, which are acceptable for safe use [20].

The external hazard index is obtained from Raeq expression through the supposition that its maximum value allowed (equal to unity) corresponds to the upper limit of Raeq (370 Bq kg^{-1}). This index value must be less than unity in order to keep the radiation hazard insignificant; i.e. the radiation exposure due to the radioactivity from construction materials is limited to 1.0 mSv y^{-1}. Then, the external hazard index can be defined as .

$$\boldsymbol{H}_{ex} = \frac{\boldsymbol{A}_{Ra}}{370} + \frac{\boldsymbol{A}_{Th}}{259} + \frac{\boldsymbol{A}_{K}}{4810} \leq 1 \qquad \ldots(3)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively.

The calculated values of external hazard index obtained in this study ranged from 0.49 to 0.91 with average value 0.70. Since these values are lower than unity, we can say that the radiation hazard is insignificant for the population living in the investigated area. From the radioprotection point of view harmful gamma-ray effects are unlikely, because the activity contents are below various limit values. This combination of all previously mentioned factors and the high level of potassium recorded in this study are expected to contribute to the curing effect for several diseases in Safaga region[47].

Conclusion

Surface textures of recent coastal sand dunes are predominantly adhering particle, low relief, rounded outline and silica precipitation. There are some difference in assemblages of textures to distinguish the coastal dune environment from the subaqueous marine environments. The analytical results proved that the samples of this particular area significantly contain three radioactive isotopes (^{226}Ra, ^{232}Th and ^{40}K), all of which probably originated in the ancient volcanic craters at the bottom of the Red Sea. The mean values of activity concentrations of these elements are 28.82, 14.03 and 558.39 Bq kg^{-1}, respectively. The average Raeq and Iyr values for the studied areas are below the internationally accepted values. The absorbed dose rate values vary from 31.67 to 67.60 n Gy h^{-1}, with a mean value of 46.10 n Gy h^{-1}. These values are lower than the estimate of average global terrestrial radiation of 55 n Gy h^{-1} and much lower than in other regions of the world with elevated radiation levels. From the radioprotection point of view harmful gamma-ray effects are unlikely, because the activity contents are below various limit values. This combination of all previously mentioned factors and the high level of potassium recorded in this study are expected to contribute to the curing effect for several diseases in Safaga region. This study supplements the data reported in the literature and opens a way for new research to understand the healing effect of Climatotherapy at Red Sea area.

References

1 UNSCEAR 2000 Sources and Effects of Ionizing Radiation. Report to the General Assembly with Annexes, United Nations, NewYork.

2 Kalyani, V D M ., Chandrasekhar Rao, M V S., Sree Krishna Murty, G., Satyanarayana, G., Sastry, Sahasrabhude, D Babu, S G and Iyer, M R 1990 Analysis of ^{232}Th and ^{238}U in the beach sands and the ocean sediments. Indian Journal of Protection 10, 931–934.

3 Abbady, A., Said, M H., El-Kamel, A H and El-Arabi, A 1994 Natural radioactivity of sand samples by low –level gamma spectrometry. Rad. Phys .Chem 44,1/2, 225-228.

4 Saad , H R and Al-Azmi, D 2002 Radioactivity concentrations in sediments and their correlation to the coastal structure in Kuwait. Appl Radiat Isot 56, 991–997.

5 Mohanty, A K., Sengupt, D., DasS. K ., Vijayan, V and Saha, S K 2004 Natural radioactivity in the newly discovered high background radiation area on the eastern coast of Orissa, India Radiation Measurements. 38, 153 – 165.

6 El-Taher , A and Makhluf, S 2010 Natural radioactivity levels in phosphate fertilizer and its environmental implications in Assuit governorate, Upper Egypt. Indian J Pure &Appl Phys 48, 697-702.

7 El-Taher and H. A Madkour 2011 Distribution and Environmental Impacts of Metals and Natural Radionuclides in Marine Sediments In-Front of Different Wadies Mouth

along the Egyptian Red Sea Coast. Appl. Radiat Isot, 69 550–558.

8 El-Taher , A., Makhluf, S., Nossair, A and Abdel Halim, A S 2010 Assessment of natural radioactivity levels and radiation hazards due to cement industry. Appl Radiat Isot 68, 169-174.

9 Birks J 1953 Scintillation Counters. Pergamon Press. Oxford.

10 Mansour, A M 1992b Internal geometry and quartz grain roundness and surface features of recent coastal sand dunes of the Egyptian Red Sea coast. Bull. Fac. Sci., Assiut univ., 21 (1-f): 57-81.

11 Folk, R L and Ward, W C 1957 Brazos River bar: a study in the significance of grain size. J. Sediment. Petrol., 27 / 1: 3-26.

12 Malecki, G 1986. SEDPAK - Charakterisierung Von Sedimenten aufgrund der Korngr. Analyse. Ber. Geol. B.- A., Blg. 12, Wien.

13 El-Taher, A., Nossair, A., Azzam A H and Kratz, K L 2004 Determination of traces of uranium and thorium in some Egyptian environmental matrices by instrumental neutron activation analysis. Environ protect Engine, 30, PP 19-30.

14 El-Taher, A 2010 Gamma spectroscopic analysis and associated radiation hazards of building materials used in Egypt. Radia. Prot. Dosi.138 (2): 158-165**.**

15 El-Taher, A 2010 Elemental analysis of two Egyptian phosphate rock mines by instrumental neutron activation analysis and atomic absorption spectrometry. Appl. Radiat Isot 68, 511-515.

16 El-Taher, A., Uosif, M A M and Orabi, A 2007 Natural radioactivity levels and radiation hazard indices in granite from Aswan to Wadi El-Allaqi south eastern desert-Egypt. Radiat. Protect. Dosim, 124: 2, 148-154.

17 Goldsmith, V 1973 Internal geometry and origin of vegetated coastal sand dunes. J. Sed. Petrol., 43: 1128 – 1142.

18 Krinsley, D H and Donahue, J 1968 Environmental interpretation of sand grain Surface textures by electron microscopy. Geol. Soc. Amer. Bull., 79: 743 – 748.

19 Krinsley, D H and Smalley, I J 1972. Sand. Amer. Sci., 60: 286 – 291.

20 UNSCEAR 1993 Sources, Effects and Risks of Ionizing Radiation. Report to the General Assembly with Scientific Annexes, United Nations, New York.

21 Adam, J A and Lowder, W M 1964 The Natural Radiation Environment. University of Chicago.

22 El Mamoney, M H and Ashraf, E M Khater 2004 Environmental characterization and radio-ecological impacts of non-nuclear industries on the Red Sea coast. J Environ Radioact 73, 151-168.

23 Higgy, R.H 2000. "Natural Radionuclides and Plutonium Isotopes in Soil and Shore Sediments on Alexandria Mediterranean Sea coast of Egypt", Radiochim. Acta, 88, 47-57.

24 Ibraheim, N M., Abd El Ghani, A H., Shawky, S M., Ashraf, E M and Farouk, M A 1993 Measurement of radioactivity levels in soil in the Nile Delta and Middle Egypt. Journal Health Physics 64 (6), 620–627.

25 Seddeek, M K., .Badran, H B., Sharshar, T and Elnimr, T 2005 Characteristics, spatial distribution and vertical pro.le of gamma-ray emitting radionuclides in the coastal environment of North Sinai. J Environ Radioact. 84, 21-50.

26 Freitas, A C and Alencar, A S 2004 Gamma dose rates and distribution of natural radionuclides in sand beaches-Ilha Grande, Southeastern Brazil. J. Environ Radioact 75, 211- 223.

27 Rosell, J R., Ortega, X and Dies, X 1991 Natural and artificial radionuclides on the northeast coast of Spain. Health Phys. 60, 709–712.

28 Narayana, Y., Somashekarappa, H M., Radhakrishna, A P., Balakrishna, K M and Siddappa, K 1994 External gamma radiation dose rates in coastal Karnataka. Journal of Radiological Protection 14, 257-264.

29 Alam, M N., Chowdhury, M I., Kamal, M., Ghose, S., Islam, M N., Mustafa, M N., Miah, M M H. and Ansary, M M 1999 The ^{226}Ra, ^{232}Th and ^{40}K activities in beach sand minerals and beach soils of Cox's Bazar, Bangladesh. J. Environ. Radioact. 46, 243–250.

30 Kamath, R R., Rajan, M R., Shukla, V K., Sadasivan, S and Nambi, K S V 1996 "Natural and fallout radioactivity measurement of Indian soils by gamma spectrometric technique. Fifth National Symposium on Environment. Calcutta, India, Institute of Nuclear Physics; 56-60.

31 Rao, S R., Londhe, V S., Pillai, K C 1983 **"**Low level radioactivity measurements using gamma ray spectrometry**".** Bull. Radiat. Protect. 6, 33-41.

32 Siddappa, K., Balakrishna, K. M., Radhakrishna, A P., Somashekarappa, H M., Narayana, Y 1994 "Distribution of natural and artifical radioactivity components in the environs of Coastal Karnataka, Kaiga and Goa". (1991-1994). Final project Report to BRNS, DAE. Mangalore, India, Managalore University.

33 Anagnostakis, M J., Hinis, E P., Simopoulos, S E and Anelopoulos, M G 1996 "Natural radioactivity mapping of Greek surface soils" Environmental International 22, 3-8.

34 Beaza, A., del Rio, M., Miro, C and Paniagua, M 1992 "Natural radioactivity in soils of the province of Caceres (Spain). Radiat. Protect. Dosim. 45, 261-263.

35 Bellia, S., Brai, M., Hauser, S and Rizzo, S 1997 **"**Natural radioactivity in a volcanic island Ustica, southern Ital**".** Appl. Radiat. Isot. 48, 287-293.

36 Djuric, G., Dragana, P and Drangana, T1996 "Activity variations and concentration factors for natural radionuclides in a soil plant-honey system" Environmental International 22, 361-363.

37 Fernandez-Aldecoa, J C., Robayna, B., Allende, A., Poffijn, A., Hernandez-Armas, J 1992" Natural radiation in Tenerife (Canary Islands)". Radiat. Protect. Dosim. 45, 545-548.

38 Florou, H and Kritidis, P 1992 "Gamma radiation measurements and dose rate in the coastal arease of a volcanic island, Aegean Sea, Greece". Radiat. Protec. Dosim. 45, 277-279.

39 Strezov, A., Milanov, M., Mishev, P and Stoilova, T 1998 "Radionuclide Accumulation in Near-Shore Sediments Along the Bulgarian Black Sea coast", Appl Radiat Isot. 49, 1721-1728.

40 (40)Lambrechts, A., Foulquier, L and Garnier-Laplace, J 1992. "Natural Radioactivity in the Aquatic Component of the Main French Rivers", J. of Radia. Prot. Dosim., 45, 253-256.

41 McAuley, I R and Moran, D 1988 Natural radioactivity in soil in the Republic of Ireland. Radia. Prot. Dosim, 24(1/4), 47-49.

42 Pan Zigiang, Yang Yin and Guo Mingquiang 1988 Radiat. Prot. Dosim. **24**, 29–38.

43 Steinhäusler, F and Lettner, H 1992 Radiometric survey in Namibia. Radiat. Prot. Dosim. 45, 553-555.

44 Yu-Ming Lin, Pei-Huo Lin, Ching-Jiang Chen and Ching-Chung Haung 1987 Health Phys, **52**, 805–811.

45 Megumi, K., Oka, T., Doi, M., Kimura, S., Tsujimoto, T., Ishiyama T and Katsurayama, K 1988 “Relationships between the Concentrations of Natural Radionuclides and the Mineral Composition of the Surface Soil”. Radia. Prot. Dosim 24, 69-72.

46 Myrick, T E., Berven, B A and Haywood, F F 1983 Health Phys, **45**, 631–642.

47 El-Nazer Hany 1998 Climatotherapy of psoriasis at Safaga – Red Sea. European Conference on Travel Medicine, Venice – Italy, Cini Foundation, 25–27 March.