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ARTICLE

Assessment of natural radioactivity levels in stony sand from Black Stone Beach of Kuantan, the Peninsular Malaysia

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Abstract – Black Stone Beach (or Pantai Batu Hitam) of Kuantan, Malaysia is a windy but unique beach located on the coastal strip, and has become an attraction for tourists from within and outside the country for many years due to its scenic dark rock formations. Considering the radiological safety of human health, a study was conducted to assess the concentrations of naturally occurring radioactive materials in the beach environment. Activity concentrations of primordial radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in the stony sand samples collected from the beach area were assessed by using HPGe γ-ray spectrometry. The measured external gamma radiation dose rates and the activity concentrations were found to ranges 22–31 nGy.h^{-1} and 9.8 ± 0.6 to 12.4 ± 0.7 Bq.kg^{-1}, 6.8 ± 0.5 to 8.8 ± 0.6 Bq.kg^{-1} and 209 ± 11 to 354 ± 17 Bq.kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K, respectively. The mean values of typical radiological indices such as radium equivalent activity (Ra$_{eq}$) and annual effective dose were found to be 17.82 Bq.kg^{-1} and 10.86×10^{-3} mSv. year^{-1} which were far below the world average values of 370 Bq.kg^{-1} and 2.4 mSv.year^{-1} set by the UNSCEAR, respectively. Present results served as an important reference for any future radiological study in Kuantan, Malaysia.

Keywords: Black Stone Beach / stony sand / gamma-ray spectrometry / NORMs / radiation hazards

1 Introduction

Naturally occurring radioactive materials (NORMs) such as uranium (^{238}U), thorium (^{232}Th) and their progeny and the primordial potassium (^{40}K) are broadly distributed in the earth's environment. Technologically enhanced naturally occurring radioactive materials (TENORMs) are the major effect from the industrial process streams that release large volume of radioactive wastes with low specific activity. In general, Uranium, Thorium and their respective decay products are the major radionuclides in TENORM (El Afifi *et al.*, 2006). These radionuclides are commonly de-excites to their ground states by releasing gamma radiation which can be considered as the major extrinsic source of irradiation to the human body, and it can also be considered as the biggest cause to the external radiation dose received by the world community (Radenković *et al.*, 2009). In addition to the natural radiation, a wide variety of artificial radionuclides has been discharged into the atmospheric and oceanic environment due to the various disaster such as the Fukushima Dai-Chi Nuclear Power Plant accident (Özmen *et al.*, 2014). Once released, these radionuclides are transported to by different media and spreads throughout a wide area, and can create adverse effects to the environment and humans. Thus, to provide a basic information on radiation, it requires the study of levels of radiation and distribution of radionuclides in the environment. This information is necessary to understand the human exposures from natural and man-made radiation sources, and also crucial for the development of radiation protection rules and regulations.

Beach sands are mineral deposits that are formed as a result of several factors such as weathering and erosions, and they mainly composed of quartz, feldspar, etc. They may have come to their sites after been transported by wind, rivers and glaciers, and are deposited on the beaches by the actions of waves and currents. The natural radioactivity in the black stony sand mainly depends on the presence of radiogenic heavy minerals deposits on bed-rocks from which they originate, in turn depending on the local geological and geographical conditions (Shuaibu *et al.*, 2017). The radiation

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hazards arising from the use of sand or soil was found to be one of the largest natural radiation contributor to external dose to the world population (Papadopoulos *et al.*, 2014). Thus, knowledge on the distribution of the ^{238}U and ^{232}Th series and ^{40}K allows better understanding of the radiological implications. Additionally, the radioactivity concentration in beach sand can provide valuable information on transport mechanisms and the environmental fate of radionuclides, reflecting both on health risks to neighbouring areas, being essential for meaningful long-standing radiation monitoring and assessment (Khandaker *et al.*, 2018).

A review of literature reveals that no earlier study is available in the present area of interest, but several similar works are reported worldwide on natural radioactivity concentrations in beach sand and sediment samples from various beach zones of France, Bangladesh, Greece, India, Pakistan, Thailand, China, Egypt, Brazil, Jordan, Turkey, KSA, Iran, Oman, Sudan, Kuwait, Yugoslavia, Malaysia (Florou and Kritidis, 1992; Ahmad *et al.*, 1997; Sam *et al.*, 1998; Vukotić *et al.*, 1998; Chowdhury *et al.*, 1999; Saad and Al-Azmi, 2002; El-bahi *et al.*, 2005; Akram *et al.*, 2006; Veiga *et al.*, 2006; Frelon *et al.*, 2007; Lu and Zhang, 2008; Ramasamy *et al.*, 2009; Eissa *et al.*, 2010; Malain *et al.*, 2010; Zare *et al.*, 2012; Korkulu and Özkan, 2013; Tari *et al.*, 2013; Huang *et al.*, 2015; Al-Ghamdi *et al.*, 2016). All of these studies bring to focus the necessity for continuous assessment of radiation dose distribution in sand and sediment samples so as to accurately evaluate the radiation risk to a population and to effectively monitor the contributions of anthropogenic activities to terrestrial gamma dose rates for any outdoor occupation (Yasmin *et al.*, 2018). In fact, the natural radioactivity present in beach sands are a source of external exposure that contributes to an increase in the environmental dose (De Meijer *et al.*, 2001; Hilal and Borai, 2018). The assessment of these doses from natural materials can be useful for the assessment of public dose rates and as well as to keep reference data records.

Black Stone Beach is one of the tourism places in Malaysia and is located along the South China Sea near Kuantan, Pahang state, Malaysia. It attracts many tourist both locals and internationals, as such study of this nature is very significant to determine the level of natural radiation and its effect to human external exposure. The main objective of this study is to determine the levels of naturally occurring ^{226}Ra, ^{232}Th and ^{40}K, and to estimate the radiological implications on public health due to the natural radionuclides of the beach sands. The study may also contributes to the radiation data bank of Malaysia, especially as it is moving towards acquiring its first operational commercial Nuclear Power Plant by 2030 (Garba *et al.*, 2016).

2 Study area

The study area is located at 10 km away from the Kuantan city, and it lies between latitude 3.88° N and longitude 103.36° E. The Black Stone Beach got its name from its special feature of beds of dark black and grey rock formations scattered along the seashore (Fig. 1).

2.1 Sample collection and preparation

Top surface beach stony sand of the first 5 cm in depth is scraped off and discarded to remove traces of contamination due to human activities. The samples were collected at 200–300 m along the beach site (Fig. 1). A total of sixteen samples each weighing 2 kg were collected and packaged in a well-labelled polyethylene plastic bag (Fig. 2). The samples were then brought to the Radiation Laboratory at University Malaya for preparation and subsequent analysis. The stony sand samples were crushed into smaller parts, grounded into powder form for homogeneity using a mechanical grinding machine, and to remove any residual moisture they were oven dried at 80 °C for 24 h until a constant weight was obtained. The samples were then sieved through a standard 1 mm mesh and then transferred to 3D Marinelli beakers and sealed accordingly (Fig. 3). All the prepared samples were kept for at least 4 weeks in order to attain secular equilibrium between ^{238}U and ^{232}Th, and their respective decay products.

Fig. 1. The Black Stone Beach in Kuantan, Malaysia.

Fig. 2. Collection of stony sand sample from the Black Stone Beach in Kuantan, Malaysia.

3 Methodology

Measurements were carried out at the laboratory using HPGe gamma-ray detector with an energy resolution of 1.67 keV (FWHM) at the 1332.5 keV peak of ^{60}Co

Fig. 3. Preparation of sample prior to HPGe gamma-ray spectrometry.

(Asaduzzaman *et al.*, 2014). The qualitative and quantitative determination of gamma-ray emitting radionuclides was achieved with a computer-based gamma-ray spectrometry system (Khandaker *et al.*, 2013). The system consist of a high resolution HPGe coaxtial detector, high voltage power supply, preamplifier, amplifier and multi channel analyzer (MCA). In order to reduce background radiation, the detector was placed in a cylindrical lead shielded chamber with a fixed bottom and a portable cover shielding the top. The samples were counted for 43 200 s and background counts for the equal estimating time were amputated to achieve the net activity. The activity of ^{226}Ra was determined based on gamma-ray emissions of ^{214}Pb (351.93 keV) and ^{214}Bi (609.32 keV); ^{232}Th activity was determined based on the emissions of ^{208}Tl (583.18 keV) and ^{228}Ac (911.20 keV) and that of ^{40}K was determined directly from the gamma-ray emission line of 1460.822 keV. Only strong and independent characteristics gamma-lines of the corresponding radionuclides were used in order to decrease the error in activity determination. For the evaluation of ^{226}Ra and ^{232}Th activity, a weighted mean approach (Khandaker *et al.*, 2019a, 2019b) was applied using the aforementioned gamma lines.

The activity concentrations of ^{226}Ra, ^{232}Thand ^{40}K in the samples were computed using the formula from (Khandaker *et al.*, 2013; Asaduzzaman *et al.*, 2015), and expressed in Bq.kg^{-1}.

$$A = \frac{\mathrm{CPS} \times 1000}{\gamma \times I_\gamma \times W}, \tag{1}$$

where A is the specific nuclide activity in Bq.kg^{-1}, CPS is the net counts per second and W is the weight of the samples in unit of gram, ϵ_γ is the efficiency of the corresponding gamma lines and I_γ is the branching ratio of the corresponding γ-ray.

3.1 Estimation of uncertainties

In these measurements, the uncertainty in each sample activity was evaluated by considering the quadratic sum of the following relevant uncertainties: statistical uncertainty of gamma-ray counting (x_1); uncertainty in sample weight (x_2); uncertainty in the detection efficiency (x_3); and uncertainty in gamma-ray intensity (x_4) as shown in equation (2).

$$y = f(x_1, x_2, \ldots x_n). \tag{2}$$

The total standard uncertainty of the estimate y is denoted by $u_c(y)$ and is obtained by using the error propagation law (Khandaker *et al.*, 2016) given in equation (3):

$$u_c^2[y(x_1, x_2, x_3 \ldots, x_n)] = \sum_{i=1}^{n} \left(\frac{\partial y}{\partial x_i}\right)^2 u^2(x_i). \tag{3}$$

4 Results and discussion

4.1 Activity concentrations of ^{226}Ra, ^{232}Th, ^{235}U and ^{40}K

The measured activity concentrations was found to be in the range of 9–10 Bq.kg^{-1} with a mean value of 11.1 ± 0.7 Bq. kg^{-1} for ^{226}Ra, 7–9 Bq.kg^{-1} with a mean value of 7.7 ± 0.6 Bq. kg^{-1} for ^{232}Th and 200–350 Bq.kg^{-1} with a mean value of 294 ± 14 Bq.kg^{-1} for ^{40}K (Tab. 1). More particularly, the sample code BHS1A recorded the highest activity concentrations of ^{226}Ra and ^{232}Th with values of 12.4 ± 0.7 Bq.kg^{-1} and 8.8 ± 0.6 Bq.kg^{-1} respectively, while the sample BHS3B recorded the highest activity concentrations of ^{40}K with a value of 342 ± 16. However, all of the samples show values lower than the world average values of 35 Bq.kg^{-1}, 30 Bq.kg^{-1} and 420 Bq.kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively as reported by (UNSCEAR, 2000; Abedin *et al.*, 2019).

4.2 Radium equivalent activity (Ra$_{\mathrm{eq}}$)

The distribution of ^{238}U, ^{232}Th and ^{40}K in the material samples is non-uniform. Thus, uniformity in the distribution with respect to radiation exposure can be defined by radium equivalent activity (Khandaker *et al.*, 2018). Ra$_{\mathrm{eq}}$ is used in assessing the associated hazards due to gamma radiation from materials that containing ^{238}U, ^{232}Th and ^{40}K. It is assumed that 370 Bq.kg^{-1} of ^{238}U, 259 Bq.kg^{-1} of ^{232}Th and 4810 Bq. kg^{-1} of ^{40}K produce similar gamma radiation dose rates. Ra$_{\mathrm{eq}}$ (Bq.kg^{-1}) is given by equation (4) (Garba *et al.*, 2015):

$$\mathrm{Ra_{eq}}\left(\mathrm{Bq.kg^{-1}}\right) = C_{\mathrm{U}} + 1.43C_{\mathrm{Th}} + 0.077C_{\mathrm{K}}, \tag{4}$$

where A_{U}, A_{Th}, and A_{K} are the specific activities of ^{226}Ra, ^{232}Th, and ^{40}K in Bq.kg^{-1}, respectively. As shown in Table 1, Ra$_{\mathrm{eq}}$ is ranged from 37 Bq.kg^{-1} to 50 Bq.kg^{-1} with a mean value of 45.4 Bq.kg^{-1} which is far below the maximum limit (370 Bq.kg^{-1}) recommended by the UNSCEAR (2000) for exposure to NORMs.

4.3 External absorbed gamma dose rates

Terrestrial radionuclides form the main sources of gamma radiation, hence there is a direct connection between terrestrial gamma radiation and radionuclide content. Outdoor air absorbed dose rate (D_R) at 1 m above the ground was determined in two ways: *in situ* measurements using a handheld radiation survey meter, and computed from the

Table 1. Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the studied stony sand samples and the associated radiological parameters.

Sample type	Location	Sample Id (×2)	Measured External Gamma Dose Rate (nGyh^{-1})	Activity concentration (Bq.kg^{-1})					Associated radiation dose		Hazard indices	
				^{235}U	^{226}Ra	^{232}Th	^{40}K	Ra$_{eq}$	γ-ray dose rate (nGyh^{-1})	AED (mSvy^{-1})	Hex	Hin
Stony sand	Pantai Batu Hitam, Kuantan, Malaysia	BHS1A	29	1.9 ± 0.2	12.4 ± 0.7	8.8 ± 0.6	310 ± 15	49	24	0.03	0.13	0.17
		BHS1B	31	2.0 ± 0.2	11.2 ± 0.7	8.0 ± 0.6	354 ± 17	50	25	0.03	0.13	0.17
		BHS2A	24	1.7 ± 0.2	10.5 ± 0.5	7.3 ± 0.6	246 ± 12	40	20	0.02	0.11	0.14
		BHS2B	24	2.0 ± 0.2	10.4 ± 0.7	6.8 ± 0.5	254 ± 12	40	20	0.02	0.11	0.14
		BHS3A	25	1.7 ± 0.2	11.7 ± 0.7	7.6 ± 0.6	318 ± 15	47	23	0.03	0.13	0.16
		BHS3B	29	2.0 ± 0.3	11.6 ± 0.7	7.7 ± 0.5	342 ± 16	49	24	0.03	0.13	0.16
		BHS4A	22	1.9 ± 0.2	9.8 ± 0.6	7.5 ± 0.5	209 ± 11	37	18	0.02	0.10	0.13
		BHS4B	25	2.1 ± 0.3	11.1 ± 0.7	7.5 ± 0.5	318 ± 15	46	23	0.03	0.13	0.16
		Range	22–31	1.7 ± 0.2–2.1 ± 0.3	9.8 ± 0.6 –12.4 ± 0.7	6.8 ± 0.5 –8.8 ± 0.6	209 ± 11 –354 ± 17	37–50	18–25	0.02–0.03	0.10–0.13	0.13–0.17
		Mean	26 ± 3	1.9 ± 0.2	11.1 ± 0.7	7.7 ± 0.6	294 ± 14	45	22	0.03	0.12	0.15
UNSCEAR (2000)			55		35 (17–60)	30 (11–64)	420 (140–850)	370	55	0.5	1	1

measured specific activities of ^{238}U, ^{232}Th and ^{40}K in the beach sands using the equation (5) (UNSCEAR, 2000).

$$D\left(\mathrm{nGy.h^{-1}}\right) = \left(0.462A_{\mathrm{U}} + 0.604A_{\mathrm{Th}} + 0.0417A_{\mathrm{K}}\right) \qquad (5)$$

where, D is the absorbed dose rate in air (nGy.h^{-1}), A_{U}, A_{Th} and A_{K} are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively, in Bq.kg^{-1}, and the constants are for conversion factors of activity to dose.

The measured external gamma dose rates was found to be in the range of 22–31 nGy.h^{-1} with a mean value of 26 ± 3 nGy.h^{-1}, while the calculated dose range was found as 18–25 nGy.h^{-1} with a mean value of 22 nGy.h^{-1}. It can be seen in Table 1 that the measured and the calculated dose rate show a similar data, and the respective mean values show less than the world and Malaysian average values of 55 nGy.h^{-1} (UNSCEAR, 2000) and 97 nGy.h^{-1} (Shuaibu *et al.*, 2017). Therefore, the beach is safe for tourist and the studied materials can be used for any purposes which may pose an insignificant radiological threat to the population.

4.4 Annual effective dose

The outdoor annual effective dose equivalent due to the activity concentrations of the natural radionuclides in the sand sample was calculated using equation (6) with the dose conversion coefficient (0.7 Sv.Gy^{-1}) and occupancy factor (0.2) for outdoors (Garba *et al.*, 2015).

$$\mathrm{AED}\left(\mathrm{mSv.}y^{-1}\right) = \mathrm{DR}\left(\mathrm{nGy.h^{-1}}\right) \times 8760 \times 0.2 \times 0.7 \times 10^{-6}, \qquad (6)$$

where D_R is the absorbed dose rate in air, 8760 h is the number of hours in a year, and 10^{-6} is the conversion factor between nano and milli. The annual effective dose to the exposed population was found to be 0.03 mSv.y^{-1} which is ~16 times smaller than the worldwide mean value of 0.5 mSv.y^{-1} due to the terrestrial gamma rays (UNSCEAR, 2000).

4.5 External and Internal hazard index (H_{ex})

The main objective of hazard index is to assess the hazards of natural gamma radiation and also keep the value less than unity (ICRP, 2000). The internal hazard index (H_{in}) gives the internal exposure to carcinogenic radon. H_{ex} and H_{in} are defined by equations (7) and (8) respectively (Veiga *et al.*, 2006; Al-Hamarneh and Awadallah, 2009; Saleh *et al.*, 2013):

$$H_{\mathrm{ex}} = \left(\frac{A_U}{370}\right) + \left(\frac{A_{\mathrm{Th}}}{259}\right) + \left(\frac{A_K}{4810}\right) \leq 1, \qquad (7)$$

$$H_{\mathrm{in}} = \left(\frac{A_U}{185}\right) + \left(\frac{A_{\mathrm{Th}}}{259}\right) + \left(\frac{A_K}{4810}\right) \leq 1, \qquad (8)$$

where A_{U}, A_{Th} and A_{K} are activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively in Bq.kg^{-1}. The mean values of external and internal hazard were found to be 0.12 and 0.15 respectively as presented in Table 1. It can be seen that the mean values of both indices were below the recommended limit value of unity (ICRP, 2000), which means the beach was safe for tourism and any other recreational purposes.

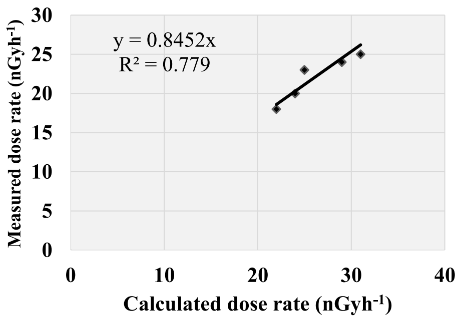

Fig. 4. Calculated gamma dose rate *versus* measured gamma dose rate (nGyh^{-1}).

4.6 Overall discussion

Generally, the stony sand found at Pantai Batu Hitam (Batu Hitam Beach) of Kuantan, Malaysia is black in color. It is known that they were originated from a volcano and consist of tiny fragments of basalt. They are usually used by miners and prospectors to indicate the presence of a placer formation. Several gemstones, such as garnet, topaz, ruby, sapphire and diamond are found in placers and in the course of placer mining, and sands of these gems are found in black sands and concentrates. Purple or ruby-colored garnet sand often forms a showy surface dressing on ocean beach placers (Fig. 1).

Larger waves can sort out sand grains leaving deposits of heavy minerals visible on the surface of erosion scarps which tend to increase mining activities in the area because of the heavy weight of minerals bearing U and Th. As such, the little fluctuations observed on the activity concentrations at different locations is not surprising, despite been lower than the world average values which could be attributed to the volcanic origin of the stony sand. This consists of Quaternary geological formation that composed of continental and marine deposits with unconsolidated humic clay, peat and silt and Permian that consists of shale, slate, and phyllite with subordinate schist and sandstone. It developed of limestone through the succession, and they are mostly found around the border of Southeast China Sea and they are well-known to be not rich in radioactivity (Gabdo *et al.*, 2016).

A strong correlation between the measured external gamma radiation dose rates with the calculated gamma radiation dose rate was found with a correlation coefficient $R^2 = 0.779$ (Fig. 4).

Table 2 presents a comparison of the primordial radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in the study area with those reported in other parts of the world as well as the world averages. As can be seen the results agree very well with most of the values reported by the different researchers across the globe, and the only difference was with those that were from areas known to be high background radiation areas as discussed in section 1.

Table 2. Comparison of ^{226}Ra, ^{232}Th and ^{40}K activity concentrations in stony beach sand samples of Kuantan (Malaysia) with that reported in other countries.

Region	Sample type	^{226}Ra (Bq.kg^{-1})	^{232}Th (Bq.kg^{-1})	^{40}K (Bq.kg^{-1})	References
Kuantan (Malaysia)	Beach stony sand	11	8	294	This study
South China Sea, Malaysia	Sediment	3.0 + 0.3	3.0 + 0.3	70 + 6	(Amin *et al.*, 2013)
Bangladesh	River sediments and coastal soils	24	57	255	(Chowdhury *et al.*, 1999)
Greece	Coastal sand	93	71	177	(Florou and Kritidis, 1992)
India	Beach sediments	8	25	275	(Ramasamy *et al.*, 2009)
Pakistan	Tidal sediments	23	14	238	(Akram *et al.*, 2006)
Thailand	Beach sand	12	19	344	(Malain *et al.*, 2010)
China	Beach sand	12	15	1079	(Lu and Zhang, 2008)
China	Beach sand	14.6 ± 4.4	10.9 ± 7.8	396.4 ± 75.1	(Huang *et al.*, 2015)
Egypt	Sand	56	53	120	(El-bahi *et al.*, 2005)
Egypt	Coastal sand	39	21	402	(Eissa *et al.*, 2010)
Brazil	Beach sand	192	1673	217	(Veiga *et al.*, 2006)
Jordan	Sand	56	29	501	(Ahmad *et al.*, 1997)
Turkey	Beach sand	4.41–14.04	2.62–16.55	11.60–513.32	(Korkulu and Özkan, 2013)
KSA	Shore sediment	11.3	6.7	153.8	(Al-Ghamdi *et al.*, 2016)
Iran	Beach sand	14.6–29.6	14.8–21.7	179.5–464.5	(Tari *et al.*, 2013)
Oman	Marine sediments	11.83–22.68	10.7–25.02	222.89–535.07	(Zare *et al.*, 2012)
Sudan	Surface sediments, Seagrass and algae	30	6	158	(Sam *et al.*, 1998)
Kuwait	Sediments	36	16	227	(Saad and Al-Azmi, 2002)
Yugoslavia	Sand	8	7	150	(Vukotić *et al.*, 1998)
Batu Ferringhi, Malaysia	Beach sand	34 ± 2	23 ± 1	271 ± 13	(Shuaibu *et al.*, 2017)
Langkawi, Malaysia	Beach sand (Black)	103	718	1478	(Khandaker *et al.*, 2018)
Langkawi, Malaysia	Beach sand (White)	9.8	5.9	102	(Khandaker *et al.*, 2018)
World Average		33	45	420	(UNSCEAR, 2000)

5 Conclusion

The assessment of external gamma radiation dose rates and activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K and their radiological implications associated with sand stone samples collected from the Black Stone Beach, Kuantan, Malaysia was carried out in this study. The mean external gamma radiation dose rates was found to range between 22–31 nGy.h^{-1} with a mean value of 26 ± 3 nGy.h^{-1} which is below the world and Malaysian average values of 55 nGy.h^{-1} and 97 nGy.h^{-1}, respectively. While the mean activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K were found to be 11.1 ± 0.7, 7.7 ± 0.6 and 294 ± 14 Bq.kg^{-1} respectively, which were all lower than the world and Malaysian averages values of 66 Bq.kg^{-1}, 82 Bq.kg^{-1} and 310 Bq.kg^{-1}. The mean radium equivalent activity, absorbed dose rates, annual effective dose and radiation hazard indices deduced from the measured activities of the stony sand samples were found to be 45.4 Bq.kg^{-1}, 22 nGy.h^{-1}, 0.03 mSv.y^{-1} and 0.12 and 0.15 respectively which were within the limit recommended by UNSCEAR. Therefore, the beach is safe for tourism and any other recreational purposes.

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