Frequency distribution of specific activities and radiological hazard assessment in surface beach sand samples collected in Bangsaen beach in Chonburi province, Thailand

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Abstract. The specific activities of natural radionuclides (40K, 226Ra and 232Th) in 50 surface beach sand samples collected from Bangsaen beach in Chonburi province in the eastern region of Thailand, were measured and evaluated. Experimental results were obtained by using a high-purity germanium (HPGe) detector and gamma spectrometry analysis system in the special laboratory at Thailand Institute of Nuclear Technology (Public Organization). The IAEA-SOIL-375 reference material was used to analyze the concentration of 40K, 226Ra and 232Th in all samples. It was found that the specific activities of 40K, 226Ra and 232Th were ranged from 510.85 - 771.35, 8.17 - 17.06 and 4.25 - 15.68 Bq/kg. Furthermore, frequency distribution of the specific activities were studied, analyzed and found to be the asymmetrical distribution by using a statistical computer program. Moreover, four radiological hazard indices for the investigated area were also calculated by using the median values of specific activities of 40K, 226Ra and 232Th. The results were also compared with the Office of Atoms for Peace (OAP) annual report data, Thailand and global radioactivity measurement and evaluations.

1. Introduction

Bangsaen beach is one of the most popular attractive places in Chonburi province which is located in the eastern region of Thailand. Thai and International Tourists usually come to visit, relax and enjoy sea breeze over here since it is very close to Bangkok, only about 1 hour drive. The 4.5 kilometer beach, also known as “Bang Saen the Utopia”, is currently dealing with its chronic problem of trash and sediment polluting the area. According to the beach is geographically located in a point that particularly receives a lot of the ocean’s incoming waves, in each annual monsoon will bring in trash collected from various “rivers’ mouths” or deltas around this area. According to the Pollution Control Department (PCD) in Thailand, the trash buildup amounted to 16 million tons for the whole year of 2012, or approximately 43,000 tons per day. On March 16, 2014, oil slicks have been reported at Bang Saen beach, causing over 100 of beach-visitors to suffer from skin irritation. All of tourists who were suffering from skin irritation were taken to nearby hospitals. The asphalt-like substance stretched...
2.5 kilometers on Bang Saen shoreline. An initial investigation suggested that the substance was bunker oil that might have come from a fishing boat that illegally dumped its used oil into the sea. The crude oil spill has been studied and found relate to the concentration of Naturally Occurring Radioactive Materials (NORM), such as $^{226}\text{Ra}$ [1-2]. For this reason, Bangsaen beach should be the best area for studying, measuring and calculating the specific activities of natural radionuclides ($^{40}\text{K}$, $^{226}\text{Ra}$ and $^{232}\text{Th}$) in this area. There are only some sampling point data in Chonburi province which were measured by Office of Atoms for Peace (OAP)[3]. Hence, systematic data of $^{40}\text{K}$, $^{226}\text{Ra}$ and $^{232}\text{Th}$ in surface beach sand samples collected along from Bangsaen beach have been performed and investigated in this study.

2. Experimental

2.1 Sample Collection and Preparation
All of 50 surface beach sand samples were collected from Bangsaen beach in Muang district in Chonburi province, Thailand. Each sample was dried up at room temperature after collection and sieved through a 2 mm mesh-sized sieve to remove stone, pebbles and other macro-impurities. Before the measurement and analysis, all beach samples were oven dried at a temperature of 100 $^\circ\text{C}$ for 3 hours for removing moisture. The homogenized sample was placed in a PVC cylindrical container. The container was sealed hermetically and externally using a cellophane tape and kept aside for about a month to ensure equilibrium between $^{226}\text{Ra}$ and its daughters and $^{228}\text{Ra}$ and its daughters before being taken for measurement and analysis by using gamma spectrometry technique.

2.2 Measurement and Analysis
The specific activities of natural radionuclides ($^{40}\text{K}$, $^{226}\text{Ra}$ and $^{232}\text{Th}$) in all 50 beach sand samples were determined by using a high-purity germanium detector (HPGe, EG&G ORTEC Model GEM 20 P4) and gamma spectrometry analysis system at advanced laboratory, Thailand Institute of Nuclear Technology (Public Organization) (TINT). The detector was enclosed in a massive 10 cm thick lead shielding. Geometric efficiency for beach sand matrices in the container was determined by the IAEA Soil-375 reference materials (International Atomic Energy Agency IAEA, Vienna, Austria). The statistic computer program was employed to analyze the frequency distribution of specific activities of natural radionuclides ($^{40}\text{K}$, $^{226}\text{Ra}$ and $^{232}\text{Th}$) in all surface beach sand samples for the investigated area. Furthermore, the results were also compared with some research data in Thailand as well as global measurements and evaluations. Moreover, four radiological hazard indices in the study area were also evaluated by using the appropriate medium values of the frequency distribution and the equations as shown in the following section.

2.3 Study on Radiological Hazard indices
By using the median values of specific activities of $^{40}\text{K}$, $^{226}\text{Ra}$ and $^{232}\text{Th}$, four radiological hazard indices which are gamma absorbed dose rate (D) [4], radium equivalent activity ($\text{Ra}_{eq}$)[5], external hazard index ($H_x$)[5] and annual external effective dose rate ($\text{AED}_{out}$) [4], were evaluated and presented in Table 3 for Bangsaen beach. Moreover, the results were also compared with some research data in Thailand and global recommended value.

3. Results and Discussions

3.1 Frequency Distribution of Specific Activities and Statistic Values
By using a statistic computer program, the frequency distribution of specific activities of $^{40}\text{K}$, $^{226}\text{Ra}$ and $^{232}\text{Th}$ in 50 surface beach sand samples collected Bangsaen beach in Chonburi province were studied, analyzed and presented in the following Figure 1. Furthermore, all statistic values which were calculated from this study, were shown in Table 1.
### Table 1. Statistic values of the frequency distribution of specific activities of $^{40}$K, $^{226}$Ra and $^{232}$Th in 50 surface beach sand samples collected from Bangsaen beach in Chonburi province (Thailand).

| Statistic values       | $^{40}$K (Bq/kg) | $^{226}$Ra (Bq/kg) | $^{232}$Th (Bq/kg) |
|------------------------|------------------|--------------------|--------------------|
| Mean                   | 615.74           | 10.18              | 7.87               |
| Median (Bq/kg)         | 620.71           | 9.79               | 7.59               |
| Mode (Bq/kg)           | 510.85           | 8.78               | 6.94               |
| Skewness               | 0.09             | 2.23               | 1.99               |
| Kurtosis               | -1.00            | 5.72               | 6.09               |
| Minimum value (Bq/kg)  | 510.85           | 8.17               | 4.25               |
| Maximum value (Bq/kg)  | 771.35           | 17.06              | 15.68              |

#### 3.2 Radiological Hazard Indices Values and Comparison

From Fig. 1(a) – (c) and all calculated statistic values in Table 1, it was found that the frequency distribution of specific activities of $^{40}$K, $^{226}$Ra and $^{232}$Th in 50 surface beach sand samples collected from Bangsaen beach in Chonburi province, were asymmetrical distribution with the skewness of 0.09, 2.23 and 1.99, respectively. For this reason, the median values of $^{40}$K, $^{226}$Ra and $^{232}$Th which were $620.71 \pm 14.60$ Bq/kg, $9.79 \pm 0.68$ Bq/kg and $7.59 \pm 0.87$ Bq/kg, for Bangsaen beach in Chonburi province, should be selected for calculation four radiological hazard indices in this area. The results and their average values were evaluated and compared with some researches data in Thailand and the recommended values reported by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) as shown in Table 2.

#### Table 2. Comparison between four radiological hazard indices for Bangsaen beach in Chonburi province with some research data in Thailand and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

| Locations                          | D (nGy/h)          | $R_{eq}$ (Bq/kg) | $H_\text{ex}$ (mSv/y) | ADE$_{\text{out}}$ (mSv/y) |
|------------------------------------|--------------------|-----------------|------------------------|-----------------------------|
| Patong beach (Phuket province) [6]  | 180.56 ± 49.70     | 348.93 ±96.11   | 0.94 ± 0.26            | 0.22 ± 0.06                 |
| Naiyang beach (Phuket province) [6]| 86.25 ± 34.75      | 167.42 ±66.70   | 0.45 ± 0.18            | 0.11 ± 0.04                 |
| Takua Pa and Thai Muang beaches (Phang Nga province)[7] | 88.55 ± 9.20 | 181.62 ±18.71 | 0.49 ± 0.05 | 0.11 ± 0.01 |

Figure 1. Frequency distribution of specific activities of (a) $^{40}$K (b) $^{226}$Ra and (c) $^{232}$Th in 50 surface beach sand samples collected from Bangsaen beach in Chonburi province (Thailand).
According to the study results in Table 2, the values of gamma absorbed dose rate (D) and radium equivalent activity (Ra\textsubscript{eq}) in Bangsaen beach were less than 55 nGy/h and 370 Bq/kg, respectively, which are the acceptable value for safe use. The values of external hazard index (H\textsubscript{ex}) obtained in this study were found to be 0.18 ± 0.01 for Bangsaen beach which were less than unity. The calculated annual effective dose (AED\textsubscript{out}) with average values 0.04 ± 0.01 mSv/y for Bangsaen beach were lower than the worldwide average value of 0.48 mSv/y as reported by UNSCEAR.

4. Conclusions
After the comparison the study results with some research data in Thailand and global radioactivity measurement and evaluations, it was found that all four radiological hazard indices (Ra\textsubscript{eq}, H\textsubscript{ex} and AED\textsubscript{out}) were lower than the recommended values. We can conclude that the radiological hazard assessment for Bangsaen beach were in the same level of natural background radiation.

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