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

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Abstract

We measured and analyzed the specific activities of ^{40}K, ^{226}Ra, and ^{232}Th in 70 surface beach sand samples collected along the Pattaya beach in Chonburi province, Thailand. The results from this study were carried out by using a high-purity germanium (HPGe) detector and low background gamma-ray spectrometry which were set-up at the advanced laboratory at Thailand Institute of Nuclear Technology (Public Organization) or TINT. The specific activities level of ^{40}K, ^{226}Ra, and ^{232}Th were found to lie in the range of 108.85 - 584.78, 4.56 - 56.98, and 4.45 - 79.17 Bq/kg with average values of 228.62 ± 9.08, 12.05 ± 0.71, 13.65 ± 1.03 Bq/kg, respectively. The frequency distribution of the specific activities of ^{40}K, ^{226}Ra, and ^{232}Th were studied and found to be the asymmetrical distribution by using a special computer program. Hence, the median values of specific activities of ^{40}K, ^{226}Ra, and ^{232}Th which were 214.65 ± 9.00, 8.43 ± 0.64, 8.94 ± 0.90 Bq/kg respectively, should be selected to be used for further studying. We also studied and calculated four radiological hazard indices for the investigated area by using these median values. Furthermore, the studied results were used to compare with some studies and literatures around the world in both national and international level. Moreover, the radioactive contour maps (RCM) of the studied area were also originated and shown in this study.

Keywords: *gamma-ray spectrometry; high-purity germanium (HPGe) detector; radioactive contour map; radiological hazard assessment; radiological hazard index; specific activity; surface beach sand.*

1. Introduction

Naturally occurring radioactive materials or NORMs usually be composed of primordial radionuclides, remaining since the beginning of the earth (United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1982). The naturally radionuclides like ^{238}U, ^{232}Th, and ^{40}K are existing everywhere in the Earth's crust. ^{40}K, ^{226}Ra, and ^{228}Ra are of most consideration because of theirs high solubility and mobility. The knowledge and information of the specific activities and frequency distributions of these radionuclides are of interest since it provides useful information in the monitoring of environmental contamination by natural radioactivity (Yii, Zaharudin, & Abdul-Kadir, 2009). The concentration of natural radionuclides in soil, beach sand and sediment depends mostly on the rock type from which they create. These natural radionuclides present exposure risks externally due to their gamma-ray emissions and internally due to radon and its progeny (UNSCEAR, 1988). According to the collective radiation exposure of the world's population, natural sources of radiation constitute about 80% (UNSCEAR, 2000). Terrestrial background radiation represents the main external source of irradiation of the human body. Hence, human beings are exposed also naturally from sources outside their bodies; mainly cosmic rays and gamma rays emitters in soil, beach sand, building materials, water, food and air (Alaamer, 2008). Once present in the environment, these radionuclides whether natural or man-made (^{137}Cs, ^{131}I, and ^{90}Sr) are available for uptake by plants and animals and find their way into human body through the food chain. For this reason, the specific activities of natural radioactivity due to gamma rays from some famous and attractive areas should be regularly concerned and measured. Some radioactivity studies have been previously carried out in soil, beach sand and sediment samples in some parts of the world (Kannan et al., 2002; Kirchner et al., 2002; Obed, Farai, & Jibiri, 2005; Patra et al., 2006; Avwiri, Enyinna, & Agbalagba, 2007; Senthilkumar et al., 2010; Zarie & Al Mugren, 2010; Saleh et al., 2013; Venunathan, Kaliprasad, & Narayana, 2016; Fares, 2017). As we know that Pattaya beach is one of the most gorgeous and attractive tourism places in Thailand kingdom. The beach is located 147 km southeast of Bangkok and be adjacent to the Gulf of Thailand as shown in Figure 1. According to annually attracts hundreds of thousands of tourists from neighboring countries and all over the world, the Pattaya beach is Thailand's principal and most flourishing beach resort in this region. Former times, only the area of Pattaya Bay known as Pattaya beach played a significant role in the tourism perspective. In present time, Pattaya has been developing to be a major business center and satisfying residence for western expatriates with the recent founding of the industrial estates of Laem Chabang to the north and that of Map Ta Phut to the south. Therefore, Pattaya beach should be the best area for studying and evaluating the specific activity of natural radionuclides and showing the assessment of some consequences of radiological hazard effect to people around the world who come to visit the excellent area.

This paper reports the specific activity of natural radionuclides ^{40}K, ^{226}Ra, and ^{232}Th and their suitable medium values for surface beach sand samples collected from Pattaya beach located in the Eastern region, Thailand. All of these results will provide useful information for estimation of the radiation exposures of human being and in monitoring of environmental radioactivity at the studied area.

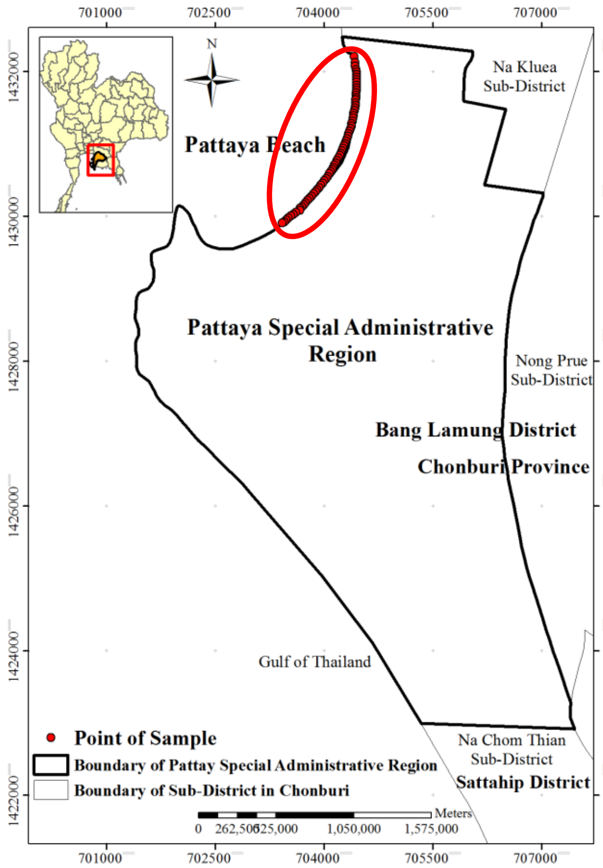


Figure 1 Geographic map and sampling locations of Pattaya beach in Chonburi province.

2. Objectives

There are five important objectives in this study which are:

2.1 Measure and analyze the specific activities of natural radionuclides (^{40}K, ^{226}Ra, and ^{232}Th) in 70 surface beach sand samples collected from Pattaya beach in Chonburi province.

2.2 Study and analyze the frequency distribution of specific activities of all radionuclides which were measured and analyzed in 2.1.

2.3 Choose the suitable medium value of the result in 2.2 and then using to assess the corresponded radiological hazard indexes for the studied area.

2.4 Compare the results to some studies and literatures in Thailand, worldwide data and recommended values.

2.5 Create the radioactive contour map (RCM) of ^{40}K, ^{226}Ra, and ^{232}Th for the investigated area.

3. Materials and methods

3.1 Sampling

Seventy (70) surface beach sand samples were examined and collected from Pattaya beach in Bang Lamung district in Chonburi province, Thailand. All beach sand samples would be taken in a similarly way, about 10–15 m from the high-tide mark towards the Pattaya beach. Each beach sand sample was taken at depth of < 10 cm from the top surface. A sampling area of 1 m^2 at each of the sample sites was considered where one wet mixed samples was taken, each weighing about 1 kg. Plastic bags were used to put the samples and then sent back to the laboratory. All 70 sampling locations were shown in Figure 1.

3.2 Sample preparations

After removing stones and other non-sample materials, the beach sand samples were weighed and then kept in a stainless steel tray for 2–3 days in open air for natural drying. Then, they were dried again in an oven at 110 °C for 3 hours, pulverized, weighed and sieved for uniform particle size (International Atomic Energy Agency (IAEA), 1989). About 500 grams of beach sand sample was kept in a PVC cylinder. By making sure of the equilibrium between ^{226}Ra and its daughters and ^{228}Ra and its daughters, the PVC container would be sealed tightly by using a strictly tape and set aside for one month before being taken for measurement and analysis. By doing this process, the radon gas would not leak from the sealed PVC container.

3.3 Sample measurements and analysis

A high-purity germanium detector (HPGe, ORTEC) and low background gamma-ray spectrometry system at Advanced Chemistry Research Laboratory in TINT were operated to measure and analyze the specific activities of natural (^{40}K, ^{226}Ra, and ^{232}Th) radionuclides in all of surface beach sand samples. The detector was enclosed in a massive 10 cm thick lead shielding. The IAEA/SOIL-375 reference material (IAEA, Vienna, Austria) which was borrowed from Office of Atom for Peace (OAP) was taken to evaluate the geometric efficiency for beach sand matrices in the container. The gamma-ray energy spectra were measured, analyzed and recorded by using the program Gamma Vision V32. The gamma-ray line of 1460.8 keV were used to evaluate the specific activity of ^{40}K; while the decay products ^{214}Pb (351.9 keV) and ^{208}Tl (583.2 keV) were used to calculate the specific activities of ^{226}Ra, and ^{232}Th, respectively. The frequency distribution of specific activities of all required natural radionuclides in the samples for the studied area could be study and analyze by using a statistic computer program. Furthermore, the suitable medium values from the frequency distribution were considered, selected and used to compare with some research data in Thailand as well as worldwide measurements and evaluations. Consequently, four radiological hazard indices for the investigated area would be also evaluated by using the selected medium values of the frequency distribution and some equations as shown in the following section. Moreover, the radioactive contour maps (RCM) of ^{40}K, ^{226}Ra, and ^{232}Th in the studied area were also created and presented in this paper.

3.4 Theory and equations

The equation (1) as shown below would be used to evaluate the value of specific activities of natural (^{40}K, ^{226}Ra, and ^{232}Th) radionuclides in all of 70 beach sand samples collected from Pattaya beach in Chonburi province:

$$S.A. = \frac{cps}{\xi \times P_\gamma \times W_t}, \quad (1)$$

Where S.A., cps, ξ, P_γ and W_t are the specific activities (Bq/kg), the net count per second (cps), the efficiency of the gamma spectrometer at the respective gamma energy, the probability of the transition of the radionuclide of interest at the respective gamma energy and the weight of the beach sand sample (kg), respectively. The “cps” was calculated using the difference between counts with samples and without samples (background). The example of the gamma-ray energy spectrum which was recorded from the beach sand sample collected from the studied area was shown in Figure 2.

By using the conversion factors presented in (Singh, Rani, & Mahajan, 2005), the absorbed dose rate (D(nGy/h)) in outdoor air at 1 m above the ground could be evaluated with the suitable medium values of specific activity of ^{40}K, ^{226}Ra, and ^{232}Th from this study and is given below

$$D\ (nGy/h) = 0.461C_{Ra} + 0.623C_{Th} + 0.0414C_K \quad (2)$$

Where C_{Ra}, C_{Th}, and C_K are the suitable medium values of specific activity of ^{226}Ra, ^{232}Th, and ^{40}K in Bq/kg, respectively. Furthermore, the radium equivalent activity (Ra_{eq}(Bq/kg)) was calculated by using the following equation (Veiga et al., 2006):

$$Ra_{eq}\ (Bq/kg) = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (3)$$

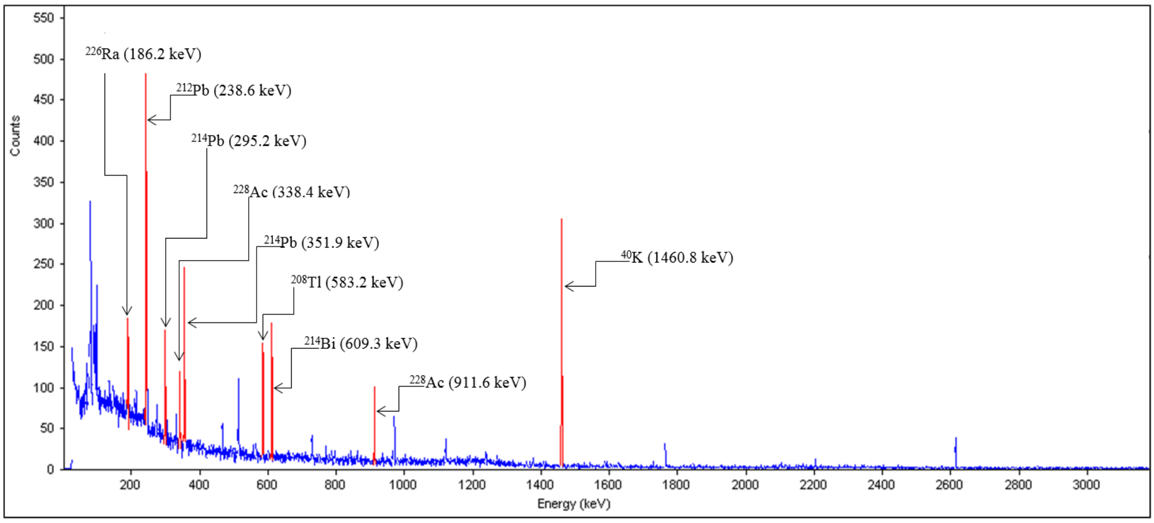


Figure 2 The example of gamma-ray energy spectrum measured from Pattaya's surface beach sand sample in Chonburi province.

Furthermore, H_{ex} which is the external hazard index for this area could be also calculated by using the equation which was defined as (Veiga et al., 2006)

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \leq 1 \quad (4)$$

By using the D (nGy/h) values which were evaluated from equation (2), taking in the conversion factor of 0.7 Sv/Gy to convert from the absorbed dose in air to the effective dose received by adults and considering that people in Thailand, on average, spend approximately 20% of their time outdoors, the annual effective dose rate (AED_{out}) would be calculated from the equation (5) as shown below (Singh, Rani, & Mahajan, 2005).

$$AED_{out}(mSv/y) = D\ (nGy/h) \times 8760\ h \times 0.2 \times 0.7(Sv/Gy) \times 10^{-6} \quad (5)$$

Moreover, the average values of all of four radiological hazard indices for the investigated area would be calculated and compared with reported values presented by some studies, literatures and OAP and worldwide averaged values reported by UNSCEAR.

4. Results and discussions

4.1 Ranges and mean values of specific activity

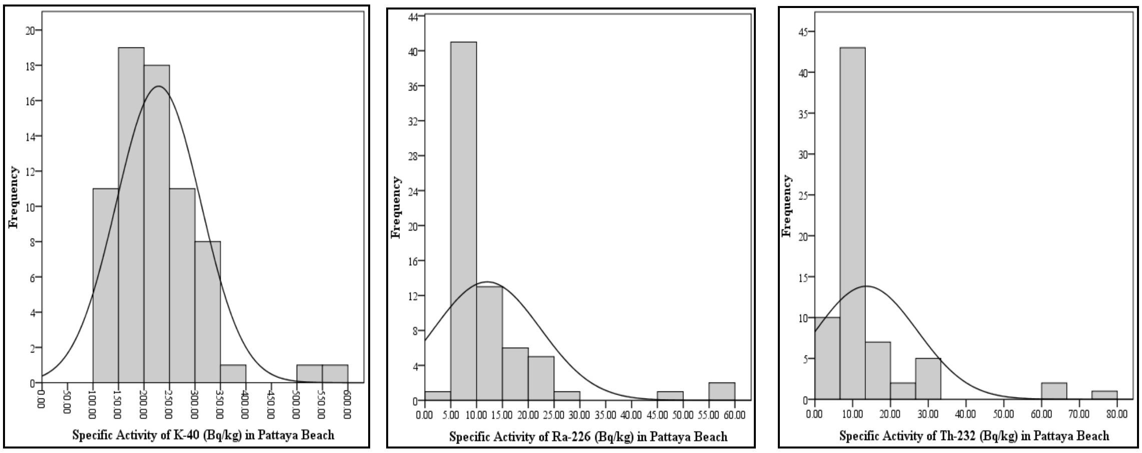
The ranges and mean values of all measured and evaluated of specific activities of three required natural radionuclides in 70 surface beach sand samples collected from Pattaya beach in Chonburi province in eastern region of Thailand were presented in Table 1.

Table 1 Specific activities ranges and mean values of ^{40}K, ^{226}Ra, and ^{232}Th in Bq/kg which evaluated in 70 surface beach sand samples collected from Pattaya beach in Chonburi province.

Surface beach Sand Samples Collected from Pattaya Beach in Chonburi Province (70 Samples)	Specific Activities (Bq/kg)		
	^{40}K	^{226}Ra	^{232}Th
Ranges	108.85– 584.78	4.56 – 56.98	4.45– 79.17
Mean values	228.62 ± 9.08	12.05 ± 0.71	13.65 ± 1.03

4.2 Frequency distribution of specific activities

By adopting the statistic computer program, the frequency distribution of specific activities of three required natural radionuclides in 70 surface beach sand samples collected from the investigated area could be studied and analyzed. The graphs of distribution from this studying were shown in Figure 3. Consequently, some important statistic values which were received from the studying were also presented in Table 2.



(a) (b) (c)

Figure 3 Graphs of frequency distribution of specific activities of (a) ^{40}K, (b) ^{226}Ra, and (c) ^{232}Th in 70 surface beach sand samples collected from Pattaya beach in Chonburi province.

4.3 Median values of natural (^{40}K, ^{226}Ra, and ^{232}Th) radionuclides

From Figure 3(a) – (c) and all calculated statistic values in Table 2, it was found that the frequency distribution of specific activities of ^{40}K, ^{226}Ra, and ^{232}Th in 70 surface beach sand samples collected from Pattaya beach in Chonburi province, were asymmetrical distribution with the skewness of 1.72, 3.20, and 3.36, respectively. For this reason, the median values of ^{40}K, ^{226}Ra, and ^{232}Th which were 214.65 ± 9.00 Bq/kg, 8.43 ± 0.64 Bq/kg, and 8.94 ± 0.90 Bq/kg, for Pattaya beach in Chonburi province, should be selected further studying and calculation some radiological hazard indices in this area.

Table 2 Some important statistic values of frequency distribution of specific activities of natural (^{40}K, ^{226}Ra, and ^{232}Th) radionuclides in 70 surface beach sand samples collected from Pattaya beach in Chonburi province (Thailand).

Statistic Values	Analyzed Values		
	^{40}K	^{226}Ra	^{232}Th
Mean (Bq/kg)	228.62	12.05	13.65
Median (Bq/kg)	**214.65**	**8.43**	**8.94**
Mode (Bq/kg)	108.85	12.00	7.21
Skewness	1.72	3.20	3.36
Kurtosis	4.98	11.14	12.27
Minimum value (Bq/kg)	108.85	4.56	4.45
Maximum value (Bq/kg)	584.78	56.98	79.17

4.4 Evaluation and comparison of radiological hazard indices

From Figure 3 and Table 2 we can see that the frequency distribution of specific activities of ^{40}K, ^{226}Ra, and ^{232}Th in 70 surface beach sand samples collected from the studied area was asymmetrical distribution with the skewness of 1.72, 3.20, and 3.36, respectively. Hence, the median values should be the suitable medium value for further studying and calculation. For this reason, four radiological hazard indices would be determined and shown in Table 3 by using the median values of ^{40}K, ^{226}Ra, and ^{232}Th which were presented in Table 2.

Table 3 Comparison of four radiological hazard indices in 70 surface beach sand samples collected from Pattaya beach in Chonburi province (Thailand) with some research literatures, OAP annual report data and worldwide average values reported by UNSCEAR.

Locations	D (nGy/h)	Ra_{eq} (Bq/kg)	H_{ex}	AED_{out} (mSv/y)
Patong beach (Phuket province) (Kessaratikoon et al., 2013)	180.56 ± 49.70	348.93 ±96.11	0.94 ± 0.26	0.22 ± 0.06
Naiyang beach (Phuket province) (Kessaratikoon et al., 2013)	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) (Kessaratikoon, Ramunset, & Boonkrongcheep, 2014)	88.55 ± 9.20	181.62 ±18.71	0.49 ± 0.05	0.11 ± 0.01
Ao Nang beach (Krabi province) (Kessaratikoon, Rhian-nui, & Boonkrongcheep, 2013)	19.41	38.33	0.10	0.02
Noppharat Thara beach (Krabi province) (Kessaratikoon, Kumnurak, & Boonkrongcheep, 2013)	18.47	36.55	0.10	0.02
Pakmeng beach (Trang province) (Kessaratikoon, Ayusuk, & Youngchauy, 2010)	17.32	37.38	0.10	0.02
Chaweng beach (Surat Thani province) (Kessaratikoon, Thaneerat, &Youngchauy, 2009)	38.80	81.24	0.22	0.05
Chalatat beach (Songkhla province) (Kessaratikoon et al., 2017)	52.14 ± 7.41	109.21 ± 14.89	0.29 ± 0.04	0.06 ± 0.01
Samila beach (Songkhla province) (Kessaratikoon et al., 2017)	64.54 ± 8.23	130.71 ± 16.51	0.35 ± 0.04	0.08 ± 0.01
Turkey (Kucukomeroglu et al., 2016)	36.92	74.42	0.20	0.05
India (Suresh Gandhi et al., 2014)	504.75	1081.86	2.92	0.62
China (Huang et al., 2015)	29.93	60.71	0.16	0.04
Malaysia (Sanusi et al., 2017)	251	424.11	1.15	0.31
Vietnam (Huy et al., 2012)	71.72	160.06	0.43	0.09
Bangsaen beach (Chonburi province) (Changkit et al., 2017)	34.94 ± 1.46	68.43 ± 3.04	0.18 ± 0.01	0.04 ± 0.00
Pattaya beach (Chonburi province)[a]	**18.33 ± 1.23**	**37.74 ± 2.62**	**0.13 ± 0.01**	**0.02 ± 0.00**
OAP (OAP, 1990-2000)	231.81 ± 2.97	512.90 ±6.30	1.39 ± 0.02	0.28 ± 0.004
UNSCEAR (UNSCEAR, 1988,1993,2000)	55	370	1	0.48

[a] Present study

From Table 3, we can see that the D and Ra_{eq} values in Pattaya beach were evaluated and found to be 18.33 ± 1.22 nGy/h and 37.74 ± 2.62 Bq/kg which were less than 55 nGy/h, and 370 Bq/kg, respectively. The values of H_{ex} for Pattaya beach received in this study were found to be 0.13 ± 0.01 which was less than unity. Furthermore, the average value of AED_{out} for Pattaya beach was also calculated and found to be 0.02 ± 0.00 mSv/y which was lower than the worldwide average value of 0.48 mSv/y as reported by UNSCEAR. Moreover, all of the average values of four radiological hazard indices were also compared with some research literatures, OAP annual report data and worldwide average values reported by UNSCEAR as shown in Table 3.

4.5 The radioactive contour maps (RCM) of the investigated area

By employing a special computer program, the RCM of ^{40}K, ^{226}Ra, and ^{232}Th in 70 surface beach sand samples collected from Pattaya beach in Chonburi province, were studied, determined and created and presented in the following Figure 4(a) – (c), respectively. It was found that the RCM of all three required radionuclides for the investigated area, were not significant different from the background radiation level.

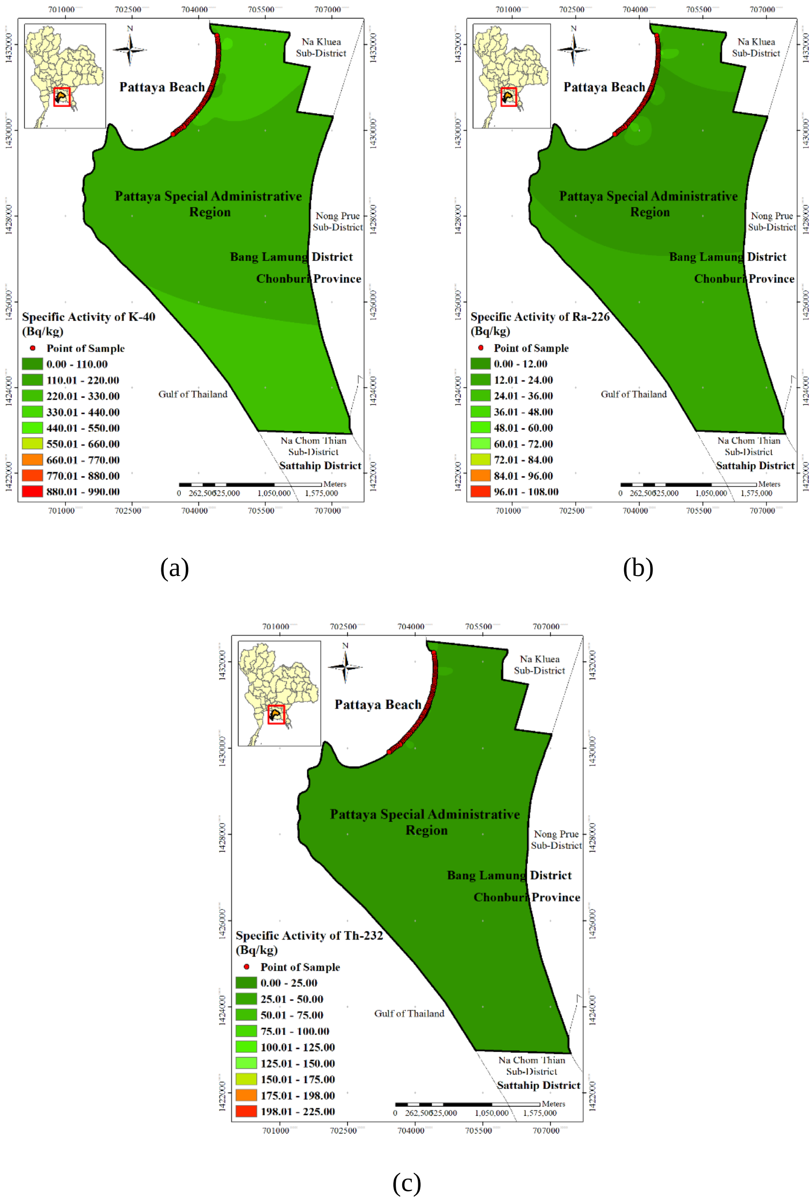


Figure 4 Radioactive contour maps (RCM) of (a) ^{40}K (b) ^{226}Ra, and (c) ^{232}Th in 70 surface beach sand samples collected from Pattaya beach in Chonburi province (Thailand).

5. Conclusion

Due to the asymmetrical distribution of specific activities of ^{40}K, ^{226}Ra, and ^{232}Th in 70 surface beach sand samples collected from Pattaya beach in Chonburi province, the median values of ^{40}K, ^{226}Ra, and ^{232}Th which were 214.65 ± 9.00, 8.43 ± 0.64, and 8.94 ± 0.90 Bq/kg respectively, were suitable chosen to evaluate the corresponding radiological hazard indices evaluation in the study area. Furthermore, all four radiological hazard indices (D, Ra_{eq}, H_{ex} and AED_{out}) in the investigated area were calculated and compared to some research data in Thailand and global radioactivity measurements and evaluations. It was found that all those radiological hazard values were significant lower than the worldwide average values. Moreover, the RCM of ^{40}K, ^{226}Ra, and ^{232}Th of the studied area were also studied, shown and found in normal level. We can conclude that the radiological hazard assessment for Pattaya beach in Chonburi province were in safety level and not much different from the level of natural background radiation.

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