ORIGINAL ARTICLE

Radionuclides Activity Concentration in Soil Samples from Residential Areas Nearby Gebeng, Kuantan

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ABSTRACT

Background: The environment today has increased the intake of harmful substance which may cause the health issue among living things. For example, the present of Rare Earth Elements (REE) in most of electronic devices and its present within industrial environment. The usage of REE might cause the production of the radioactive by-products where it may present the radiological risk to the surrounding area nearby to the source of the radioactive material. Neighbourhood and residential areas located within the short radius with industrial zone such as Gebeng, Kuantan are crucial to be concerned as they are exposed to the soil contamination form the radionuclides released during the manufacturing activity at the industrial zone. Therefore, this article aims to determine the radionuclides activity concentration in soil samples from residential areas nearby Gebeng which are Taman Sungai Ular Jaya, Taman Balok Perdana, Taman Baluk Permai and Taman Batu Hitam. **Methods:** The soil samples from four residential areas nearby the Gebeng Industrial Park were collected at the playground area of each residential areas. The rocks, pebbles, dried leaves, roots, and other foreign objects were removed prior to weighing and the sample were dried for 24 hours with 60°C to eliminate the moisture. The sample were stored in a storage room for a month under room temperature for it to reach equilibrium state. To identify the radionuclide activity, the High Sensitivity Gamma Spectrometer (GDM10) was used measure to the concentration. **Results:** The average radionuclide activity concentration for four of residential areas includes ^{40}K, ^{232}Th and ^{226}Ra were 0.584 x 10^{-6} Bq.kg^{-1}, 1.246 x 10^{-6} Bq.kg^{-1} and 2.862 x $^{10-6}$ Bq.kg^{-1} respectively. The ^{40}K was not detected in Taman Balok Perdana. ^{226}Ra was not detected in Taman Batu Hitam. **Conclusion:** The finding revealed that all soil samples contained different levels of radionuclide activity concentration. All the concentration of all radionuclides were found to be within the specific limits recommended by UNSCEAR. Taman Batu Hitam and Taman Balok Perdana recorded undetected ^{226}Ra and ^{40}K respectively while both of Taman Sungai Ular Jaya and Taman Baluk Permai demonstrated similar trend of reading with ^{40}K as the lowest average radionuclide activity concentration and ^{226}Ra as the highest.

Keywords:
radioactivity in soil; soil contamination; radionuclide level

INTRODUCTION

Radionuclides are naturally occurring radioactive elements present in the environment, including soil, water, and air. The study of radionuclides in soil is critical because their activity concentrations can directly impact human health and the environment, particularly in residential areas. Gebeng, Kuantan, known for its industrial and residential zones, has drawn attention due to its proximity to industries that may contribute to environmental radiation levels since understanding radionuclide activity concentrations in this area is vital to assess potential health risks. Limited research has been conducted to specifically evaluate residential areas near industrial hubs, such as Gebeng.

The lack of localized data on radionuclides in soil samples from these residential zones highlights a need for focused studies to address potential environmental and health implications. This study aims to measure radionuclide activity concentrations in soil from residential areas near Gebeng and compare the findings with international safety standards specifically UNSCEAR (2000). The results will provide valuable data to guide regulations, assess environmental safety, and raise public awareness about potential radiation exposure. All residential areas are located nearby one of the biggest industrial processing facilities for Rare Earth Elements (REEs) in the world, located in Gebeng, Pahang. The main component is the lanthanide concentrate (LC), which is imported to Malaysia from Australia's Mount Weld mine (Al-Areqi, Majid & Sarmani,2014).

As stated by Missimer et al. (2019) the main cause of naturally occurring radioactivity in rock and soil is from the radionuclides such as mainly the decay chains of Uranium-

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238 (^{238}U), Thorium-232(^{232}Th), and Potassium-40 (^{40}K). The parent and their daughter's radionuclides' decays are responsible for the release of radiation. The mineralogical composition of soil and rock determines their natural radiation content. Natural radioactivity is relatively high in rock made of minerals containing relatively high amounts of uranium, thorium, and potassium. The radionuclide concentrations of the parent rock are usually reflected in the soils. These were also agreed by Ahmad et al. (2015), where they mentioned that the primary sources of natural radioactivity in soil are of ^{238}U, ^{232}Th, ^{40}K, and ^{226}Ra.

MATERIALS AND METHODS

Sample Preparation

This is an experimental study on radionuclide activity concentration in soil from four selected residential areas which are Taman Sungai Ular Jaya, Taman Balok Perdana, Taman Baluk Permai, and Taman Batu Hitam. The residential areas included in this study were specifically selected based on their close proximity to the Gebeng Industrial Park, which is a significant industrial zone. The distances of these residential areas from the Gebeng Industrial Park as shown in Table 1. The collection of soil samples was carried out for one day at 4 different locations with three different times:11.00 a.m., 11.40 a.m., 12.20 p.m. and 1.00 p.m. (40 minutes interval time between each place). These times were chosen to ensure consistency in environmental conditions, such as temperature and sunlight, which can affect the moisture content and surface characteristics of the soil.

Table 1: The specifications and coordinates of the processing facilities (REE) and the four residential areas.

Point label	Description	Coordinates
Main Point (MP)	Processing facilities for rare earth elements (REE)	4.0028°N, 103.3718°E
Sample 1 (S1)	Distance from main point: 3.99km	4.0158°N, 103.4052°E
Sample 2 (S2)	Distance from main point: 5.09km	3.9570°N, 103.3693°E
Sample 3 (S3)	Distance from main point: 7.54km	3.9355°N, 103.3630°E
Sample 4 (S4)	Distance from main point: 13.3km	3.8834°N, 103.3629°E

200g of soil samples were originally collected from the four selected residential areas with similar size of area which was 30 cm x 30 cm square and a depth of 10 cm. Then, the collected sample were placed into a High-Density Polyethylene (HDPE) plastic bag, each with its label and seal. All the rocks, pebbles, plants, dried leaves, roots, and other objects were removed from all four samples using soil strainer. All samples were dried 24 hours under 60 °C using the dehydrator to eliminate any moisture. The dried samples were then crushed by using mortar and pestle until it became powder. The digital weighing scale was used to measure 30g of the soil samples from each of the residential areas and they were placed into three different containers according to the respective residential areas. In total there were 12 containers which, 3 containers for each residential area. Each container was labelled accordingly and were stored in a storage room for a month under room temperature for it to reach equilibrium state. The radionuclide activity concentration of the samples then were identified and compared with the standard value given by UNSCEAR (2000).

Radioactivity Count

The collected samples from the four residential areas radionuclide activity were counted by using High Sensitivity Gamma Spectrometer Model GDM 10-C which then followed by the analysis using the WinDas Software version 3.4.20. The detector or also known as a scintillation detector, consists of a cylindrical NaI crystal. The measurements of height and the diameter of the crystal is 5cm. The energy resolution is less than 7.0 % Full Width Half Maximum (FWHM) at 661 keV. Meanwhile the high-voltage supply is 10-1500 V which can be adjustable continuously by a 10-turn potentiometer. The Cobalt (Co-60) at 1173.2 keV and 1332.5 keV was used for the calibration purpose to ensure an accurate functioning of the detectors.

The radioactivity concentration was quantified after each sample was run for 43,200 (12 hours) seconds using the GDM 10-C in order to minimize statistical uncertainty. Meanwhile, the background radiation was quantified by the absence of the 12 samples. The net counts for each sample were calculated by subtracting each sample count with the background counts. The mean value for the four residential area soil sample count, were calculated by taking the counts for three sample in each of the area.

Data Analysis

The radioactivity concentration in $Bq.kg^{-1}$ for each sample were calculated using the Equation 1 as given by Sedeeq et al. (2019):

$$\text{Activity concentration } (Bq.kg^{-1}) = \frac{(Net\ count)}{\varepsilon \times I\gamma \times t \times m} \quad (1)$$

Where, $I\gamma$ = emission probability per decay of the specific peak
ε = absolute gamma peak efficiency for the detector at a particular photopeak
t = is the counting time in seconds
m = mass of the sample in kilogram.

The specific activity of the sample that have different amount of ^{40}K, ^{232}Th and ^{226}Ra was compared by using one value which is the radium equivalent Ra_{eq} by using the Equation 2 given by Sedeeq et al. (2019):

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \quad (2)$$

where, A_{Ra} = activity concentration of ^{226}Ra
A_{Th} = activity concentration of ^{232}Th
A_{K} = activity concentration of ^{40}K

The external hazard index (H_{ext}) is used to regulate radiation exposure for the annual effective dose to be limited to below 1 mSv per year. The external hazard index (H_{ext}) can be calculated by using the Equation 3 from Missimer et al. (2019):

$$H_{ext} = \frac{A_{Ra}}{370Bq.kg^{-1}} + \frac{A_{Th}}{259Bq.kg^{-1}} + \frac{A_{K}}{4810Bq.kg^{-1}} \quad (3)$$

RESULT

The activity concentration for ^{40}K was found in three of the areas except Taman Balok Perdana. The range of ^{40}K is from 0.839×10^{-6} $Bq.kg^{-1}$ to 3.061×10^{-6} $Bq.kg^{-1}$. As for the activity concentration for ^{232}Th, it can be found in all samples and the highest average activity concentration value was at Taman Baluk Permai. Meanwhile the lowest activity concentration of ^{232}Th was at Taman Batu Hitam. The result also indicated that ^{226}Ra activity concentration was not detected in the soil samples from Taman Batu Hitam while Taman Balok Perdana recorded the highest ^{226}Raactivity concentraton among the sampled locations. The activity concentrations of all involved radionuclides in soil samples are shown in Table 2.

Table 2: The activity concentrations of radionuclides ^{40}K, ^{232}Th and ^{226}Ra in soil samples

Location	**Activity Concentration × 10^{-6} ($Bq.kg^{-1}$)**		
	^{40}K	**^{232}Th**	**^{226}Ra**
Taman Sungai Ular Jaya	3.061	3.663	ND
	ND	ND	3.929
	ND	0.169	ND
Average	1.020	1.277	1.310
Taman Balok Perdana	ND	0.117	2.170
	ND	2.514	ND
	ND	0.482	17.194
Average	-	1.038	6.455
Taman Baluk Permai	1.037	3.123	ND
	ND	ND	11.046
	0.839	3.104	ND
Average	0.625	2.076	3.682
Taman Batu Hitam	ND	0.467	ND
	2.073	0.560	ND
	ND	0.755	ND
Average	0.691	0.594	-
Minimum	0.625	0.594	1.310
Maximum	1.020	2.076	6.455
Mean	0.584	1.246	2.862

*ND: Not Detectable

The activity concentrations of radionuclides ^{40}K, ^{232}Th and ^{226}Ra in all soil samples are compared to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000). All of the samples showed that the values obtained for ^{40}K, ^{232}Th and ^{226}Ra were lower than the UNSCEAR specified values of 400 $Bq.kg^{-1}$, 30 $Bq.kg^{-1}$ and 35 $Bq.kg^{-1}$ respectively.

All activity concentration of ^{40}K, ^{232}Th and ^{226}Ra from each residential area shows values that are very close to zero, hence the percentage deviation is large or is considered as 100% percentage deviation from the specified values by UNSCEAR. The percentage deviation with the UNSCEAR specified limit is shown in Table 3.

Table 3: The percentage deviation with UNSCEAR specified limit.

Location	Percentage Deviation with UNSCEAR Specified Limit (%)		
	^{40}K	^{232}Th	^{226}Ra
Taman Sungai Ular Jaya	100	100	100
Taman Balok Perdana	-	100	100
Taman Baluk Permai	100	100	100
Taman Batu Hitam	100	100	-

The Radium equivalent (Ra_{eq}) value at Taman Balok Perdana was found to be the highest among all the residential areas investigated, although it remains well below the maximum recommended safety limit of 370 Bq.kg$^{-1,}$ as stated by UNSCEAR. This suggests that while the Ra_{eq} at Taman Balok Perdana is elevated compared to other locations, it still falls within the safe range for human exposure. On the other hand, Taman Batu Hitam exhibit the lowest Ra_{eq} indicating a comparatively lower presence of radium in the soil in this residential area.

When examining the External Hazard Index (H_{ext}), Taman Balok Perdana again recorded the highest value, reflecting a slightly higher potential for external radiation exposure. Taman Batu Hitam had the lowest H_{ext} indicating a minimal external radiation hazard. Despite these variations, all residential areas studied had a H_{ext} value of less than 1, which signifies that the annual radiation dose received by individuals in these areas is below 1 mSv that is the threshold for additional risk of adverse health effects. The detailed Ra_{eq} and H_{ext} values for the soil samples from the different residential areas are provided in Table 4.

Table 4: The Radium equivalent (Ra_{eq}) and External hazard index (H_{ext})

Location	Activity Concentration × 10^{-6} (Bq.kg^{-1})			Ra_{eq} × 10^{-6} (Bq/kg)	H_{ex} × 10^{-9}
	^{40}K	^{232}Th	^{226}Ra		
Taman Sungai Ular Jaya	1.020	1.277	1.310	3.144	8.990
Taman Balok Perdana	ND	1.038	6.455	7.940	11.454
Taman Balok Permai	0.625	2.076	3.682	6.701	18.778
Taman Batu Hitam	0.691	0.594	ND	0.901	2.437
Minimum	0.625	0.594	1.310	0.901	2.437
Maximum	1.020	2.076	6.455	7.940	18.778
Mean	0.584	1.246	2.862	4.672	10.415

*ND: Not Detectable

CONCLUSION

This experiment aims to measure the radionuclides activity concentrations in soil samples collected from four selected residential areas in Gebeng, Kuantan by using GDM-10C and doing a comparison with the UNSCEAR (2000) recommendation limit. The findings reveal that all the soil samples have various levels of radionuclide activity concentrations with some samples showing concentrations that are below the detection limit for ^{40}K, ^{232}Th and ^{226}Ra. This study's findings might be different from other previous studies, which potentially might be influenced by sample size and detector sensitivity. However, the radionuclide activity concentrations of ^{40}K, ^{232}Th and ^{226}Ra are within the UNSCEAR acceptable threshold.

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