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NATURAL RADIOACTIVITY IN MAJOR RIVERS OF KELANTAN STATE, MALAYSIA

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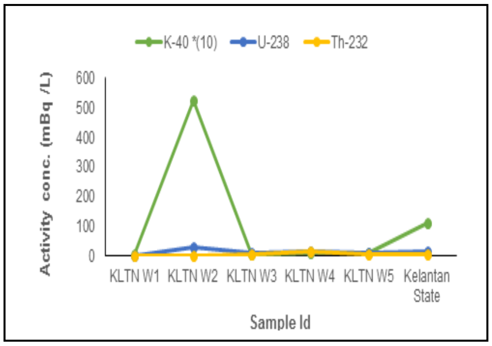
Graphical abstract



Abstract

Assessment of natural radionuclides (^{238}U, ^{232}Th, and ^{40}K) and terrestrial gamma radiation dose rates (TGRD) in major rivers of Kelantan states, Malaysia were conducted. Measurements were carried out using a portable [NaI(Tl)] micro roentgen (μR) survey meter and inductively coupled plasma mass spectrometer (ICP-MS) for in situ TGRD and the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in water samples, respectively. The mean TGRD was found to be 312.98 nGy h^{-1} and from water samples analyzed, the mean activity concentrations of ^{238}U, ^{232}Th, and ^{40}K was found to be 13.31 mBq L^{-1}, 4.39 mBq L^{-1} and 1118.72 mBq L^{-1} which were about 3 times and slightly higher than the world average values of 5 mBq L^{-1} and 3 mBq L^{-1} respectively.

Keywords: Radioactivity, ICP-MS, Major Rivers, TGRD, AGDE

1.0 INTRODUCTION

Water is the most abundant substance on earth and is the principal constituent of all living things. Man uses water for many purposes such as power generation, agriculture and above all for domestic purposes.

Water for human consumption should be free from chemical, microbiological and radiological contamination [1]. Radioactivity in terrestrial, fresh water and marine media arises mainly from the primordial radionuclides decay series of ^{238}U, ^{232}Th and ^{40}K. Radiological impact assessment to the population in both human and non-human biota system as a result of radiation emitted by these natural radionuclides is important, since they contribute to the collective dose of the population [2, 3]. Exposure to ionizing radiation from natural sources is a continuous and unavoidable feature of life on earth [4].

In order to limit radiation exposure to members of the public as low as reasonably as achievable (ALARA), assessment of radionuclide concentrations in water has become necessary. [5]. Radiation exposure through water may be due to ingestion (drinking water) and inhalation (from household water), both of these mechanisms pose potential health hazard [6-8]. This study is the first of its kind, which aim to measure the natural radionuclides levels in major rivers of Kelantan State, Malaysia. The data obtained will be useful in assessing the radiological health implications associated with the natural radionuclides, which will be needed in formulating safety standards and national guidelines for Malaysia in light of international recommendations.

2.0 EXPERIMENTAL

2.1 Study Area

Kelantan state is located in the North-Eastern part of Peninsula Malaysia, covering latitude 4^0 0' to 5^0 15' N and longitude 101^0 15' to 102^0 45'. It is tropic with temperature ranges from 21 to 32 °C and intermittent rain fall throughout the year. It is located on granites set which is undifferentiated intrusive rock [9, 10]. The state consists of eight underlying geological formations (Table 1) which was overlain by twelve soil types (Table 2).

Table 1 Geological formations of Kelantan [11, 12]

S/N	Name	Description
1	Quaternary (1)	Composed of continental and marine deposits with unconsolidated sand mainly marine.
2	Quaternary (2)	Composed of continental and marine deposits with unconsolidated silt and clay (main).
3	Quaternary (4)	Consists of marine and continental deposits with unconsolidated clay, silt, sand and gravel undifferentiated.
4	Triassic (14)	Characterized by lithologies consisting of interbedded sandstone, silt, shale, conglomerate and chert.
5	Permian (21)	Consists of shale, slate, and phyllite with subordinate schist and sandstone. It developed of limestone through the succession. Rhyolitic, volcanic to andesitic in composition widespread, with unconsolidated deposit of ignimbrite.
6	Permian (22)	Consists of Permian (21), with unconsolidated deposit of ignimbite.
7	Silurian Ordovician (35)	Underlain by acid intrusion and overlain by Triassic which shows that the area has a contact with sea water being leached out under pressure.
8	Acid Intrusive (38)	Consists of undifferentiated igneous rocks; they are mostly granitic rocks.

Table 2 Soil types of Kelantan [12, 13]

Soil type label	FAO UNIT	Local Name
1	Humic Podzols -Dytstric Fluvisols	Rudua- Rusila
10	Dystric Histosols	Gambut
11	Dystric Fluvisols - Dystric Gleysol	Telemong Akob- Tanah Lanar Tempatan
12	Haplic Acrisol- Haplic Acrisol-Gleyic Luvisol	Tokyong- Chempaka – lundang
13	Dystric Fluvisols- Gleyic Acrisol	Lubok itek- lubok sending
14	Gleyic Nitosols- Acric Ferralsols	Batu Hilam- Kampong Tepus- Sungai Amin
17	Xanthic Ferrasols -Dystric Gleysols	Holyrood Lunas
25	Plinthic Ferralsols- Plinthic Ferralsols- Plinthic ferralsol	Melaka- Tavy- Gajah Mati
32	Dystric Nitosols - Orthic Ferrasols	Rengam Jerangau
37	Ferric Acrisols- Orthic Ferralsols	Batang Merbau – Munchong
39	Ferric Acrisols- Orthic Ferralsols- Ferric Acrisols	Durian – Munchong – Bungor
4	Steep land	Tanah churam

2.2 Sample Collection

2 liters of water samples were collected each from major rivers in Kelantan. A total of five samples were collected and the coordinates of each of the sampling locations were recorded with the aid of Global Positioning System, Garmin (GPS Map76). The samples were collected in an airtight plastic bottles with minimal aeration, and about 2 mL of nitric acid (HNO_3) were added to avoid ions from being

adsorbed to the bottle wall [14] and then transported to the laboratory for preparation and analysis.

2.3 Sample Preparation and Analysis

The samples were filtered through a Whatman no.42 filter paper and then 10 mL of each sample was placed in a test tube for analysis. The analysis was performed using an inductively coupled plasma mass spectrometer (ICP-MS) instrument model ELAN 6000 at the Malaysian Nuclear Agency. A blank solution was run to estimate the background activity of ^{238}U, ^{232}Th and ^{40}K due to the system. The measurement procedure includes use of calibration standard and two quality control (QC) samples for each set of the samples.

3.0 RESULTS AND DISCUSSION

A details TGRD assessment of Kelantan was conducted by Garba *et al*. [12], and reported a mean TGRD values of 209 nGy h^{-1} and 150 nGy h^{-1}, which was more than twice the world average value of 59 nGy h^{-1}. Due to the anomaly observed in the measured TGRD, it was expected that water resources of the area might be affected by this high background radioactivity usually caused by uranium and thorium.

The activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the samples measured using ICP-MS technique and the measured TGRD at each sampling point were presented in Table 3. The mean activity concentration of ^{238}U, ^{232}Th and ^{40}K were found to be 13.31 mBq L^{-1} and 1118.72 mBq L^{-1}, respectively. It can be seen from (Table 3) that the mean activity concentrations of ^{238}U and ^{232}Th (13.31 and 4.39) mBq L^{-1} in Kelantan rivers are about 3 times and slightly higher than the world average values of 5 mBq L^{-1} and 3 mBq L^{-1} respectively [15], and are also about 15 and 88 times higher than the corresponding values reported for New York City which was 0.9 mBq L^{-1} and 0.05 mBq L^{-1} for ^{238}U and ^{232}Th respectively [16] and 3 and 2 times higher than that of north western

Table 3 Activity concentrations of ^{238}U, ^{232}Th and ^{40}K and measured TGRD rates

Location	Sample Id	D (nGy h^{-1})	^{40}K (mBq L^{-1})	238U (mBq L-1)	^{232}Th (mBq L^{-1})	(^{232}Th/^{238}U) Ratio
Hutan Rizab Gunung Sabab	KLTN W1	413.25	68.92 ± 0.91	0.79 ± 0.01	0.36 ± 0.04	0.46
Kolam Air Panas Batu Melati	KLTN W2	380.63	5259.85 ± 151.15	31.66 ± 5.42	0.44 ± 0.04	0.01
Kg. Pasar Era	KLTN W3	326.25	72.55 ± 0.06	10.68 ± 0.06	3.38 ± 0.01	0.32
Kg. Sg. Sok	KLTN W4	324.08	99.15 ± 0.06	14.17 ± 0.49	13.19 ± 0.04	0.93
Kg. Rela Jabo	KLTN W5	120.71	93.11 ± 0.30	9.25 ± 0.26	4.56 ± 0.24	0.49
Kelantan State	**Mean**	**312.98**	**1118.72 ± 30.71**	**13.31 ± 1.25**	**4.39 ± 0.07**	**0.33 ~ 1:3**

Pakistan with the values of 3.9 mBq L^{-1} and 2 mBq L^{-1} as well as about 1.5, 2 and 4 times higher than those reported for Pahang rivers, Malaysia which are 8.49 mBq L^{-1}, 1.74 mBq L^{-1} and 77 mBq L^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively [17, 18].

This can be attributed to the geological formations of Kelantan which is predominantly granitic in nature. Granites and metamorphic areas are rich in uranium, thorium and potassium with uranium having higher transfer potential to water due to high solubility of some of its compound [19]. Previous studies in other areas shows high concentration of uranium, thorium and potassium in areas covered by granites and metamorphic rocks [20, 21]. The mean ratio of thorium to uranium (Th/U) concentration in the rivers were found to be 0.33 and 0.32 which stands for 1:3 for both rivers, and this is due to the higher solubility of uranium in water.

A graph showing the variation of 238U, 232Th and 40K concentrations of in the major rivers was plotted and presented below as Figure 1.

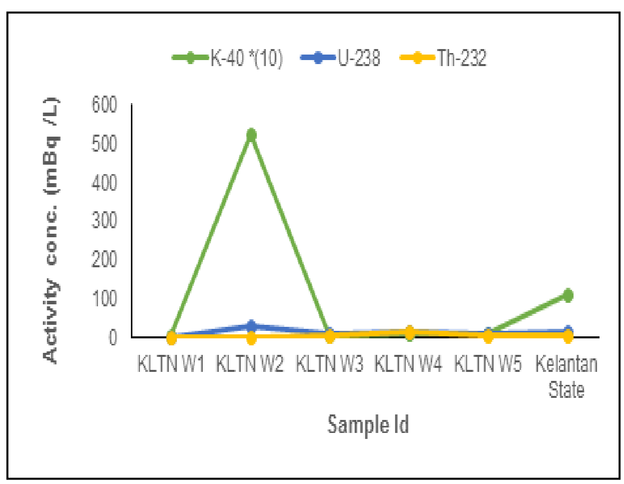


Figure 1 Activity concentrations of ^{238}U, ^{232}Th and ^{40}K

High concentrations of ^{238}U and ^{40}K in Kelantan was observed in sample with Id KLTN W2 which was collected from Kolam Air Panas Batu Melati (Hot Spring) with a value of 5259.85 and 31.66 mBq L^{-1} respectively, which flows and spread over a granitic rock and serve as a tourist attraction site while high ^{232}Th concentration was observed in sample with Id KLTN W4 collected from Kg. Sg. Sok with a value of 13.19 mBq L^{-1}, which exceeded the world average values of 5 mBq L^{-1} and 3 mBq L^{-1} respectively [15], while low concentrations ^{238}U and ^{232}Th were observed in sample with Id KLTN W1 and that of ^{40}K in sample with Id KLTN W5 collected from Hutan Rizab Gunung Sabab and Kg. Rela Jabo respectively both in Kelantan with respective values of 0.79, 0.36 and 120.71 mBq L^{-1}.

However, the high concentrations of the radionuclides observed in some of the samples collected can be attributed to geological formations of the areas which mostly consists of granites and gneisses which contained high concentration of ^{238}U, ^{232}Th series and ^{40}K [5] while some may be due to continuous movement of water from nearby granitic region. Samples with Id's KLTN W2 and KLTN W4 were collected from areas underlain by acid intrusive and Triassic geological formations. These areas have high TGRD of values 380.63 nGy h^{-1} and 324.08 nGy h^{-1} respectively. On the other hand with the lowest value for both ^{238}U and ^{232}Th were from areas dominated by Carboniferous geological formation which was known to be originated from sedimentary rocks than that originated from igneous rock.

4.0 CONCLUSION

TGRD and ^{238}U, ^{232}Th and ^{40}K activity concentrations in major rivers of Kelantan was carried out. The mean TGRD was found to be 312.98 nGy h^{-1} with specific activity concentrations of ^{238}U, ^{232}Th and ^{40}K found to be 13.31 mBq L^{-1}, 4.39 mBq L^{-1} and 1118.72 mBq L^{-1} for Kelantan respectively. The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K obtained was found to be about 3 times and slightly higher than the world average values of 5 mBq L^{-1} and 3 mBq L^{-1} respectively, which can be attributed to the geological formations in the state which was predominantly granitic in nature.

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