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ASSESSMENT OF NATURAL RADIONUCLIDES IN RIVERS OF PAHANG STATE MALAYSIA

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ABSTRACT

Investigations were conducted to determine the radionuclide concentration levels in the major rivers in Pahang state, Malaysia. Since the rivers are the main sources for water supply in the state, it is important to measure natural radionuclide concentrations in the rivers. Seventeen water samples were collected from major rivers in Pahang state. The concentration of uranium, thorium and potassium were analyzed using inductively coupled plasma mass spectrometer (ICP-MS). The samples were found to contain permissible levels of radionuclides with a mean activity concentrations of uranium, thorium and potassium found to be 8.49 ± 0.34 mBq L^{-1}, 1.74 ± 0.27 mBq $L^{-1}$and 77.85 ± 0.96 mBq L^{-1}respectively. The ratio between thorium and uranium concentration is found to be 3:4 due to the higher solubility of uranium than thorium in water. Radionuclide concentrations obtained were compared with the terrestrial gamma radiation dose rate measured around the area. A good relation was observed between uranium and thorium concentrations with gamma dose rate obtained around the area while no relation was found between the potassium concentrations with gamma dose rate. Significance of the results obtained is discussed.

Keywords; river water; natural radionuclides concentrations; geological formations; activity concentrations

1.0 INTRODUCTION

Natural radioactivity in marine and aquatic media mainly comes from the uranium and thorium series and from potassium [4]. In aquatic ecosystem radionuclides are found in very low concentrations and normally range from 10^{-15} to 10^{-20} molars. In spite of low concentration in the aquatic environment, the aquatic behavior of radionuclides plays an important role, since water is crucial to life and it is one of the prime agents that help to move and distribute elements on earth. Consequently, the aquatic ecosystem greatly affects as well as is affected by the fate of radioactive substances [8].

Assessment of radionuclide concentrations in water is important in the effort to limit radiation exposures to members of the public to be as low as reasonably achievable. Some radionuclides in water can be released into indoor air through cooking, showers, humidifiers, clothes washer, and dishwasher [1]. Exposure by radioactivity of water may occur due to ingestion (drinking water) and also due to inhalation (from household water). Both of those mechanisms pose potential health hazard [12], [14] and [15]. Protection of population against high concentration of radionuclides in water is recognized in most countries.

Granites and metamorphic areas are rich in uranium, thorium and potassium. Uranium especially has higher potential to be transferred to water due to higher solubility of some of its compound [5]. From the previous study on environmental radiology, higher concentration of uranium, thorium and potassium in soil were found in areas that are covered by granites and metamorphic rocks [9] and [10]. Natural radionuclide migrates from terrestrial sources into water through weathering.

This study presents an assessment of the level of natural radionuclides in the rivers of Pahang state, Malaysia. For this purpose, the radioactivity concentration from natural radionuclides was determined in water samples collected from the major rivers in the state. The relation between the radionuclides concentration and gamma dose rates around the area were investigated. These results were compared with the previous works.

2.0 STUDY AREA

Pahang is the largest State in Peninsular Malaysia. It covers an area of 36,137 km^2 with a population of 1,500,817 inhabitance [3]. It is located between latitudes 2° 29’ and 4° 46’ North and longitudes 101° 20’ and 103° 37’ East. Pahang state can be divided into eight major geological groups of different geological age [2] as shown in Figure 2.1 and Table 2.1. The geological features are (a) Quaternary (b) Jurassic (c) Triassic (d) Permian (e) carboniferous (f) Devonian (g) Siurian Ordovician and (h) Acid intrusive geological formations. Quaternary, Triassic and acid intrusive geological features are the most abundant in Pahang state.

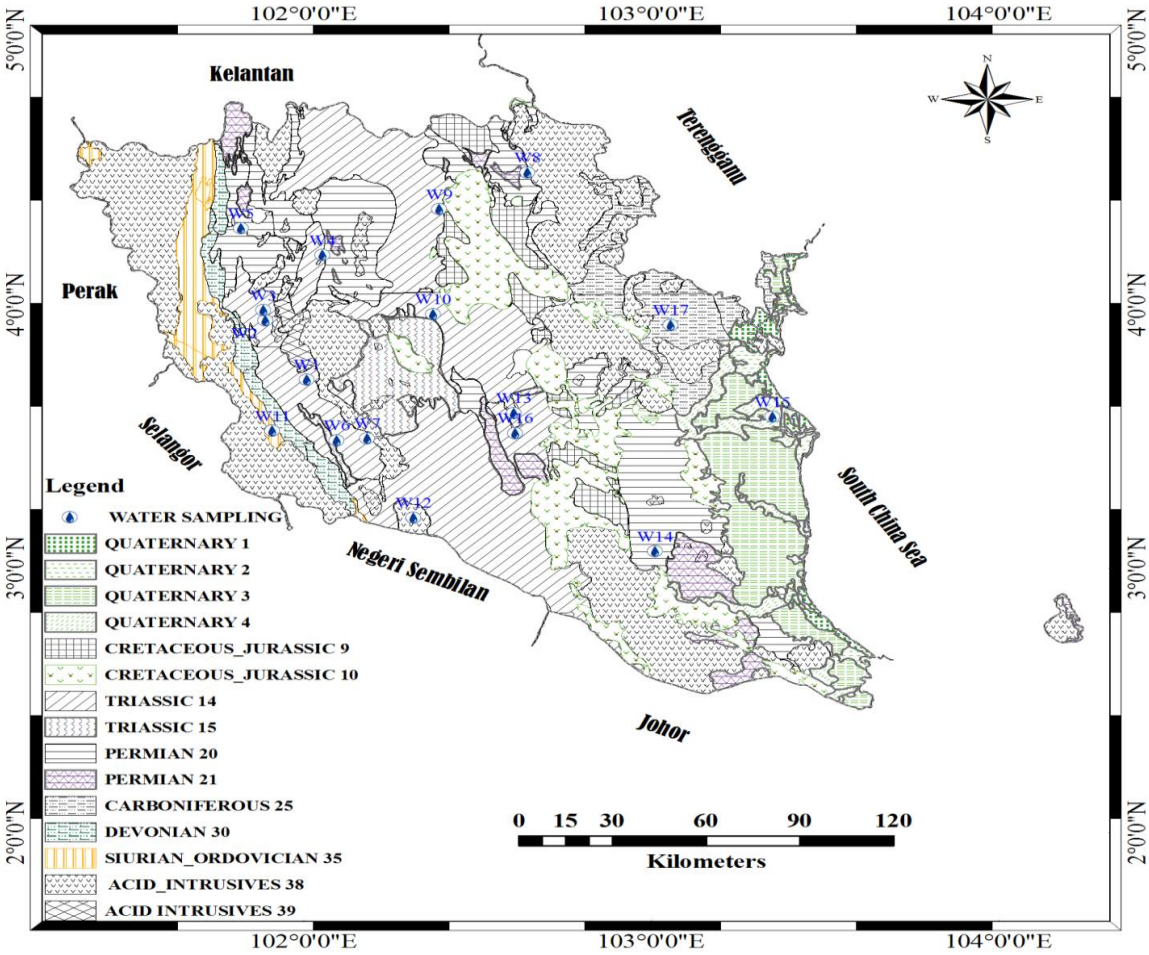

Figure 2.1 Geology map of pahang state showing sampling locations [2]

Table 2.1 Geological formations in Pahang state

GEOLOGY TYPE	GEOLOGY NAME	DESCRIPTION
(1)	Quaternary	Composed of continental and marine deposits with unconsolidated sand
(2)	Quaternary	Composed of continental and marine deposits with unconsolidated silt and clay
(3)	Quaternary	Composed of continental and marine deposits with unconsolidated humic clay, peat and silt.
(4)	Quaternary	Composed of continental and marine deposits with unconsolidated clay, sand, silt and gravel-undifferentiated.
(9)	Cretaceous-Jurassic	Composed of thick, cross – bedded sandstone with subordinate conglomerate and shale/ mudstone
(10)	Cretaceous-Jurassic	Cretaceous-Jurassic (9) with metamorphic and sedimentary rocks of sandstone/metastone.
(14)	Triassic	Composed of interblended sandstone, siltstone and shale; widespread volcanic.
(15)	Triassic	Triassic (14) with extrusive rocks deposits of acid to intermediate volcanic
(20)	Permian	Composed of shale, slate, and phyllite with subordinate schist and sandstone.
(21)	Permian	Permian (20) with extrusive rocks deposits of intermediate to basic volcanic.
(25)	Carboniferous	Composed of phyllite, slate and sandstone; argillaceous rock are commonly carbonaceous.
(35)	Devonian	Composed of phyllite, schist and slate; limestone and sandstone locally prominent.
(30)	Silurian-Ordovician	Composed of schist, phyllite, slate and limestone. Minor intercalations of sandstone and volcanic.
(38)	Acid Intrusive	Composed of undifferentiated igneous rock with acid intrusive;
(39)	Intermediate Intrusive	Composed of undifferentiated igneous rock with intermediate intrusive.

3.0 MATERIALS AND METHODS

The water sampling was carried out of seventeen locations on rivers that are sources for water supply and where there are fishing activities in the state. The study covered the main rivers of Pahang state with locations as shown in Figure 1. 2 L of water was collected from the surface water of these rivers. The water was then placed in airtight bottles with minimal aeration. About 2 mL of nitric acid (HNO3) were added to avoid ions from being adsorbed to the bottle wall [11].

The water samples collected were filtered through a Whatman no.42 filter paper; 10 mL of the water sample was put in the test tube to be analyzed. The inductively coupled plasma mass spectrometer (ICP-MS) instrument model ELAN 6000 was used in determining radionuclide concentration in the water. The samples analyses were performed at Nuclear Malaysia (NM). A blank solution was run to estimate the amount of uranium, thorium and potassium due to the system. The measurement procedure includes use of calibration standard and two quality control (QC) samples for each set of seventeen river water samples.

4.0 RESULT AND DISCUSSION

Extensive radiological survey was carried out in Pahang state [6]. The terrestrial gamma radiation dose rate ranged from 26 nGy h^{-1} to 750 nGy h^{-1} with a mean value of 176 nGy h^{-1}. The area has anomalous terrestrial radioactivity, it was expected that water resources of the area might be affected by this high background radioactivity caused by uranium and thorium. The concentrations of uranium, thorium and potassium in river water using ICP-MS technique and gamma dose rates around the area are presented in Table 4.1. The mean value for uranium and thorium activity concentrations in Pahang rivers are (8.49 ± 0.34) mBq L^{-1} and (1.74 ± 0.27) mBq L^{-1} (Table 4.2) which is higher compared to the value for New York City; 0.9 mBq L^{-1} and 0.05 mBq L^{-1} respectively [13] and two times higher than that of north western Pakistan with the values of 3.9 mBqL^{-1} and 2 mBq L^{-1} respectively [7]. The world averages for uranium and thorium activity concentrations are 5 mBq L^{-1} and 3 mBq L^{-1} respectively [8]. The mean ratio of Th:U concentration in the rivers of Pahang state is 3:4. This is due to higher solubility of uranium in water.

Figure 4.1 and 4.2 shows the bar chart for uranium, thorium and potassium concentration in the river water samples in Pahang State. Figure 4.1 shows that Uranium and Thorium concentrations in water samples vary. Sample W7 has the highest concentration of uranium and sample W17 has the lowest. Sample W12 has the highest concentration of Thorium and sample W17 has the lowest. In figure 4.2sample W3 has the highest concentration of potassium while sample W9 has the lowest.

Table 4.1 The activity concentrations of ^{238}U, ^{232}Th ^{40}K and dose rates around.

S/N	Name Of River	Sample Id.	Dose Rate Around the area (nGy h^{-1})	^{238}U (mBq L^{-1})	^{232}Th (mBq L^{-1})	^{40}K (mBq L^{-1})	Ratio Th/U
1	Sg. Temir	W1	381	5.91±0.12	1.21±0.08	61.36±0.30	0.6
2	Sg. Lipis	W2	203	5.54±0.49	2.18±0.32	132.10±6.35	1.2
3	Sg. Dong	W3	104	8.62±0.25	1.41±0.16	305.31±1.81	0.5
4	Sg. Jelai	W4	232	8.99±0.37	1.05±0.48	63.48±0.30	0.4
5	Sg. Koyan	W5	257	4.68±0.25	0.48±0.20	53.20±0.30	0.3
6	Sg. Semantan	W6	178	12.81±0.12	2.26±0.28	129.98±0.60	0.5
7	Sg. Cermang	W7	500	31.54±0.49	4.32±0.28	117.89±1.51	0.4
8	Sg. Tembeling	W8	228	2.83±0.62	1.57±1.57	33.55±0.30	1.7
9	Kuala Tahan	W9	235	4.19±0.49	0.60±0.08	30.83±0.30	0.4
10	Sg. Jerantut	W10	84	7.27±0.37	1.05±0.24	44.13±0.30	0.4
11	Sg. Bentong	W11	185	9.12±0.25	1.09±0.08	39.30±0.30	0.4
12	Sg. Pekan Bera	W12	522	19.71±0.62	6.17±0.20	35.97±1.21	1.0
13	Kg. Denai	W13	65	3.08±0.49	1.61±0.32	53.81±0.30	1.6
14	Kg. Avv.	W14	72	3.82±0.12	2.22±0.12	84.04±0.30	1.8
15	Kg. Pulan Serai	W15	174	6.90±0.25	1.21±0.04	52.90±1.21	0.5
16	Kg. Sanding	W16	201	8.01±0.12	0.81±0.12	47.46±0.30	0.3
17	Sg. Lembing	W17	178	1.36±0.37	0.40±0.04	38.09±0.60	0.9
	Mean		**224 ± 32**	**8.49±0.34**	**1.74±0.27**	**77.85±0.96**	**0.76 ~ 3:4**

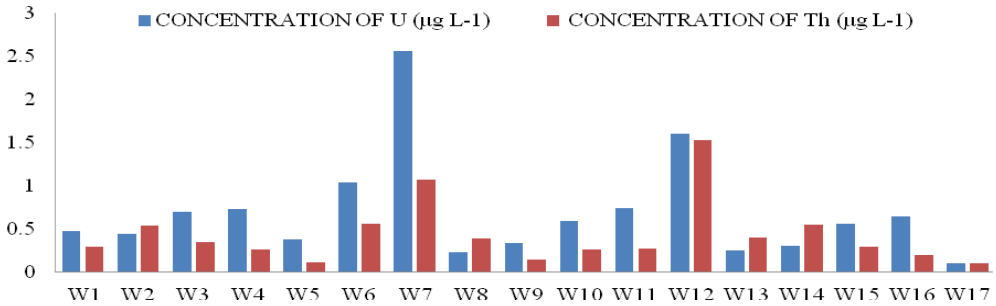

Fig. 4.1 Uranium and thorium concentrations in rivers of the Pahang State-(µg L^{-1})

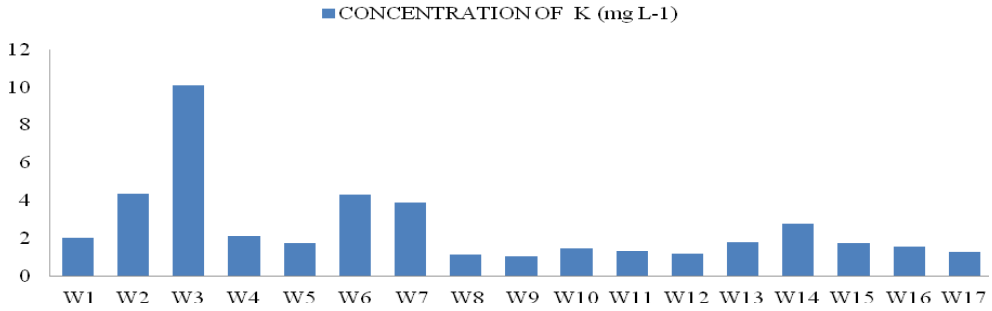

Fig. 4.2 Potassium concentrations in river of the Pahang State-(mg L^{-1})

Higher concentration of radionuclides in some of the samples collected are attributed to geological areas consisting of granites and gneisses which contain higher concentration of ^{238}U, ^{232}Th series and ^{40}K [1] while some may be due to continuous movement of water from nearby granitic region. Samples W7 and W12 were collected from Sg. Pahang and Sg. Pekan-Bera. Sample W12 is underlain by acid intrusive G38, sample W7 is underlain by Triassic 14 geological structure but is adjacent to acid intrusive formation (Figure 2.1). These areas have high terrestrial gamma dose rate of 522 nGy h^{-1} and 500 nGy h^{-1} respectively. Sample W17 on the other hand with the lowest value for both uranium and Thorium and was collected from Sg. Lembing. The collection point has a gamma dose rate of 178 nGy h^{-1} and is underlay by Carboniferous (G25) geological formation. Sample W3 and W9 were collected from Sg. Sengkela and Sg. Kuala Tahan with underlying Triassic (G14) geological structure. These sampling points have gamma dose rates of 104 nGy h^{-1} and 235 nGy h^{-1} respectively.

Radioactivity level in this sedimentary formation is generally lower than that from igneous formations. Figures (4.3), (4.4) and (4.5) study the relation between the concentrations of uranium, thorium, and potassium in samples and

gamma dose rates around the sampling sites respectively. A good correlation was obtained for both uranium and thorium with correlation coefficients of 0.711 and 0.664, respectively, while there was no correlation found between potassium and gamma dose rates around the sampling sites.

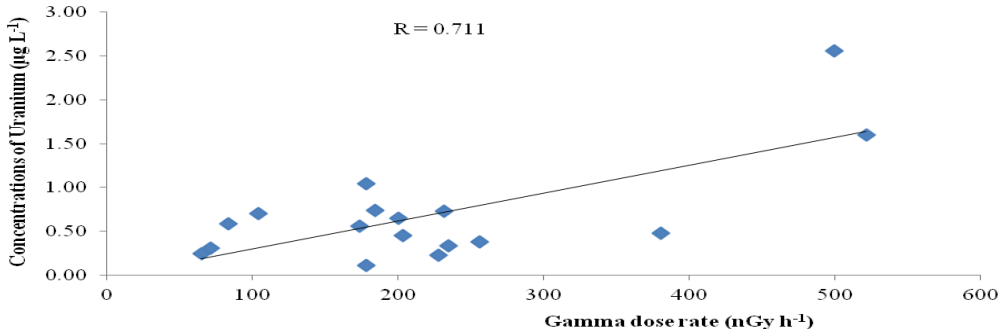

Fig. 4.3 Correlation between concentrations of uranium and gamma dose rate

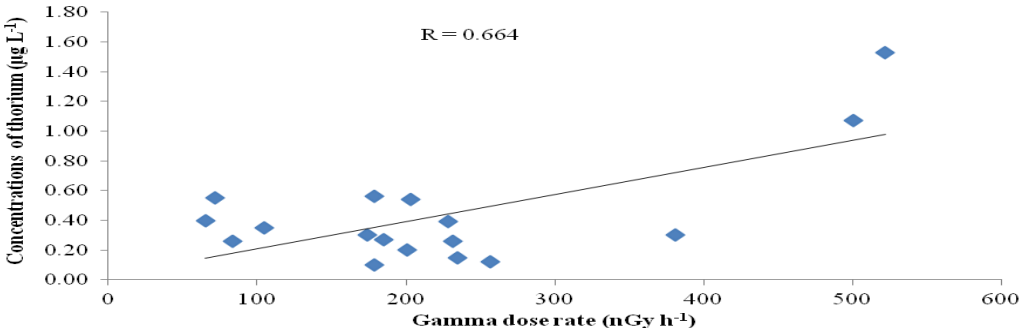

Fig 4.4 Correlation between concentrations of thorium and gamma dose rate.

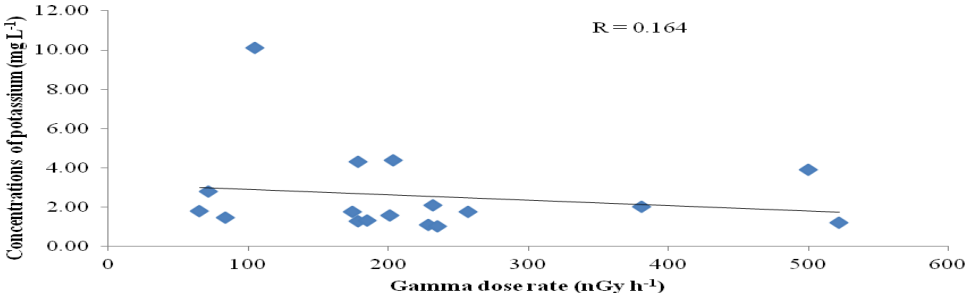

Fig. 4.5 Correlation between concentrations of potassium and gamma dose rate

5.0 CONCLUSION

Water resources from the rivers of Pahang state are affected to some degree by uranium, thorium and potassium present in the surrounding area. The mean specific activity concentrations are 8.49 mBq L^{-1}, 1.74 mBq L^{-1} and 77.85 mBq L^{-1} respectively. The values for uranium and thorium concentrations in the state are higher compared to the value for New York City; 0.9 mBq L^{-1} and 0.05 mBq L^{-1} respectively. In the north western Pakistan the uranium and thorium activity concentration has values of 3.9 mBq$L^{-1}$and 2 mBq L^{-1}.The world average values are 5mBq L^{-1} and 3mBq L^{-1} for uranium and thorium respectively.The concentration of uranium and thorium in water samples vary depending on geological formation in the area. The river water overlaying acid intrusive geologic formations have higher concentrations of radionuclides than others on other geologic formations. The ratio for Th: U concentration is 3:4 due to the higher solubility of uranium in the river waters. Good relation was observed between the radionuclides concentrations of uranium, thorium and the gamma dose rates around the area it shows that the higher the gamma dose rates the higher is the concentrations.

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