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Full Length Research Paper

Natural radioactivity in drinking and mineral water in Johor Bahru (Malaysia)

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The radiological quality of ^{238}U, ^{232}Th and ^{40}K in some samples of drinking and mineral water collected in Johor Bahru, Malaysia has been measured by direct γ ray spectroscopy using high purity germanium detector in this paper. Mean activity concentration of ^{238}U, ^{232}Th and ^{40}K in drinking and mineral water were found 1.48 ± 0.12, 9.59 ± 0.83, 39.67 ± 1.69 ppm and 2.16 ± 0.15, 15.88 ± 1.16, 41.47 ± 1.76 ppm respectively. The mean estimated dose of ^{238}U, ^{232}Th and ^{40}K to an adult from the drinking and mineral water intake was 0.0015 ± 0.0001, 0.0122 ± 0.0011, 5.53 ± 0.23 nSv year^{-1} and 0.0021 ± 0.0001, 0.0203 ± 0.0015 , 5.80 ± 0.23 nSv year^{-1} respectively.

Key words: Drinking water, mineral, Johor Bahru (Malaysia), potassium, thorium, uranium.

INTRODUCTION

Terrestrial radiations are give out from natural radioactive elements present in varying amounts in all types of water, soils, air, rocks food, etc in the human body itself and other environmental materials around us. Higher concentrations of radioactivity in environmental media are connected with risk to humans and higher radiation damage such as kidney damage, mutagenicity, leukaemia as well as cancer of bladder, kidney, testis and lung (Guogang et al., 2009).

The decay of radio-nuclides got hold into the body through inhalation and ingestion by internal exposures of humans to ionising radiations. The water and food chain use (both for drinking and domestic purposes) are the two components of the pathway of ingestion to body. The levels of concentrations of radio-nuclides according to nature in ground waters are mainly depend on uranium and thorium-bearing soil and rock mineral or with uranium, thorium and radium deposits.

Therefore, the happening and dispensation of natural radioactivity in water depend on the local geological characteristic of the source, soil or rock (Ajayi and Achuka, 2009; Ajayi and Adesida, 2009).

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Increased concern for the radiological quality of drinking water has led to an increased demand for data about water quality. The total dose for radiological aspects in the directive basically corresponds with the recommendations given in the second edition the world health organization (WHO) guidelines for drinking water quality (WHO, 1998). In the WHO guidelines (WHO, 2004), the recommended reference dose level (RDL) of committed effective dose is 100 μSv from 1 year's consumption of drinking water and for practical purposes, there are more than 3,000 brands of mineral water commercially available worldwide. Gamma rays can enter the skin and interact with tissue. Uranium and Radium found in water and do not emit strong gamma radiation, so showering and bathing do not pose significant risk. However, if these radio-nuclides are consumed or inhaled through eating or drinking, the emissions can come into direct contact with sensitive tissues in the body. Radio-nuclide uranium can dissolve out of soils and mineral deposits into water, resulting in areas with elevated levels of radio-nuclides in ground water. Long-term exposure to uranium in drinking water may cause toxic effects to the kidney, and can lead to cancer (Guogang and Giancarlo, 2007).

In a research article studied that natural radioactivity of different brands of commonly sold bottled drinking water

in the federal capital Islamabad and Rawalpindi city of Pakistan and found mean concentrations of ^{226}Ra, ^{232}Th and ^{40}K were 11.3 ± 2.3, 5.2 ± 0.4 and 140.9 ± 30.6 $mBqL^{-1}$, respectively using gamma spectroscopy technique (Fatima et al., 2007). The determination of γ-emitters of ^{238}U and ^{234}U vary between 0.91 to 17.27 and 2.13 to 22.01 mBq L^{-1} on radioactivity in drinking water from three lakes in the region of Attika in Greece (Kehagia et al., 2007). A monitoring of natural radioactivity in some bottled mineral waters produced in Italy was performed which the results revealed that the concentrations (mBq L^{-1}) of ^{226}Ra, ^{238}U, ^{234}U and ^{210}Po ranged from <10.00 to 52.50, from <0.17 to 89.00, from <0.17 to 79.00, and from <0.04 to 21.01, respectively (Desideri et al., 2007a, b). The ^{238}U concentration using inductively coupled plasma mass spectrometry, whereas thermal ionisation mass spectrometry has been used for the measurement of isotopes ratios, varies in the range 0.00137 to 0.0632 Bq L^{-1} from the dose effect for South Serbians due to ^{238}U in natural drinking water (Sahoo et al., 2007). Activity concentrations of ^{40}K was measured by using high-purity germanium (HPGe) detector (Canberra Industries Inc.) in some sachet drinking water samples produced in Nigeria ranged from 0.57 ± 0.21 to 34.08 ± 5.61 Bq L^{-1} (Ajayi and Adesida, 2009). Therefore, monitoring of natural radioactivity in drinking water is an important parameter for public health studies, which allows the assessment of population exposure to radiation by the consumption of water. The occurrence of radionuclide's in drinking water causes health hazards owing to human internal exposure from the decay of radio-nuclides absorbed into the body through ingestion. This study is performed to investigate the presence of natural radioactivity elements in drinking and mineral water using gamma spectrometry technique and comparison between the level of concentration of radioactive elements; ^{238}U, ^{232}Th and ^{40}K found in water samples and its safety to humans.

MATERIALS AND METHODS

Sample pre-treatment / pre-concentration

Bottled Drinking Water is drinking water packaged in plastic or glass containers. The dominant form is water packaged in new Polyethylene terephthalate bottles. Another method of packaging is in larger high-density polyethylene plastic bottles, or polycarbonate plastic bottles, often used with water coolers. The sample of Shell bottled drinking and mineral water was collected as follows: one litres of water was stored in bottles and the original pH value of water was measured and added to nitric acid (HNO_3) until the pH reading indicates between pH 1-3. Nitric acid was used in this sampling method is to retain the element in the water from missing or deficient. Then the water was processed through the evaporation until 0.5 litres. To obtain equilibrium state for gamma spectroscopy, the samples were kept in Marinelli beaker for one month.

Due to smaller life-time of the daughter radio-nuclides in the decay series of ^{233}Th and ^{238}U, the ^{232}Th activity was determined from the average activities of ^{208}Tl at 583 keV and ^{228}Ac at 911 keV in the samples, and that of ^{238}U was determined from the average activities of the decay products ^{214}Pb at 352 keV and ^{214}Bi at 609 keV. The activity of ^{40}K was based on 1460 keV peak.

Experiments

Gamma counting

The experiments for radioactivity measurement of the drinking and mineral water were carried out at the nuclear laboratory, physics department, Universiti Teknologi Malaysia using gamma ray spectroscopy system with high purity germanium detector (HPGe) of efficiency 20% which connected to a multi-channel analyser (MCA). The gamma spectroscopy system consists of a p-type coaxial HPGe detector (EG & G ORTEC), lead shield 47 cm thick, a preamplifier, a linear amplifier, high voltage power supply, a multichannel analyzer and a printer. The detector has an energy resolution of 1.8 keV at 1332 keV gamma energy. In this work, the energy calibrations of the gamma ray spectra were done using standard radioactive sources of ^{137}Cs, ^{60}Co and ^{152}Eu.

RESULTS AND DISCUSSION

Concentrations of ^{238}U, ^{232}Th, and ^{40}K

In order to obtain the concentration, C, of an element,

$$C_s = \frac{N_s C_p}{N_p} \quad (1)$$

N_S = Counts of sample, N_p = Counts of standard and C_p = Concentration of standard and C_s = Concentration of sample

The uncertainty of concentration ΔC_s of an element;

$$\Delta C_s = C_s \times \left[\left(\frac{\Delta Ns}{Ns} \right)^2 + \left(\frac{\Delta Cp}{Cp} \right)^2 + \left(\frac{\Delta Np}{Np} \right)^2 \right]^{0.5} \quad (2)$$

Where, ΔC_s is uncertainty for concentration, N_s stands for sample counts, ΔN_s for uncertainty for sample counts, N_p for standard counts, ΔN_p for uncertainty for standard counts, C_p is concentration of standard, ΔC_p is uncertainty concentration of standard.

The annual effective dose to an individual due to intake of natural radio-nuclides from the 2 water samples is estimated using the following relationship;

$$D_w = C_w CR_w Dc_w \quad (3)$$

In the Equation (3), D_w is the annual effective dose (nSv y^{-1}) due to the ingestion of radio-nuclides from the consumption of water, C_w is the activity concentration of radio-nuclides in the ingested water (Bq L^{-1}), CR_w is the annual intake of drinking water (for age > 17 yr; 2 liter per day, so 731 litre per year) and Dc_w is the ingested dose conversion factor for radio-nuclides (mSv Bq^{-1}).

On the basis of calculation; the standard concentration for different radio-nuclides and concentrations of ^{238}U,

Table 1. Concentrations of ^{238}U, ^{232}Th and ^{40}K in drinking and mineral water.

Samples	Mass of the sample (± 0.01g)	Radio-nuclides	Type	Sample Count (N_s)	Standard Count (N_p)	Concentration (ppm)	Average Concentration (ppm)
Drinking	500.00	^{238}U	^{214}Pb	68±8	666±26	0.48±0.06	1.48±0.12
			^{214}Bi	317±18	606±25	2.47±0.17	
		^{232}Th	^{208}Tl	165±13	1740±42	9.41±0.75	9.59±0.83
			^{228}Ac	124±11	1260±36	9.76±0.91	
		^{40}K		1100±33	1080±33	39.67±1.69	39.67±1.69
Mineral	500.00	^{238}U	^{214}Pb	67±8	666±26	0.47±0.06	2.16±0.15
			^{214}Bi	493±22	606±25	3.84±0.23	
		^{232}Th	^{208}Tl	253±16	1740±42	14.43±1.10	15.88±1.16
			^{228}Ac	220±15	1260±36	17.32±1.21	
		^{40}K		1150±34	1080±33	41.47±1.76	41.47±1.76

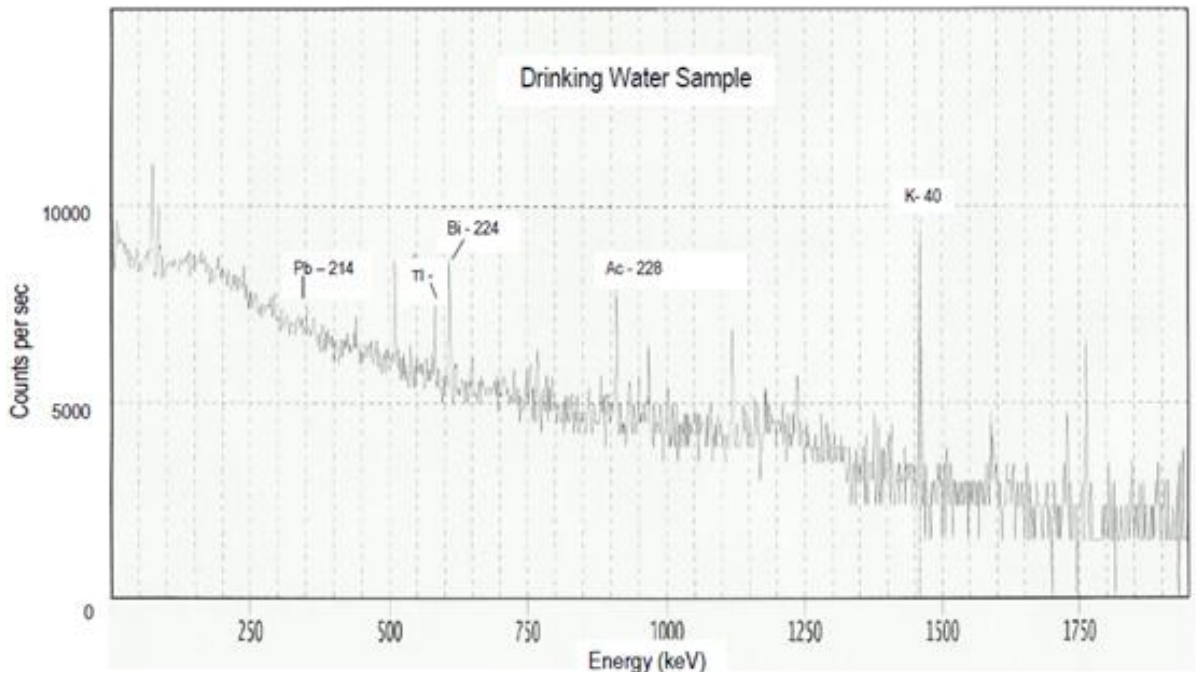

Figure 1. Gamma ray spectrum of drinking water at Johor bahru, Malaysia.

^{232}Th, and ^{40}K in the drinking and mineral water samples were tabulated in Table 1.

Figures 1 and 2 show the typical spectrum of drinking and mineral water samples. The energy peaks for the various radio-nuclides are indicated in Figures 1 and 2. The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in the drinking water sample are 1.48 ± 0.12 ppm, 9.59 ± 0.83 ppm, 39.67 ± 1.69 ppm, which is equivalent to specific activity 0.0182 ± 0.0015 Bq L^{-1}, 0.0389 ± 0.0034 Bq L^{-1} and 1.22 ± 0.05 Bq L^{-1} respectively (Table 2). The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in the mineral water samples were 2.16 ± 0.15 ppm, 15.88 ± 1.16 ppm, 41.47 ± 1.76 ppm respectively, which is equivalent to specific activity 0.0266 ± 0.0018 Bq L^{-1}, 0.0645 ± 0.0047 Bq L^{-1}, 1.28 ± 0.05 Bq L^{-1}.

Figure 3 shows the specific activity of uranium, thorium and potassium in drinking and mineral water. It is shown that activity concentration of potassium is higher than thorium and the concentration of uranium is lower than thorium in both of the samples. The concentration of ^{238}U, ^{232}Th, and ^{40}K in the mineral water are greater than drinking water. The ± values associated with the mean

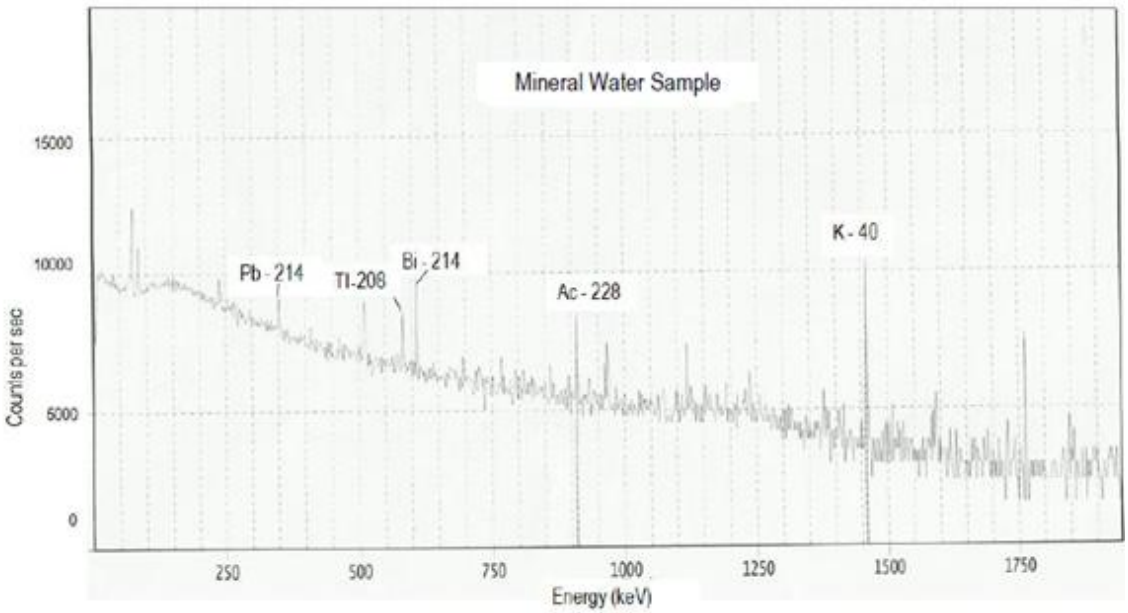

Figure 2. Gamma ray spectrum of mineral water at Johor bahru, Malaysia.

Table 2. Specific activity of ^{238}U, ^{232}Th and ^{40}K in drinking and mineral water samples.

Samples	Radio-nuclides	Present work (BqL^{-1})	Ref. range (BqL^{-1})
Drinking	^{238}U	0.0182 ± 0.0015	0.00021 – 0.103 (Guogang J. et al., 2007)
	^{232}Th	0.0389 ± 0.0034	-
	^{40}K	1.22 ± 0.05	0.57 ± 0.21 – 34.08±5.61 (Ajayi and Adesida, 2009)
Mineral	^{238}U	0.0266 ± 0.0018	0.00017 – 0.089 (Desideri D. et al., 2007a, b)
	^{232}Th	0.0645 ± 0.0047	0.018 – 0.073 (Yasar K. et al., 2011)
	^{40}K	1.28 ± 0.05	0.108 – 1.404 (Yasar K. et al., 2011)

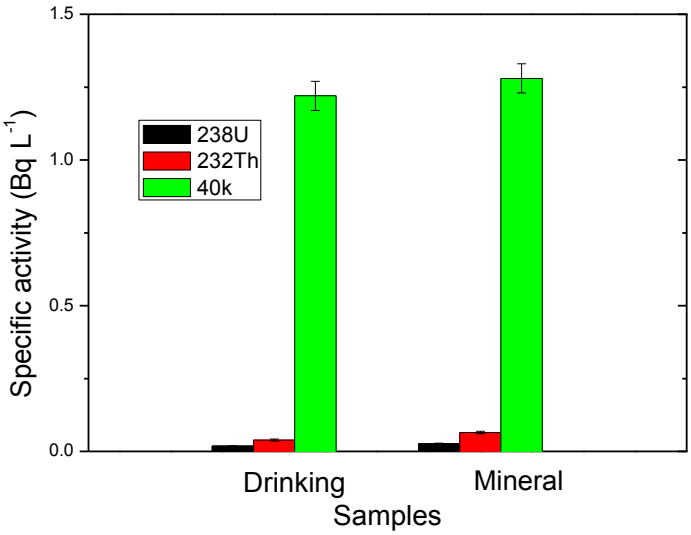

Figure 3. The specific activity (Bq L^{-1}) of uranium, thorium and potassium in drinking and mineral water.

Table 3. Dose Conversion factor $D_{cw.}$

Radio-nuclides	Ingested dose conversion factor (mSv Bq^{-1})
Uranium	1.1×10^{-10}
Thorium	4.3×10^{-10}
Potassium	6.2×10^{-9}

Table 4. Annual effective dose of ^{238}U, ^{232}Th and ^{40}K in drinking and mineral water samples.

Samples	Annual effective dose (nSv $year^{-1}$)		
	^{238}U	^{232}Th	^{40}K
Drinking	0.0015±0.0001	0.0122±0.0011	5.53±0.23
Mineral	0.0021±0.0001	0.0203±0.0015	5.80±0.23

values represent the variability (standard deviation) in the activity concentration values of the radionuclide.

Table 3 present the dose conversion factor Dc_w. Table 4 shows the annual effective dose of ^{238}U, ^{232}Th, and ^{40}K for drinking and mineral water samples are 0.0015 ± 0.0001 nSv $year^{-1}$, 0.0122 ± 0.0011 nSv $year^{-1}$, 5.53 ± 0.23 nSv $year^{-1}$ and 0.0021 ± 0.0001 nSv $year^{-1}$, 0.0203 ± 0.0015 nSv $year^{-1}$ and 5.80 ± 0.23 nSv $year^{-1}$ respectively. It is shown that the sample contributed much lower effective dose compared to the (UNSCEAR 2000) report (Ajayi and Adesida, 2009). This study shows that the drinking water sample give much lower internal exposures than the UNSCEAR reported world average value of 0.12 mSv $year^{-1}$ and the WHO and ICRP preference limit of 0.1 mSv $year^{-1}$ and 1.0 mSv $year^{-1}$ respectively (Ajayi and Adesida, 2009). The United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) (2000) has been reported that the average worldwide exposure to natural sources in foods and drinking water (ingestion exposure) is 0.29 mSv $year^{-1}$ (about 0.17 mSv $year^{-1}$ from ^{40}K and about 0.12 mSv $year^{-1}$ from Uranium and Thorium) (Ajayi and Adesida, 2009).

Conclusion

The activity concentrations of ^{238}U, ^{232}Th and ^{40}K radionuclide in the drinking and mineral water at Johor bahru, Malaysia were measured using gamma-ray spectroscopy. This study showed that ^{40}K contributed the largest activity concentration and ^{238}U contributed least activity in the drinking and mineral water sample. The use of water samples that have been investigated in this study show much lower internal exposures than the UNSCEAR reported world average value of 0.12 mSv $year^{-1}$ and the WHO and ICRP reference limits of 0.1 mSv $year^{-1}$ and 1.0 mSv $year^{-1}$ respectively (Ajayi and Adesida, 2009). The radioactive concentration of ^{238}U, ^{232}Th, and ^{40}K of drinking water are lesser than mineral water. Moreover, both water samples in Johor bahru, Malaysia are safe to be used by human either as drinking water or daily routine activity.

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REFERENCES

Ajayi OS, Adesida G (2009). Radioactivity in some sachet drinking water samples produced in Nigeria. Iran. J. Radiat. Res., 7(3) 151 - 153.

Ajayi OS, and Achuka J (2009). Radioactivity in drilled and dug well drinking water of Ogun State Southwestern Nigeria and consequent dose estimates. Rad. Prot. Dos., 135(1) 54-63.

Desideri D, Meli MA, Feduzi L, Roselli C, Rongoni A, Saetta D, (2007a). ^{238}U, ^{234}U, ^{226}Ra, ^{210}Po concentrations of bottled mineral waters in Italy and their dose contribution. J. Envir. Rad., 94: 86-97.

Desideri D, Roselli C, Feduzi L, Meli MA (2007b). Radiological characterization of drinking waters in Central Italy. Micro. J., 87: 13-19.

Fatima I, Zaidi JH, Arif M, Tahir SNA (2007). Measurement of natural radioactivity in bottled drinking water in Pakistan and consequent dose estimates. Rad. Prot. Dos., 123(2).

Guogang J, Giancarlo T, (2007) Estimation of Radiation Doses to members of the public in Italy from intakes of some important Naturally Occuring Radionuclides (^{238}U, ^{234}U, ^{235}U, ^{226}Ra, ^{228}Ra, ^{224}Ra and ^{210}Po) in Drinking Water. App. Rad. Isot., 65: 849-857.

Guogang J, Giancarlo T, Leandro M, (2009). Concentrations of ^{238}U, ^{234}U, ^{235}U, ^{232}Th, ^{230}Th, ^{228Th}, ^{226}Ra, ^{228}Ra, ^{224}Ra, ^{210}Po, ^{210}Pb And ^{212}Pb in Drinking Water in Italy: Reconciling Safety Standards Based on Measurements of gross α and β. J Environ. Rad., 100: 941-949

Kehagia K, Koukouliou V, Bratakos S, Seferlis S, Tzoumerkas F, Potiriadis C, (2007). Radioactivity monitoring in drinking water of Attika, Greece. Desalination, 213: 98-103.

Sahoo SK, Matsumoto M, Shiraishi K, Fujimoto K, Cuknic O, and Zunic ZS, (2007). Dose effect for South Serbians due to ^{238}U in natural drinking water. Rad. Pro. Dosi., 127(1-4): 407-410.

United Nations Scientific Committee on the Effect of Atomic Radiation. (2000) Sources and effect of ionizing radiation. Report to the General Assembly (NY: UN).
WHO (1998). Guidelines for drinking-Water Quality, second edition. Geneva, Switzerland.
WHO (2004). Guidelines for Drinking-Water Quality, third ed. Geneva, Switzerland.
Yasar K, Nevzat D, Ugur C (2011). Radiochemical characterization of mineral waters in the Eastern Black Sea Region, Turkey. Environ. Monit. Assess., 182: 415-422.