



## Natural Radioactivity in Various Water Tasters Using $\gamma$ -Ray Measurement

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### Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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### ABSTRACT

This paper has explained the contamination of natural radionuclides in various water testers using gamma ray measurement which is very significant as part of health scrutiny programs to progress the ecological knowledge. Natural radioactivity was determined in five groups of water samples (rain, mine, tap, drinking and mineral) from different places at Johor, Malaysia by means of gamma-ray spectrometry tool. The annual cumulative effective doses were estimated 6.05 mSv /yr for rain, 9.49 mSv/ yr for mine, 6.39 mSv /yr for tap, 5.67 mSv /yr for drinking, and 6.01 mSv/yr for mineral water. Among the five samples, mine water gave the highest value in annual effective dose measurement. The measured data are compared with the reported value. The activity concentrations of five water samples provided that bottled drinking water was the lowest than other water samples. This research is useful to provide some information to the public about the amount of radionuclide content uranium, thorium and potassium that present in water.

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## 1. INTRODUCTION

During the last decades, the global pollution by radioisotopes and after that, nuclear blasts in higher layers of the atmosphere polluted the earth [1-2] callously. The dangerous radionuclides, formed owing to individual's explosions, polluted the complete environment such as layers of soil, food and water etc. These hazardous isotopes go to the human body by taking drinking water and food. Fresh intake water is very important to human and natural life. Safe drinking water has developed gradually and significantly almost everywhere in the world [3-4].

Radio-isotopes go inside the body and work together with interior tissue. Radium and Uranium isotopes are investigated in intake water and they don't produce great quantities of gamma radiation, so showering and washing do not carry major risk. Nevertheless, these radionuclides are consumed through eating or drinking; the radiations can absorb directly with the body and interact with tissues. Uranium is a naturally-occurring radionuclide which can melt with soils and minerals with water, subsequently at high levels of radio-isotopes can exist in groundwater. Uranium has a destructive effect on the kidney during long-term drinking water and clues to cancer [5].

Fatima et al [6] and Ben et al. [7] studied radionuclide of gamma-ray emitters in bottled water. Kawabata et al. [8] and Somlaj et al. [9] measured radioactivity of Uranium and thorium in soil and water. Salih et al. [10] measured natural radioactivity  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ra}$ ,  $^{222}\text{Rn}$  and  $^{210}\text{Po}$  in drinking groundwater samples. Para et al. [11] and Rahman et al. [12] determined radioactivity levels of U, Th and other impurities in Molybdenum by radiochemical neutron activation analysis. Yusuf et al. [13] determined usual radiation in mineral and drinking water in Johr Bahru, Malaysia. In this paper, we would like to perform the existence of usual radio-nuclei in different tasters of water using  $\gamma$ -ray measurement.

## 2. STATEMENT OF PROBLEM

Water has taken in the body in a variety of ways. They are vital to our health and well-being. The existence of radionuclides in drinking water causes health threats owing to human interior exposure from the decay of radionuclides immersed into the body through ingestion. Many

countries have conducted studies to resolve this problem. Radiation exposure due to water will be directly to the public through the internal and external exposure. When the gamma ray emits inside and outside the body, it will contribute to the collective's dose in individuals. The purpose of this work for monitoring of normal radioactivity in drinking water is a significant parameter for public health studies, which permits the assessment of population exposure to radiation by the ingesting of water. The measure of concentration of the radionuclides can be calculated to find the effective dose per individual and rising awareness over the polluted drinking water correlated to sicknesses.

This research measured the amount of natural radionuclides in different sources of water that are usually taken in Malaysia and also for many countries. The results obtained from this research were compared with reported data and from the internationally recommended values as sated in ICRP (International Commission Radiation Protection). Since there are growing concerns about the amount of radioactive source, this research is useful to provide some information to the public about the amount of radionuclide content which are uranium, thorium and potassium that present in water. It is important to know the radionuclide contained in each source of water so that we can optimize the dose level from the human risk from over-exposure. This research shows only incremental advance over prior research results that display the originality of this work.

## 3. EXPERIMENTAL TOOLS

### 3.1 Sampling

The water tasters were taken from different locations in Malaysia. The first water sample is rainwater that falls in the middle of the city of Johor Bahru. The second water sample was taken from mining areas in Taiping, Perak. The third sample is tap water from residential areas surrounded by an industrial area in Pasir Gudang, Johor. The fourth and fifth samples are bottled drinking and mineral water sold in stores around Johor Bahru. Each sample of water about one liter was kept in bottles and the pure PH data was determined and extra nitric acid ( $\text{HNO}_3$ ) was added until the PH analysis shows 1-3. The  $\text{HNO}_3$  was useful to hold the component of water from disappearing or lacking. The water evaporated until 0.5 liters. In order to find

equipoise for  $\gamma$ -ray spectroscopy, the samples were taken in Marinelli cup for a month.

### 3.2 Instrumentation

The measurements were done using facilities of  $\gamma$ -ray spectroscopy tool at the Department of Physics, Universiti Teknologi Malaysia. It comprises a high purity germanium (HPGe) detector, pre-amplifier, amplifier, scalar and multi-channel analyzer (MCA). The efficiency of the detector is 0.2. The resolution of the detector is  $1.8 \times 10^3$  eV at peak energy 1.333 MeV. To protect the detector from cosmic rays, lead shields of 470 mm thick, 2 mm coated with tin and copper were used. The  $^{137}\text{Cs}$ ,  $^{60}\text{Co}$ ,  $^{152}\text{Eu}$  etc sources were used for energy calibrations of the gamma ray spectra.

## 4. RESULTS AND DISCUSSION

The concentration of  $\text{U}^{238}$ ,  $\text{Th}^{232}$ , and  $\text{K}^{40}$  are obtained using equation (1).

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

Where,  $N_p$  counts of standard,  $N_s$  are counts of sample,  $C_s$  concentration of sample.  $C_p$  concentration of standard and the uncertainty or error ( $\Delta$ ) of concentration are found using equation (2)

$$\Delta C_s = \left( \frac{\Delta N_s}{N_s} + \frac{\Delta C_p}{C_p} + \frac{\Delta N_p}{N_p} \right) \quad (2)$$

Where,  $N_s$  stands for sample counts,  $N_p$  for standard counts,  $\Delta C_s$  is error for concentration,  $\Delta N_s$  error for tester counts,  $\Delta N_p$  error standard counts,  $NP$  indicate mass standard,  $\Delta NP$  indicate uncertainty mass standard.

Table 1 shows specific activity of  $\text{U}^{238}$ ,  $\text{Th}^{232}$  and  $\text{K}^{40}$  in 5 water testers. The activity of  $\text{U}^{238}$ ,  $\text{Th}^{232}$  and  $\text{K}^{40}$  in the five water testers ranged from  $18.20 \pm 3.20$  Bq /Kg to  $40.83 \pm 1.23$  Bq/ kg,  $38.68 \pm 0.44$  Bq/ kg to  $110.10 \pm 0.32$  Bq/ kg and  $122.19 \pm 0.01$  Bq /Kg to  $201.06 \pm 0.01$  Bq/Kg respectively. Mine water samples had the highest specific activity of all radionuclide's ( $\text{U}^{238}$ ,  $\text{Th}^{232}$  and  $\text{K}^{40}$ ) while drinking water samples had the lowest activity.

The specific activity of standard soil samples, SL-1 supplied by IAEA for different radio-nuclides of  $\text{U}^{238}$ ,  $\text{Th}^{232}$  and  $\text{K}^{40}$  were tabulated in Table 2. Comparison of mean and range of concentration of  $\text{U}^{238}$ ,  $\text{Th}^{232}$  and  $\text{K}^{40}$  in present work with those

of ref. [14-18] are also presented in Table 2. The mean activity was  $28.24 \pm 8.13$ ,  $65.79 \pm 26.62$  and  $143.29 \pm 32.70$  Bq/ kg for  $\text{U}^{238}$ ,  $\text{Th}^{232}$  and  $\text{K}^{40}$  respectively in the present work. Thus  $^{40}\text{K}$  is the major activity and  $^{238}\text{U}$  is the smallest activity in the water testers of present work. Desideri et al., [14, 16] determined the mean and range concentration of  $\text{U}^{238}$  of mineral waters in Italy. The values are  $8.97 \pm 14.72$  mBqL<sup>-1</sup> and 0.17 to 89.00 mBqL<sup>-1</sup> and  $9.52 \pm 10.92$  mBqL<sup>-1</sup> and 0.65-48.77 mBqL<sup>-1</sup> respectively. Ajayi et al. [15] measured  $19.09 \pm 10.05$  Bqkg<sup>-1</sup> and  $0.57 \pm 0.21$ - $34.08 \pm 5.61$  Bq/kg mean and range activity concentration of  $\text{K}^{40}$  in drinking water in Nigeria. Fatima et al. [17] determined the mean and range concentration of  $\text{Th}^{232}$  and  $\text{K}^{40}$  in bottled drinking water in Pakistan  $5.2 \pm 0.9$  mBqL<sup>-1</sup> and  $4 \pm 0.5$  -  $6 \pm 0.8$  mBqL<sup>-1</sup> and  $140.9 \pm 30.6$  mBqL<sup>-1</sup> and  $92 \pm 5$  -  $216 \pm 10$  mBqL<sup>-1</sup> respectively. Ajayi et al. [18] measured 2.94 BqL<sup>-1</sup> and 1.74 – 4.69 BqL<sup>-1</sup> for mean and range activity concentration in drilled and dug well drinking water of Ogun state southwestern Nigeria.

The results of the calculated yearly actual dose ( $\mu\text{Sv}/\text{yr}$ ) are given in Table 3. The yearly actual dose owing to the consumption of  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  from water testers are  $0.01 \pm 0.007$  to  $0.03 \pm 0.01$   $\mu\text{Sv yr}^{-1}$ ,  $0.12 \pm 0.06$  to  $0.35 \pm 0.08$   $\mu\text{Sv yr}^{-1}$  and  $5.54 \pm 1.38$  to  $9.91 \pm 1.48$   $\mu\text{Sv yr}^{-1}$  respectively. The mean yearly actual doses from  $^{238}\text{U}$  to the age group is  $0.02 \pm 0.007$   $\mu\text{Sv}/\text{yr}$  and that due to  $^{232}\text{Th}$  in the sample is  $0.21 \pm 0.08$   $\mu\text{Sv}/\text{yr}$  and also the mean annual effective dose for  $^{40}\text{K}$  is  $6.49 \pm 1.48$   $\mu\text{Sv}/\text{yr}$ . The yearly actual doses from  $^{40}\text{K}$  to the age group was the highest than the  $^{232}\text{Th}$  and  $^{238}\text{U}$ . The total annual effective dose varied from  $5.67 \pm 1.34$  to  $9.49 \pm 1.57$   $\mu\text{Sv yr}^{-1}$  and with a mean of  $6.72 \pm 1.57$   $\mu\text{Sv yr}^{-1}$ . This study shows radio-logically safe to use the water testers. We found that all testers gave much lower internal exposures than the United Nation Scientific Committee on Effects of Atomic Radiation (UNSCEAR) [1] testified world average value of  $0.12$  mSvyr<sup>-1</sup> and the WHO [19] and ICRP [20] reference limits of  $0.1$  mSvyr<sup>-1</sup> respectively. The UNSCEAR [1] reported the average worldwide ingestion exposure (about  $0.17$  mSv/yr from K-40 and about  $0.12$  mSv/yr from U-238 and Th-232) for usual food and drinking water. The water testers of annual effective dose for  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  were  $0.02 \pm 0.007$   $\mu\text{Svyr}^{-1}$ ,  $0.21 \pm 0.08$   $\mu\text{Svyr}^{-1}$  and  $6.49 \pm 1.48$   $\mu\text{Sv yr}^{-1}$  respectively. Therefore these testers have a greatly lower actual dose than the report of the UNSCEAR.

**Table 1. Specific Activity, A<sub>s</sub>**

Samples	<sup>238</sup> U (Bq kg <sup>-1</sup> )	<sup>232</sup> Th (Bq kg <sup>-1</sup> )	<sup>40</sup> K (Bq kg <sup>-1</sup> )
Rain	28.78±1.35	60.74±0.40	128.85±0.01
Mine	40.83±1.23	110.10±0.32	201.06±0.01
Tap	26.81±1.35	55.41±0.44	136.63±0.01
Drinking	18.20±3.20	38.68±0.44	122.19±0.01
Mineral	26.57±1.60	64.04±0.40	127.74±0.01

**Table 2. Comparison of mean and range of concentration of <sup>238</sup>U, <sup>232</sup>Th and <sup>40</sup>K in present work with those of ref. [14-18]**

Samples	Annual Effective Dose (± 0.01μSv yr <sup>-1</sup> )			
	<sup>238</sup> U	<sup>232</sup> Th	<sup>40</sup> K	Total
Rain	0.02	0.19	5.84	6.05
Mine	0.03	0.35	9.11	9.49
Tap	0.02	0.17	6.19	6.39
Drinking	0.01	0.12	5.54	5.67
Mineral	0.02	0.20	5.79	6.01
Range	0.01 – 0.03	0.12 – 0.35	5.54 – 9.11	5.67 – 9.49
Mean	0.02	0.21	6.49	6.72
Standard Deviation	0.007	0.08	1.48	1.57

**Table 3. Annual Effective Dose**

Radio-nucl.	Standard Con. (Bq kg <sup>-1</sup> )	Present Mean (Bq kg <sup>-1</sup> )	Ref. Mean (Bq kg <sup>-1</sup> )	Present Range (Bq kg <sup>-1</sup> )	Ref. Range (Bq kg <sup>-1</sup> )
<sup>238</sup> U	58.06 ± 0.12	28.24 ± 8.13	0.009 ± 0.001[14] 0.010 ± 0.011[16]	18.20 ± 8.13 to 40.83 ± 8.13	0.0002 to 0.089[14] 0.0007 to 0.048[16]
<sup>232</sup> Th	400.15±0.04	65.79 ±26.62	0.005 ± 0.001[17]	38.68 ± 26.62 to 110.10 ± 26.62	0.004 ±0.001 to 0.06 ± 0.001 [17]
<sup>40</sup> K	119.97 ±0.03	143.29 ±32.7	19.09 ± 10.05[15] 0.14 ± 0.03[17] 2.94± 0.79[18]	122.19 ± 32.70 to 201.06 ± 32.70	0.57 ± 0.21 to 34.08 ± 5.61[15] 0.09 ± 0.01 to 0.22 ± 0.01[17] 1.74 to 4.69[18]

## 5. CONCLUSION

This ecological study was carried out to provide information about concentrations of radionuclides in five groups of water testers (rain, mine, tap, drinking and mineral) from different places at Johor, Malaysia by using high purity Ge type gamma spectrometers. The activity of U<sup>238</sup>, K<sup>40</sup>, and Th<sup>232</sup> (Bq/ Kg) were measured 28.78 ± 1.35, 128.85 ± 0.01 and 60.74 ± 0.40 respectively for rain water, 40.83 ± 1.23, 201.06 ± 0.01 and 110.10 ± 0.32 for mine water, 26.81 ± 1.35, 136.63 ± 0.01 and 55.41 ± 0.44 for tap water, 18.20 ± 3.20, 122.19 ± 0.01 and 38.68 ± 0.44 for drinking water, 26.57 ± 1.60, 127.74 ± 0.01 and 64.04 ± 0.40 for mineral water. The mean activity

of five group of water was 28.24 ± 8.13, 65.79 ± 26.62 and 143.29 ± 32.70 Bq/ kg for U<sup>238</sup>, Th<sup>232</sup> and K<sup>40</sup> respectively in the present work. This study showed that mine water consist the highest specific activity in <sup>238</sup>U, <sup>232</sup>Th and <sup>40</sup>K which 40.83 ± 1.23 Bq/ kg, 110.10 ± 0.32 Bq/ kg and 201.06 ± 0.01 Bq/ kg respectively as well as high in volume of the annual effective dose which 9.49 ± 0.01 μSv /yr. The drinking water had the lowest activity of 18.20 ± 3.20 Bq/ kg in <sup>238</sup>U, 38.68 ± 0.44 Bq/ kg in <sup>232</sup>Th and 122.19 ± 0.01 Bq/kg in <sup>40</sup>K respectively. All the five water testers are safe compared to the UNSCEAR report. Present testers annual estimated effective doses were less compared to the World Health Organization (WHO) limit 0.1mSv yr<sup>-1</sup>.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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