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Assessment of Liquid Scintillation Technique for Measurement of Gross Alpha and Gross Beta in Aqueous Environmental Samples

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Abstract. Aqueous environmental samples are always subjected to greater concern since there is a need for analysis of several important parameters including gross alpha and gross beta content to ensure the safe consumption and applications of this water. Former tin mining lake contains water which is useful for food supplies, water resource and recreational activities, without realizing that this water contains some amount of natural radionuclides originating from the past tin mine activities. Somehow this will have some effect on human life, animals, plants and environment. This study is focusing on measurement of gross alpha and gross beta in former tin mines water using liquid scintillation counting (LSC) technique. This technique is capable in detecting the radionuclides present in the water samples collected from various tin mines lakes from Kg Gajah, Perak. The samples were collected from the middle part of the lake at 1 meter depth using water sampler. The sample preparation was done by mixing the filtered water samples with scintillation cocktail made up of PPO and POPOP dissolved in toluene and added the Triton N101 as emulsifier. The LSC model Packard Tricab 2700, was set up at specific discriminator level and alpha-beta counting mode. The results show some samples contain gross alpha and gross beta which are higher than the limit set in the Malaysian Water Quality Standard i.e. 1.0 Bq/L and 0.1 Bq/L for gross beta and gross alpha respectively. The MDA was determined to be 0.05 and 0.22 Bq/L for gross alpha and gross beta respectively. The spectra generated from the LSC alpha beta counting mode supported the results.

Keywords: liquid scintillation counting, cocktail, emulsifier, Triton N101

1. Introduction

The quality of water is important in environmental studies because of daily use for human consumption and its ability to transport pollutants [1]. Measuring the gross alpha and beta activities will help to estimate the radiological assessment of the surface water in the area of interest [1] which is considered to be an important factor in increasing the natural radiation exposure in human [2]. The common method for measurement of gross alpha and gross beta in water samples is using proportional counter. Since this method has its own drawback such as self absorption since the water samples were reduced normally through evaporation to a solid material [3].

The availability of low background liquid scintillation counter equipped with alpha and beta discrimination provides an alternative for gross alpha and beta determinations and offers several advantages over the traditional procedure. The LSC technique requires a minimal sample preparation time. There is no self-absorption problem like the one observed in the conventional analytical method where the sample is evaporated to dryness on a planchet, in the liquid scintillation technique the sample is homogenously mixed with the scintillation cocktail, the counting geometry is essentially 4π, providing high efficiencies nearly 100 % and eliminating matrix effects [4, 5, 6, 7, 8].

Pulse Shape Analysis (PSA) in LSC is a pulse shape discrimination technique that is based on a method that integrates the charge of 'tail' of scintillation pulse and compares it with the total charge in the same pulse. Different settings of the PSA level assign the pulse into either a long (alpha-like) or short (beta-like)

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category. Thus, different PSA settings allow pulses to be categorized according to their length (shape). Typically, increasing the PSA setting will direct more pulses toward the long or alpha category. However, depending on how the technique is implemented, the reverse can also be true, i.e., increasing the setting may direct more alpha counts into the beta category. There are several methods of accomplishing pulse shape analysis including slow crossover timing, fast crossover timing, and constant fraction of pulse-height trigger [9].

This study is aim at establishing the method of measuring gross alpha and gross beta using LSC by applying alpha-beta mode of counting in order to count both alpha and beta simultaneously. The water sample from former tin mining lake was known to be relatively high activity concentration of natural radionuclide. The Kinta Valley was chosen as a study area for it was the largest mining area in the past 40 – 50 years.

2. Method

2.1. Sampling

The study area chosen was located in Kg Gajah area in Kinta Valley in the State of Perak. Table 1 shows the latitude and longitude of 14 sampling locations in the study area. The water samples were collected using water sampler at the middle of the lake and 1 meter depth. The water samples were transferred into 20 liters polyethylene container acidified with concentrated nitric acid and filtered before analysis.

Table 1: Location of sampling measured using GPS

Sample	Sample ID	Location		Sample	Sample ID	Location	
		Latitude	Longitude			Latitude	Longitude
Kelapa Sawit Sebatang	KG-001	$04^{0}26.680'$	$101^{0}00.160'$	Lombong luas (2)	KG-008	$04^{0}13.579'$	$101^{0}01.945$
Rantau panjang	KG-002	$04^{0}14.528'$	$101^{0}04.559'$	Kapal 3 (1)	KG-009	$04^{0}14.471'$	$101^{0}03.650$
Cangkat Pinggan	KG-003	$04^{0}13.915'$	$101^{0}03.141'$	Kapal 3(2)	KG-010	$04^{0}14.471'$	$101^{0}03.650$
Ayer Hitam	KG-004	$04^{0}12.525'$	$101^{0}02.742'$	AP1 (1)	KG-011	$04^{0}14.439'$	$101^{0}03.658$
Akasia	KG-005	$04^{0}14.898'$	$101^{0}03.058'$	AP1 (2)	KG-012	$04^{0}14.439'$	$101^{0}03.658$
SK2	KG-006	$04^{0}23.730'$	$101^{0}03.900'$	Lombong Tembak (1)	KG-013	$04^{0}13.848'$	$101^{0}04.459$
Lombong Luas (1)	KG-007	$04^{0}13.579'$	$101^{0}01.945'$	Lombong Tembak (2)	KG-014	$04^{0}13.848'$	$101^{0}04.459$

2.2. Sample Preparation

In this study, the focus is on the development of the best scintillation cocktail and establishes the best discriminator setting for LSC TRICAB 2700 from Packard that available in Malaysian Nuclear Agency (NM) in Bangi, Malaysia. The scintillation cocktail was developed using emulsifier (Triton N-101) mixed with solvent (toluene) and scintillator (2,5-diphenyloxazole, PPO and 1,4-bis(5-diphenyloxazol-2-yl)-benzene, POPOP). 4.0 g PPO and 0.4 g POPOP were dissolved in scintillation grade toluene. This toluene will be mixed with Triton N101 and water in a ratio 4:8:8 for water:toluene:Triton N101 respectively. This ratio was obtained from the experiment using Van de Laarse method using 36 vials and the best ratio was determined through the best merit value. The commercial cocktail (Instagel) was used to compare the result with the homemade cocktail.

2.3. Instrument Setting

Liquid Scintillation Counting model Packard TRICAB 2700 is capable to measure alpha and beta concurrently. One need to set up the counter using alpha beta counting mode and the discriminator level at 120 with the window 0 to 1000 and 0 to 2000 for alpha and beta respectively. The counter was calibrated using ^{36}Cl and ^{241}Am. The samples and blank were counted for 120 minutes each.

3. Results and Discussion

3.1. Spill Over and Recovery

Spill over from computer setting of the counting system were 1.55 and 1.50 percent for beta and alpha respectively. These are in agreement with the calculation value of 2.01 and 1.47 percent. The recovery of radium and strontium are 95 percent both.

3.2. Sample Analysis

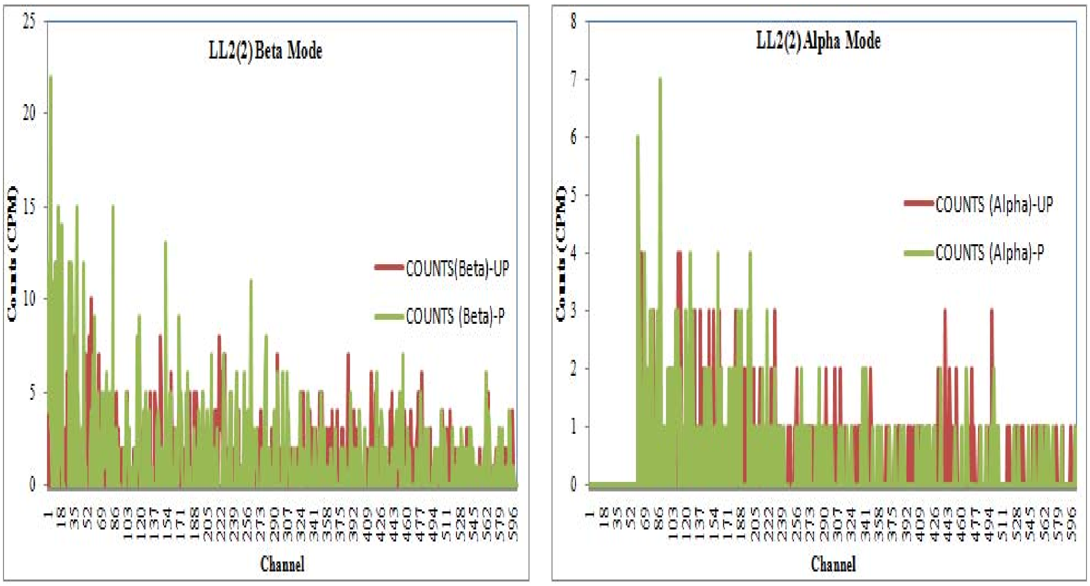
Table 2 shows the results of sample analysis using the above setting and sample preparation procedure. The beta activity concentrations ranging from 0.8 to 9.26 Bq/L, for sample number 5, 7 and 14. The rest of the samples have activity concentration below MDA. The alpha activity concentrations ranging from 1.15 to 8.56 Bq/L, with sample number 1, 3, 6, 10 and 14 are below MDA. The MDA for alpha and beta are 0.05 and 0.22 Bq/L respectively.

Table 2: Activity concentration of gross alpha and beta for samples from former tin mining lake

Sample ID	In-house cocktail		Instagel		Malaysian Standard	
	Gross Alpha (Bq/L)	Gross Beta (Bq/L)	Gross Alpha (Bq/L)	Gross Beta (Bq/L)	Gross Alpha	Gross Beta
KG-001	<MDA	<MDA	3.90±0.01	0.54±0.05	0.5	1.0
KG-002	6.83±0.03	<MDA	4.00±0.01	0.96±0.05	0.5	1.0
KG-003	<MDA	<MDA	4.95±0.01	<MDA	0.5	1.0
KG-004	4.32±0.03	<MDA	4.72±0.01	<MDA	0.5	1.0
KG-005	5.46±0.03	0.80±0.13	4.98±0.01	4.02±0.05	0.5	1.0
KG-006	<MDA	<MDA	4.37±0.01	<MDA	0.5	1.0
KG-007	6.91±0.03	9.26±0.13	3.71±0.01	4.18±0.05	0.5	1.0
KG-008	8.56±0.03	<MDA	4.52±0.01	2.98±0.05	0.5	1.0
KG-009	3.30±0.03	<MDA	4.49±0.01	5.04±0.05	0.5	1.0
KG-010	<MDA	<MDA	6.47±0.01	1.69±0.05	0.5	1.0
KG-011	1.58±0.02	<MDA	3.71±0.01	0.96±0.05	0.5	1.0
KG-012	1.15±0.02	<MDA	4.37±0.01	1.82±0.05	0.5	1.0
KG-013	6.33±0.03	<MDA	<MDA	<MDA	0.5	1.0
KG-014	<MDA	5.44±0.13	5.76±0.01	4.88±0.05	0.5	1.0

MDA Gross Alpha 0.03 Bq/L; Gross Beta 0.08 Bq/L

All activity concentrations being detected are above the Malaysian Standard for Water Quality. For all we know that the mining activity has attenuated the levels of gross alpha and gross beta in the aqueous samples. The major source of radionuclide in the former tin mining are is tin tailing that contain heavy minerals such as monazite, ilminite and zircon.



(a) (b)

Fig. 1: (a) Beta spectrum, and (b) alpha spectrum of the samples from Location 8 obtained from LSC.

The results obtained were compared with the commercial cocktail (Instagel) to see any inconsistency. The mixture of Instagel and water sample is following the ratio of 10:10 mL for water and Instagel. Since the amount of water sample is bigger than the one using in-house cocktail, the activity concentration is much easier to be detectable. From Table 2, the activity concentrations of gross alpha ranging from 3.71 to 6.47 Bq/L while gross beta from 0.54 to 4.88 Bq/L. Gross alpha exhibit about similar activity concentration between in-house cocktail and Instagel, but gross beta are more detectable using Instagel. Perhaps this is due to the amount of water samples as well as the stability of the radionuclides decay series in acquiring their secular equilibrium. Alena *et al.* (2008) [10] have done a study in water from Slovakia using LSC, found a need of measuring ^{210}Pb and ^{210}Po since they are co-exist with ^{226}Ra and ^{222}Rn in water.

The spectra collected from the LSC system show the presence of mix radionuclides contributing to alpha and beta activities. Figure 1 below shows a few spectra collected during the counting of the samples. Since there is no specific software applied for the spectrum analysis, the quantitative analysis cannot be done.

In the spectrum (a) there is at least two beta emitter's presence and in spectrum (b) also similar case happens. At least the spectrum helps in identification purposes and to conform the presence of radionuclides in the water samples.

4. Conclusion

From the results obtained, LSC can be applied for measuring gross alpha and beta in water samples for screening purposes. The in-house cocktail prepared using solvent and emulsifier is applicable the work. Further work can be done by applying suitable radiochemical procedure for measuring specific radionuclides using LSC. The application of special software for spectrum analysis may enhance this technique to be the most convenience technique for analyzing radionuclide in water samples.

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