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Determination of Sediment Profile for ^{210}Pb, Pb, U and Th from Sultan Abu Bakar Dam Due to Soil Erosion from Highland Agriculture Area, Cameron Highlands, Malaysia

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Abstract: Problem statement: Sultan Abu Bakar Dam in Cameron Highlands act as a catchment's to accumulate all eroded soil carried by the run off flow through Bertam River, the main river that passes through the highland agriculture area. All suspended solid that carried out by the river contain various kind of hazard potential to the environment. U, Th and Pb are the potential hazard elements carried out by water and accumulate at the dam. **Approach:** Five sampling point were selected where five 30cm core collected at each sampling point. Each core were sliced at 2cm and homogenized. ^{210}Pb in homogenize sliced was determine using Alpha Spectrometry method. Plot of concentration against depth produce vertical distribution profile of the elements. This study will measure the activity of ^{210}Pb in sediment at Sultan Abu Bakar Dam and measure the concentration of U, Th and Pb using Energy Dispersive X-Ray Fluorescence (EDXRF) technique. **Results:** The concentration of ^{210}Pb, Pb, U and Th was found that there is no obvious distribution pattern was observed in the depth profile. Activity of ^{210}Pb ranged between 134.4-323.4 Bq kg^{-1} while the concentration of total U, Th and Pb range between 21.51-28.81, 40.73-69.58 and 53.62-72.68 mg kg^{-1} respectively. **Conclusion:** Accumulation of U was observed at one of the study point. This observation maybe attributed due to the high rate of vertical accumulation of sediment when it enter the dam.

Key words: ^{210}Pb profile, alpha spectroscopy, disturb sediment, EDXRF, hydro power, cameron highlands, sediment accumulation, phosphate fertilizer

INTRODUCTION

Cameron Highlands is known for its agricultural activities with gross production of agriculture produce increases every year (FAO, 2004). The forest at Cameron highlands was being cleared for agriculture and construction activities (International Energy Agency, I., 2006). This activity involves heavy usage of fertilizers and poses serious erosion problem. With the record of heavy rainfall throughout the year (annual average about 500 mm), one can aspect a lot of runoff being carried away and settles down at the dam. The study area is acting as the catchment's lake for Cameron Highlands and the dam serve as the water resource for hydro power located at the downstream of the river. The high sedimentation rate causes problem to the hydro power plant since sediment always rise up to the intake level and loss its gross storage and need to be remove every year to deepen the intake area (International Energy Agency, I., 2006).

Many applications were develop and used to determine the accumulation rate of radionuclides that has been reported such as Pb-210 method, Cs-137 method (Al-Zamel *et al*., 2005; Robbins and Edgington, 1975; Noller, 2000; Rai *et al*., 2007; Siang *et al*., 2007). This method gives some information that useful in many cases, but in some cases they may have limited successful since the post depositional process that disturb the history of the sediment (Cheevaporn and Mokkongpai, 1996). Therefore this will alter the sequence of the history stored in the sediment column and make the chronology of sediment accumulation to be difficult to study.

The U, Th and Pb accumulation in the catchment's may cause from the application of phosphate fertilizer

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that contain U, Th and Pb. Natural weathering agent such as rainfall will cause soil erosion and enrichment of these element (Sheppard and Evenden, 1992; Nziguheba and Smolders, 2008). These elements were transported by the water through river and deposited at the bottom of the lake together with the sediment (Begy *et al*., 2009; Swarzenski *et al*., 2003). New areas are increasing to be used as agriculture activity without control may lead to the accumulation of U, Th and Pb in the catchments. Many of the dissolve metals were also carried out through the river by adsorbing into colloid particles (Bhattacharya *et al*., 2008).

^{210}Pb is one of the indicators to monitor the load that has been accumulates in the dam. ^{210}Pb is an isotope that decays to ^{222}Rn, a gas that can escape from the earth crust to the environment (Choy *et al*., 2007). The concentration of ^{210}Pb within the sediment form by a source input overlying water through sedimentation, in-situ production and also radioactive decays (Kamaruzzaman and Ong, 2008). These present study explore the sedimentation behaviors of the sediment by looking at the vertical profile of ^{210}Pb, U, Th and Pb that has been accumulated in the dam.

MATERIALS AND METHODS

Sampling: Sediment samples were collected at Sultan Abu Bakar Dam, in Cameron Highlands, Malaysia. Five locations were selected across the dam (Fig. 1) and at each location five cores of samples were taken to form representative samples of the location. The sampling location was determined by using Global Positioning System (GPS) (Table 1). The sediment was taken by using a gravity corer with PVC lining column of 45 cm length and 4.5 cm diameter. The core columns were air dried first until the sediment samples obtain the shape of the PVC column. The cores were slice at 2 cm interval and the samples were oven dried at 60°C until the constant weight (Kamaruzzaman *et al*., 2010). Core of the same depth from each location were ground, homogenize and sieve using 250 µm sieves. This represents the sample for the stated depth.

Alpha Spectrometry Measurement: Each sample and 0.20 g of ^{209}Po tracer was digested using concentrated HNO_3 65% and HCl 37% at 90°C (Saat *et al*., 2010). Between reactions of acid with samples, H_2O_2 was added to act as catalyst to increase the reaction rate to destroy organic matter. Silver disc 2×2 cm with one side of the disc was covered with glue to make sure only one side of the disc are platting with ^{210}Po and ^{209}Po. The auto platting time was carried out for 24 h with the stirrer present.

Table 1: Sampling point location

Locations	Longitude latitude
Z2	4°25.249' N 101°23.420' E
Z3	4°25.400' N 101°23.400' E
Z4	4°25.496' N 101°23.327' E
Z5	4°25.542' N 101°23.284' E
Z6	4°25.554' N 101°23.237' E

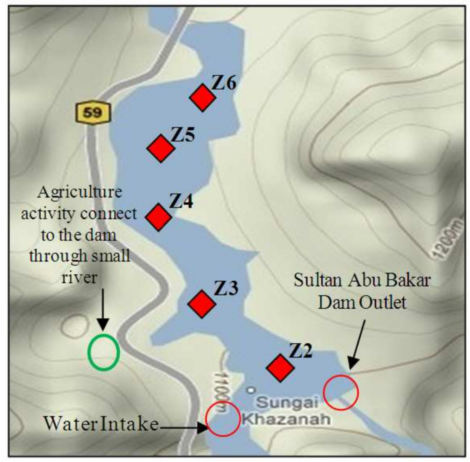


Fig. 1: Sampling Point View (googleMap.com)

The duplicate samples measurement using alpha spectrometry (EG & G, ORTEC) was carried out at Malaysia Nuclear Agency for 24 h counting time for each samples. ^{210}Pb was determined indirectly by measuring ^{210}Po by assuming secular equilibrium between parent and daughter (Noller *et al*., 2000; Cheevaporn and Mokkongpai, 1996).

Energy Dispersive X-Ray Fluorescence (EDXRF) measurement: Sample preparation were carried out by pressing about two gram sample using fusion machine at 15 tonne to make a pellet with diameter of 32 mm and 2 mm thickness. Duplicate samples were prepared and measured by using Rh target Minipal4 PANalytical bench-top EDXRF and the tube ratings were set to 300 mV, 150 µA and using Mo filter with 100 second measurement. Calibration was carried out by measuring Lα line for U, Th and Pb (Natarajan *et al*., 2008; Yu *et al*., 2002). Standard Reference Material IAEA 312, IAEA 313, IAEA SL-1, IAEA Soil 7 and IAEA SL-1 for U and Pb, while for Th Standard IAEA RG-Th-1 was used for calibration. The standard was prepared and measured in the same manner as the samples (Jorgensen *et al*., 2005).

RESULTS

Figure 2-5 show the vertical profile of ^{210}Pb, Pb, U and Th at the various locations. In this study, the activity concentration of ^{210}Pb is consistence even up to 30 cm depth. It shows that the sedimentation rate is very high, more than 100 cm year^{-1}. From this study, the activity of ^{210}Pb shows monotonic pattern with depth and somewhat opposite to usual decreasing pattern of ^{210}Pb profile for old sediment. The range of ^{210}Pb activity of point Z2, Z3, Z4, Z5 and Z6 is 159.3-235.1 Bq kg^{-1}, 216.8-323.4, 155.1-193.1, 134.4-214.5 and 161.5-196.4 Bq kg^{-1} respectively. The concentration range of Pb, U and Th in sediment is 53.62-72.68 mg kg^{-1}, 21.51-28.81 mg kg^{-1} and 40.73-69.58 mg kg^{-1} respectively.

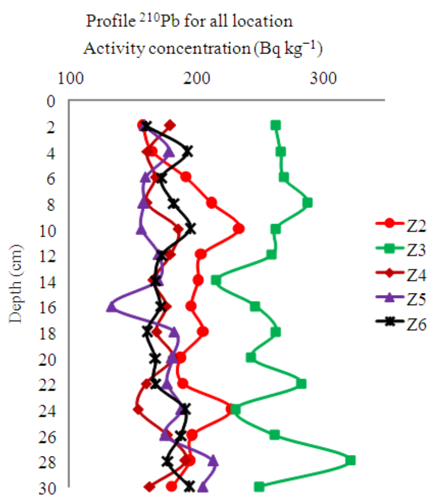


Fig. 2: Activity ^{210}Pb depth profile for all location

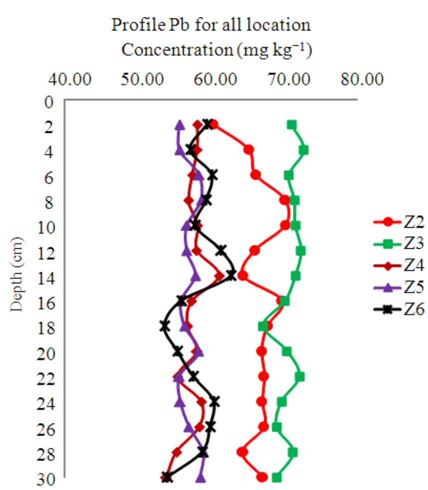


Fig. 3: Pb depth profile according to location

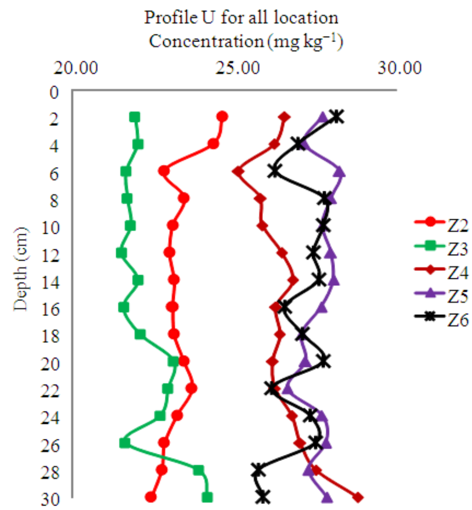


Fig. 4: U depth profile according to location

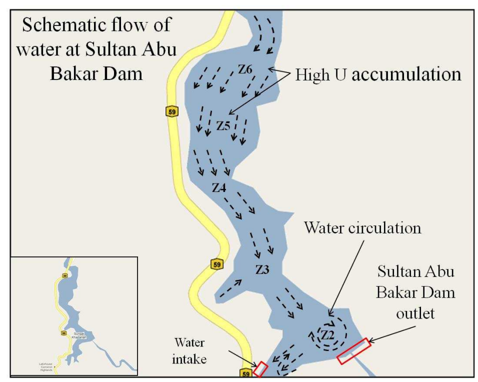


Fig. 5: Schematic flow of water atSultan Abu Bakar am

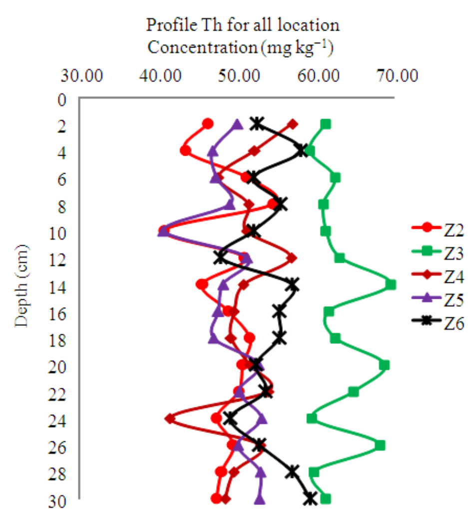


Fig. 6: Th depth profile according to location

DISCUSSION

The activity concentration of ^{210}Pb does not show any observable trends in all location (Fig. 2). Hence, it is not possible to determine the sedimentation rate to determine ^{210}Pb dating method. This can be explained by the fact that the sediment was very recent, where the record shows that every two years the lake has to be emptied and the sediment was taken out to make sure the lake depth is lower than intake depth. Moreover the fast flowing river due to the high gradient will cause of the sediment mixing in the dam. Based on the hydro electric power operator information, the sedimentation rate in the study area is more than 100 cm per year and the sediments were periodically removed. This evidence was supported by water turbidity and total dissolve solid that exceed Interim National Quality Standards for Malaysia (INWQS) (Riduan *et al*., 2009).

Location Z3 has the highest range and mean of activity concentration of ^{210}Pb as obviously seen in Fig. 2. As Z3 is located near to estuary of a small river connected to the dam hence this may cause extra sediment input to the area from the agriculture activities upstream the small river.

Location Z2 and Z3, concentration of Pb is higher than the other locations where the same pattern of Pb was occur with ^{210}Pb. This is in agreement with the ^{210}Pb results where Z2 and Z3 is higher than other location. ^{210}Pb was originated from ^{238}U decay series while Pb may be from uranium decay series and exist in the soil that has become sediment. The correlation coefficient shows no correlation between Pb and ^{210}Pb, except for location Z2, where it shows some correlation (Table 2).

The concentration of U is lower at Z2 and Z3 compared to Z4, Z5 and Z6. Due to uniqueness of U, which being extremely mobile in stream water and does not precipitate, hence, when it crosses the sediment-water interface, the uranium will reduce to U(IV) then lost from solution and transferred to sediment (Benson and Leach, 1979; Ueda *et al*., 2000). The dissolve U will diffuse into the sediment and then precipitated (Anderson *et al*., 1989). At location Z4, Z5 and Z6, the concentration is higher than at Z2 and Z3, suggested that, the U in the stream water is transferred to the sediment in less amount as it pass through location Z6 to Z2 and this may be due to the effect of particle size. The concentration at Z2 is a bit higher than at Z3, suggesting that the accumulation occur for U at Z2 due to circulation of water at the outlet of the dam as illustrated scematically in Fig. 5. At Z3, runoff from the small river will render the sediment particle size corser, hence they maybe different compared to the other locations.

All location show identical concentration profile for Th except for Z3 that shows higher concentration (Fig. 6). Th is insoluble in water and usually associated with solid matter (Martinez-Aguirre *et al*., 1995). Due to the extra input from a small river connected to location Z3, the Th from the suspended solid will accumulate at the junction of the river. The meeting of the two rivers will increase the content of the element in the sediment itself. The trend of higher concentration of Th at Z3 is also observe for ^{210}Pb and Pb may be attributed to the same reason. This prove that the agricultural activity give impact to the catchment's area.

The ratio of Th to U in the sediment samples is higher than 1, which is normal for the Malaysian soil (Table 3) (Ramli *et al*., 2005). According to Martinez-Aguirre *et al*., (1995) the Ratio Th to U is above unity for solid while in water is below unity. The accumulation of U, Th and Pb in sediment is influence from natural process of heavy soil erosion from higher altitude locations to the dam (Ong and Kamaruzzaman, 2009). The suspended solids that being carried away by the river water from plantation area also contributed to the accumulation of these elements. The monotonic pattern of ^{210}Pb profile proved that the behavior of the accumulation at the dam is in higher rates of sedimentation.

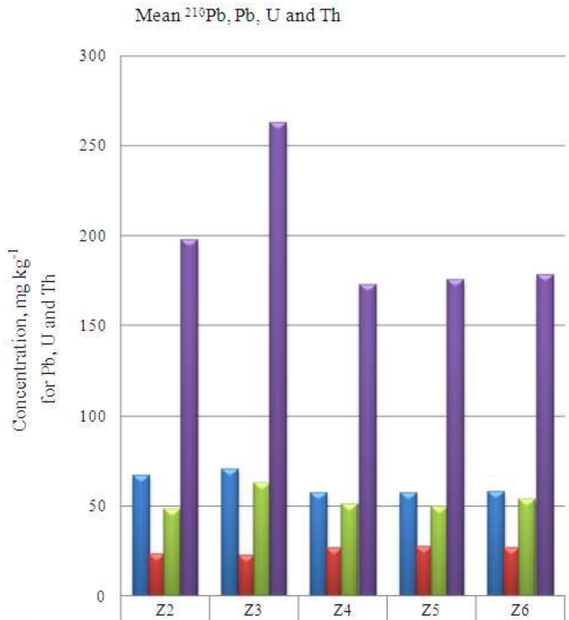
The mean concentration results show that the concentration ^{210}Pb, Pb and Th is higher at location Z3 except for U (Fig. 7). However, mean concentrations for Z4, Z5 and Z6 show no different with each other. This observation can be explained by the same reason described earlier for profiles results.

Table 2: Correlation between Pb and ^{210}Pb

Locations	Pearson correlation
Z2	0.663
Z3	0.210
Z4	0.000
Z5	0.351
Z6	-0.016

Table 3: Th to U ratio in Sediment

Depth (cm)	Z2	Z3	Z4	Z5	Z6
2	1.9	2.8	2.1	1.8	1.9
4	1.8	2.7	2.0	1.7	2.2
6	2.2	2.9	1.9	1.7	2.0
8	2.3	2.8	2.0	1.8	2.0
10	1.8	2.8	2.0	1.5	1.9
12	2.2	2.9	2.1	1.8	1.7
14	2.0	3.2	1.9	1.7	2.1
16	2.1	2.9	1.9	1.7	2.1
18	2.2	2.8	1.9	1.7	2.0
20	2.2	3.0	2.0	1.9	1.9
22	2.1	2.8	2.1	1.9	2.1
24	2.0	2.6	1.6	1.9	1.8
26	2.2	3.2	2.0	1.8	1.9
28	2.1	2.5	1.8	1.9	2.2
30	2.1	2.5	1.7	1.9	2.3



	Z2	Z3	Z4	Z5	Z6
Pb	66.63	70.65	57.43	57.05	58.21
U	23.28	22.32	26.54	27.61	27.06
Th	48.49	62.99	50.98	49.38	54.05
210Pb(Bq/kg)	197.71	262.91	172.93	175.24	178.60

Fig.7: Mean concentration for^{210}Pb, Pb, u and Th

CONCLUSION

No vertical and horizontal trends of profile was observe for all element at all study location except for U where accumulation was observed at Z3. Determination of ^{210}Pb, Pb, U and Th was established by using alpha spectrometry and EDXRF. The activity range of ^{210}Pb is 134.4-323.4 Bq kg^{-1} and the concentration range of Pb, U and Th is 53.62-72.68 mg kg^{-1}, 21.51-28.81 mg kg^{-1} and 40.73-69.58 mg kg^{-1} respectively.

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