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Natural thorium isotopes levels in marine sediments of Coal-Fired Power Plant

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Abstract — Three sediment cores about 50 cm lengths collected from the coastal of Coal-Fired Power Plant at Kapar, Selangor, Malaysia on 25th October 2003 to investigate fluctuation activity of natural thorium isotopes such as thorium-232, thorium-230 and thorium-228 in various depths of sediments core at the effluent area of Kapar Coal electric power station. Then also affect from the coal-fired power station operation in enhancement activities of natural thorium isotopes to the marine environment. The unsupported activity of thorium-228 used to estimate the sediment mixing with extremely high rate value of 12455 $cm^2\,yr^{-1}$ at the hot water discharge station. The activity range of thorium-232, thorium-230 and thorium-228 was from 4.38±0.14 to 11.75±0.51 dpm/g, 2.73±0.11 to 9.54±0.43 dpm/g and 3.34±0.19 to 12.38±0.61 dpm/g, respectively. All three isotopes display non-uniform and greatly fluctuated distribution from surface to the deeper layers as revealed by high sediments mixing. The ratio values of thorium-230/thorium-232 and thorium-228/thorium-232 also exhibited as non-uniform profile where the average ratio of thorium-228/thorium-232 was about 0.76 indicating low contain activity of uranium-238 or uranium-234 in the detrital materials and that uranium was tends to diffuse from sediments during the weathering, erosion and sediments transport. Meanwhile, the ratio of thorium-228/thorium-232 less than unity cause by the leach out process of radium-228 from sediment-water interface. The statistical correlation coefficient value obtained from the Pearson method have a positive correlation between thorium-232, thorium-230 and thorium-228 with Al, Fe and Mn, indicating thorium isotopes were attached with the oxides metals. Then the total carbon value also shows a significant negative correlation with thorium-232 and thorium-228 where these isotopes tend to decrease with increasing total carbon content in the sediments.

Key words: coastal water, sedimentation rate, radioactive, metals, pollution

Introduction

Interactions between physical and biological processes in estuarine systems, and their affect on the sediment mixing and particle residence times, are important for determining the fate and transport of sediment and the process of strata formation. Mixing is accomplished through physical and biological processes, and their relative dominance in depositional systems exists as a continuum between end-members (Dellapenna et al., 1998). Physical mixing tends to be episodic and event driven, and through resuspension may reset sedimentary structures and sea-bed geochemical profiles. This kind of mixing is modulated on a variety of frequencies and depths depending on the driving physical processes, such as wind, waves, tides and surges (Kuehl et al., 1995; Wei et al., 2007). Meanwhile, the duration, depth and degree of sediment disturbance by biological processes depends on benthic community structure and its temporal and spatial variability (Rice, 1986).

Study of cores from three sedimentary provinces of Venezuela Basin was analyzed (Cole et al., 1985) and revealed thorium-232 (^{232}Th) activity in carbonate free was nearly constant with depth and location. The uniform activities with depth indicate a constant source for at least 11,000 years. Same as the Venezuela Basin, sediments off northeastern Taiwan also showed fairly uniform activities at about 3.1 dpm/g that had similar content in the shale, slate and black schist from Taiwan (Chung and Chang, 1996). The values of ^{230}Th/^{232}Th activity ratios were constant at 0.6 in the cored sediments and in the mentioned crustal rocks, suggesting that thorium has not been leached out in transit of final deposition. Meanwhile, thorium-228/thorium-232 (^{228}Th/^{232}Th) ratios were close to unity except for the top few centimeters where the ratios were greater than unity due to the thorium-228 (^{228}Th) derived from radium-228 (^{228}Ra) decay in the water column under rapid deposition. The penetration depth for this excess ^{228}Th is about 4 cm which is consistent with the prediction based on the known sedimentation rates of about 0.3–0.5 cm/yr and the excess of ^{228}Th also obtained at the uppermost layers as published by Koide et al., (1973). Then the purpose of this study is to investigate fluctuation activity of natural thorium isotopes in various depths of sedi-

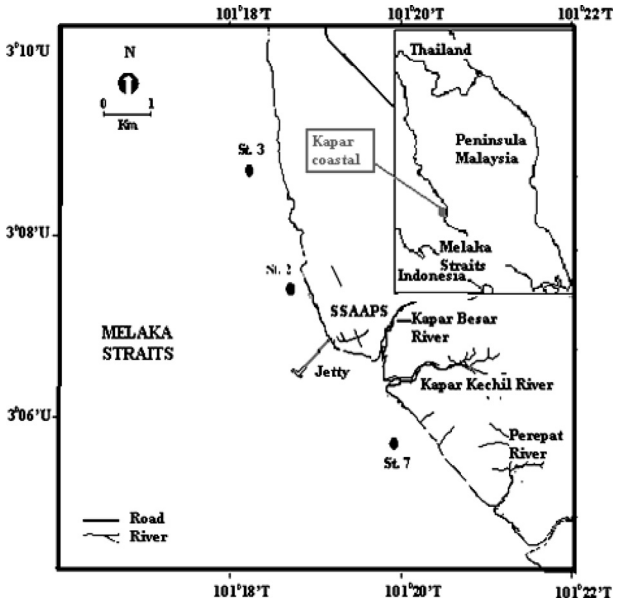

Fig. 1. Three sampling stations at Kapar, Selangor, Malaysia (Shafie et al., 2007).

ments core at the effluent Kapar Coal electric power station and also the affect from coal-fired power station operation in enhancement of thorium isotopes activities to the marine environment.

Materials and Methods

Study area

Kapar coastal is a semi-diurnal tidal coastal area, humid and tropical weathering and fishery activity is done in a small scale. It is located 56 km from Kuala Lumpur and only a few kilometers from Klang Port (Fig. 1). Sultan Salahuddin Abdul Aziz Power Plant (SSAAPS) nearby the Kapar coastal has been running since 1985 with capacity extent to 2420 MW with coal consuming 2.5 mtpa (million tonne per year) of raw charcoal, as a main fuel and is the biggest power plant in Malaysia that contribute 23% of electricity demand to the country. Raw charcoal is imported from Australia, Indonesia, South Africa, China and a few from Sarawak, Malaysia. The power plant is occupied with ESP (Electrostatic Precipitators) and its efficiency is up to 99.2% (TNB Generation 2003). Station 2 (St. 2) is located at the point of hot water discharge from the power plant cooling system, Station 3 (St. 3) is 2.5 km away from Station 2 and Station 7 (St. 7) is an estuary area with salinity 21.05 psu. Water column depth at St. 2, St. 3 and St. 7 are 0.3 m, 1 m and 1.5 m, respectively.

Sampling

Three sediment cores, consisting of a total of 40 subsamples, were collected at Kapar coastal on 25th October 2003 (Shafie et al., 2007). Cores were sliced to 3 cm interval during the sampling and stored frozen until laboratory analysis. Sub-samples were dried at 60°C to a constant weight after the large shell fragments were removed. Sediments were weighed before and after the drying process for estimating the porosity value (Equation 1). Dried samples were lightly pestle with mortar and sieved with mechanical sieve through 2 mm, 1 mm, 250 μm, 125 μm and 63 μm to get the grain size percentage for each sub-samples (Shafie et al., 2007). Afterwards, the sediments were well mixed from all sizes in order to homogenize the sample before an aliquot was taken for analysis.

Radionuclide analysis

About 0.5–1.0 g sample was taken from the above preparation and treated with 15 ml of 8 M HCl for partial digestion and ^{229}Th was spiked with known activity (0.258 Bq/mL) as chemical yield tracer. Thorium extracted from partial digestion showed that it was from the organic matter (Krishnaswami and Sarin, 1976; Mohamed et al., 1996). Samples were heated for 2–3 hours at 80ºC, cooled down and filtered through the membrane filter with the pore size of 0.45 μm and dried the supernatants. Then continued adding with HNO_3 acid and slightly heating, if any black layer existed a few drops of H_2O_2 were added as an oxidized agent (Schwarcz, 1982). After that rinsed beaker with 5 ml of 7.5 M HNO_3 and diluted to 30 ml with double distiller water for purification using anion Bio-Rad resin mesh size 100–200 mesh. Thorium was eluted with 20 ml of 8 M HCl (Adam et al., 1998). Finally, thorium was electrodeposited onto stainless steel disc according to Buesseler et al., (1992) method and counted with the alpha spectrometry (Ortec EG & G, Model 676 A ALPHA KING^{TM}) for 2 to 3 days. The accuracy of the analytical determinations was established using the four replicates analysis of standard reference materials (SRM IAEA-300) with activity of ^{230}Th and ^{232}Th were in the 95% of confidence interval.

Results and Discussion

Sediment mixing rate, D, using excess ^{228}Th ($^{228}Th_{ex}$)

Mixing rates at Kapar coastal area were calculated using an excess of ^{228}Th activity that obtained directly through the partial digestion, without any reduction from the ^{232}Th activity. Surface mixing rate were obtained using the equation 1 (Dellapenna et al., 1998);

$$D = \lambda[z\{1/\ln(C_o/C_z)\}]^2 \quad (1)$$

Where D is the mixing rate (cm^2 year^{-1}); λ; is the ^{228}Th decay constant (year^{-1}); C_o is the activity of radioisotope at an upper level of the profile (dpm/g) and C_z is the activity of radioisotope at z depth below C_o (dpm/g). This formula is applied when the sediment mixing is intense ($\lambda D \gg A^2$) and ac-

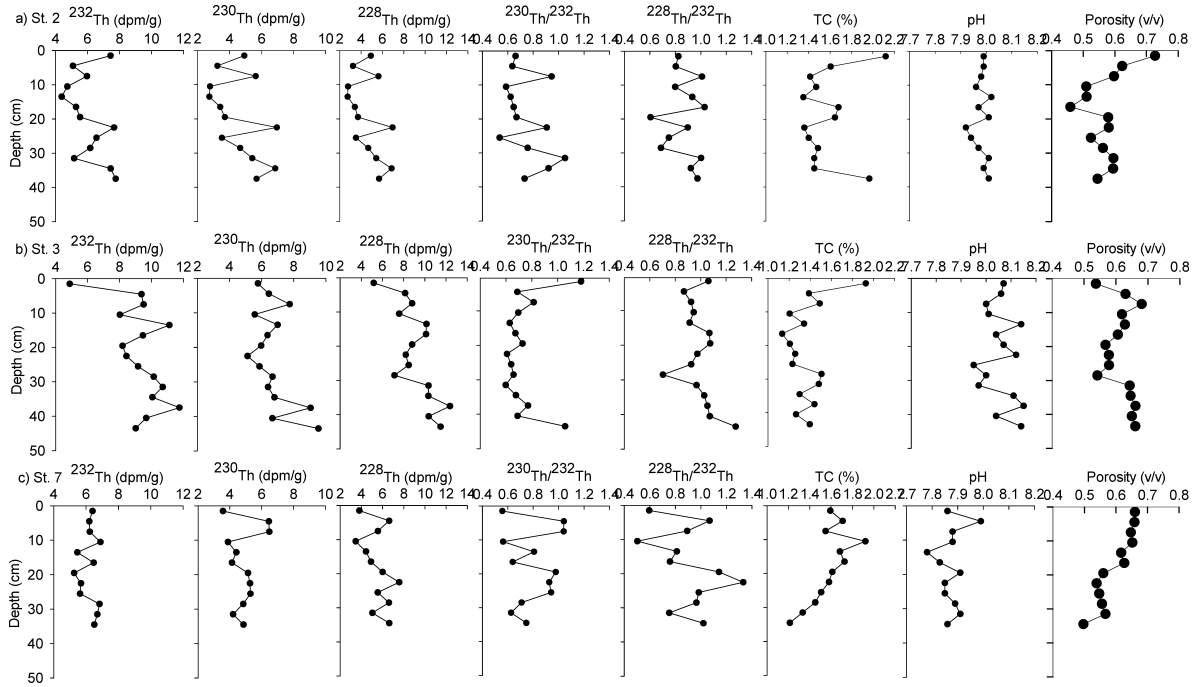

Fig. 2. Vertical distribution of thorium and others parameter.

cumulation is low with A (accumulation rate, cm year^{-1});

$$A=[\lambda z\{1/\ln(C_o/C_z)\}]-[D/z\ \{\ln(C_o/C_z)\}] \quad (2)$$

If mixing rate is negligible, (i.e. D≈0), equation 2 simplifies to equation 3 (Dellapenna et al., 1998; Mohamed et al., 2008);

$$A=\lambda z[1/\ln(C_o/C_z)] \quad (3)$$

Relative to the radioisotope half-life, ^{228}Th activities at Kapar are homogenized in the mixed layer reveal rapid sediment mixing. In this paper, C_o taken from 0–3 cm depth meanwhile C_z the activities from the deepest layer in each core. These are because of the variables $^{228}Th_{ex}$ activities and none of the profiles show exponential decrease in the deeper layer (Fig. 2), which means the whole length of the cores considered mixing.

The calculated mixing rates demonstrate that the mixing of the coastal bed is relatively vigorous. Highest mixing rate value are obtained at station St 2 with D is 12455 cm^2 yr^{-1}, compare to the other two stations at St 3 and St 7 where D are 1157 cm^2 yr^{-1} and 1528 cm^2 yr^{-1}, respectively. Turbidity value is extraordinary high (391 NTU) at St 2 station (point of hot water discharge from power plant operation), indicates the higher turbidity of the water column will increase the sediment mixing rate rapidly. As mentioned before, there are no clear section layers neither the transient layer, zone of intense biological and physical mixing or zone of accumulation as obtained by Dellapenna et al., (1998) which is below the mixed layer, activity of the isotope decreased logarithmically as a function of its half-life (Koide et al., 1973). These prove that the Kapar area has very intense coastal bed mixing, reveal the whole core length represent new sediment deposition that $^{228}Th_{ex}$ could penetrate to the deepest layer of the cores.

These values were much greater than mixing coefficient obtained by previous studied areas (Table 1), using $^{210}Pb_{ex}$ and $^{234}Th_{ex}$. The isotope of $^{228}Th_{ex}$ characterizes processes on ten years timescale with mixing depth to 45 cm at station St 3. This depth of mixing should be more extended that cores sampled in this study may not long enough to reveal the actual penetration of $^{228}Th_{ex}$. Further, the fluctuated of $^{228}Th_{ex}$ in sediment layers indicating the deposition of materials accumulated less than ten years as well explaining by Koide et al., (1973). The rapid mixing rates and fluctuated $^{228}Th_{ex}$ at study area resulted from the physical factors such as semi-diurnal tidal, dredging activity in this area for deepening the water column for the ships pathway and disturbed sediment by hot water discharge (especially at St 2).

Vertical distribution of thorium nuclides

a) ^{232}Th (Thorium-232)

Activities of ^{232}Th in the all three cores show variables distribution and non-constant profiles (Fig. 3) and lies in the ranged of 4.38 to 11.75 dpm/g. Origin of ^{232}Th in marine sediments contained in the detrital component and non-constancy of ^{232}Th in the studied sediments suggests supply of detrital sediments was not consistent and a relatively non-uniform depositional environment during the past centuries (Mamolejo- Rodriguez et al., 2008). According to Lalou,

Table 1. Mixing coefficient rate at various marine environment.

Surface mixing coefficient D (cm^2/yr)	Method	Note	Area	Reference
1157–12455	$^{228}Th_{ex}$	Receiving large effluents of hot water during operation	Kapar coastal	This study
3.5–≥89	$^{210}Pb_{ex}$	Margin~water column depth; 16–46 m	Gulf of Thailand	Srisuksawad et al. ('97)
0.26–≥33		Central basin~water column depth; 48–70 m		
		Nutrient-rich, affected by human activities		
>80–>172	$^{210}Pb_{ex}$	Cherrystone (12–15 m depth)	Chesapeake Bay, North America	Dellapenna et al. (1998)
6–29		Wolf Trap (11–12 m depth)		
3–50	$^{234}Th_{ex}$	Water column depth; 16–808 m	Santa Monica Bay coastal, California	Alexander & Venherm (2003)
		Anthropogenic contaminant from wastewater treatment facilities, stromwater runoff, atmospheric fallout & marine-related activities		
0.20	$^{234}Th_{ex}$	Water column depth; 910 m	Santa Monica Basin	Chih-An Huh et al. (1987)
		Most intense level of human activities in the borderland area		

(1982), ^{232}Th typically decreased with depth in a sediment core and not migrate in the sedimentary column. ^{232}Th activities at St 3 are varied in a wider range compare to St 2 and St 7, from 4.88±0.19 dpm/g to 11.75±0.51 dpm/g with the highest activity average at St 3 (9.30±0.42 dpm/g). Higher activity of ^{232}Th obtained at station St 3 clearly showed this station has receive large source from the fired-coal station which is directly deposited on the sediment because the mixing coefficient rate value was less than other studied stations and easy particles deposit on the surface sediment. Then on the top layer of 3 cm depths has lowest value comparing with other two stations resulted from intensive sediment disturbance the active coastal currents.

b) ^{230}Th (Thorium-230)

The downward variations of ^{230}Th contain quite large values, varied from 2.73 dpm/g to 9.54 dpm/g (average; 5.47±0.28 dpm/g). The differentiations of ^{230}Th activities between maximum to minimum were 4.22 dpm/g, 4.42 dpm/g and 2.92 dpm/g in each core of stations St 2, St 3 and St 7, respectively.

The obtained results obviously different with other region such as northeastern Taiwan (<1 dpm/g) and Gulf of Thailand (2.44 dpm/g) reported by Chung and Chang, (1996) and Srisuksawad et al., (1997), respectively. More than 76% ratio value of ^{230}Th/^{232}Th was about 0.76 and quite similar with the sediments of northeastern Taiwan continental slope (60%), where most of this isotope likely transported together with the original, land-derived detrital particles or created by net ^{234}U dissolution in water column. The particulate scavenging of ^{230}Th discharged from the thermal activity have been transported vertically or horizontally before depositing onto the sediment by bottom or tidal currents. This means the scavenging and local physical factors have been strongly affected the distribution of thorium in the sediment was proven by the mixing rate values (Table 1). But a significant correlation between ^{230}Th and ^{232}Th, with $r=0.733$ at $p<0.01$, show that ^{230}Th in core are mostly derived from the ^{230}Th from detrital source (Table 3).

The ^{230}Th/^{232}Th activity ratios measured from this study area exit it non-uniform profiles with the ratio ranged from 0.54 to 1.18 (Fig. 3 and Table 2). The vertical profile shows a little enrichment of ^{230}Th/^{232}Th at top 10 cm layer in each core, meaning the high input of ^{230}Th was derived from the particulate or from ^{234}U decay in the water column. However, the ratios are not constant at the deeper layers and also reached to the similar ratios as at the surface or more. These can be interpreted by the high sediment mixing rates at Kapar area but St 3 shows more constancy ratios than the other two stations as station St 3 has the lowest mixing rate (same as ^{232}Th profiles explanation). Mostly the ratios in this study were less than unities in average about 0.76 indicating the study area has high input of thorium and less input of uranium from the fired-coal station. This average was quite

Table 2. Thorium isotopes at various marine environments.

^{232}Th	^{230}Th	^{228}Th	^{230}Th/^{232}Th	^{228}Th/^{232}Th	Digestion/phase	Note	Area	Reference
dpm/g								
4.38–11.75 (7.32)	2.73–9.54 (5.47)	3.34–12.38 (6.80)	0.54–1.18 (0.76)	0.50–1.33 (0.92)	8 M HCl	Effluent discharge	Kapar	This study
2.38–6.37	2.70–12.45	2.21–9.30	0.69–1.95	0.83–1.46	8 M HCl	Island	Redang Island	
0.91–8.21	1.22–11.83	1.07–9.72	0.24–5.58	0.18–5.07	Total digest	0–6 cm layer	Kapar	Mohamed et al., (2001)
3.64–7.78	1.92–5.62	3.36–6.66	0.53–0.72	0.71–1.00	$<$200 μm HNO_3, $HClO_4$, HCl	Coastal/estuary	East Coast of Malaysia	Azlina & Mohamed (2005)
1.70–4.92	1.33–3.77	1.95–5.05	0.54–0.91	0.78–1.35	Total digest	Nutrient-rich, affected by human activities	Gulf of Thailand	Srisuksawad et al., ('97)
6.3					INAA	Normal background along coastal region	Vietnam	Duong et al., 1996
3.06–5.28					Karnaphuli River	Karnaphuli-near phosphate	Chittagong, Bangladesh	Manzatul et al., (1999)
3.12–3.72					Shango River	factory & heavy industrial		
1.70–7.92					Coastal			
2.72–3.64	1.5–2.30	2.82–3.85	0.51–0.68	0.91–1.22	Total digest	Continental slope	Northeastern Taiwan	Chung and Chang, (1996)
0.84–3.24					$<$63 μm Total digest	Tropical hot, humid climatic zone	Kali River & coast of India	Balakrishna et al., (2001)
0.92–1.76	1.48–11.76				Total digest	Slope,trench, oceanic basin	Japan Trench	Mohamed et al., ('96)
				$<$1	Acid leachates	Marine sediments Authigenic minerals, phillipsites, barites		Koide et al., (1973)
				$<$1–23				
			0.8			Earth crustal		Levinson et al., (1983)
			0.8–0.9			River sediments	Charente River	Scott (1982)
2.21–4.46							Detrital component of marine sediment (clay)	Lalou (1982)
							Authigenic~metalliferous sediments;	
3.15							Phillipsite	
24.24							Deep sea Mn nodules	
0.56–1.21							Shallow Mn nodules	

Parenthesis show the average of isotopes activities

Table 3. Pearson correlations coefficient for all Th ^{232}Th, ^{230}Th and ^{228}Th and others variables for Kapar sediments cores samples.

Variable	^{232}Th	^{230}Th	^{228}Th	Al	Fe	Mn	TC	pH
^{232}Th	1							
^{230}Th	0.733**	1						
^{228}Th	0.866**	0.838**	1					
Al	0.543*	0.427**	0.482**	1				
Fe	0.497**	0.463**	0.351*	0.814**	1			
Mn	0.493**	0.349*	0.434**	0.141	0.222	1		
TC	−0.374*	−0.248	−0.444**	−0.159	0.101	−0.122	1	
pH	0.551**	0.518**	0.615**	0.105	0.115	0.658**	−0.264	1

*Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

similar to the ^{230}Th/^{232}Th ratio in rocks of the earth's crust with approximately 0.8 values. Lower ^{238}U (^{230}Th grandparent) activities resulted from the characteristic of uranium that tends to leach out in the processes of weathering, erosion and sediments transport and it is well known that thorium is extremely insoluble in aqueous media in comparison with uranium (Levison et al., 1982).

c) ^{228}Th (Thorium-228)

Like the others thorium isotopes, ^{228}Th also shows fluctuated profiles from surface to the deeper layers where the activities were from 3.34 dpm/g to 12.38 dpm/g with average of 6.80±0.39 dpm/g. All profiles show no decrease of ^{228}Th activities with depth and no constant activities at deeper layer. Again, one must be remembered that in this study, ^{228}Th activities data were assumes as an excess ^{228}Th ($^{228}Th_{ex}$). The penetration of this unsupported ^{228}Th till the deepest layer of the cores shows the sediments were mixing rapidly at this area and sediments age less than ten years (five times of ^{228}Th half life, t=1.91 yrs) or much more less than that. The enrichment of ^{228}Th has not only can be seen at the top 10 cm, rather it occurred along the cores length with several peaks. One can see ^{228}Th activities started to increase again from 30 cm downward at St 3 and 10 cm downward at St 7 to higher activities than its surface. ^{228}Th has grown in from its parent ^{228}Ra in solution (Scott, 1982) that indicated deeper depth of sediment cores still received the supply of ^{228}Ra from the water column. Like ^{230}Th, ^{228}Th was also shows significant correlation with ^{232}Th ($r=0.866$, $p<0.01$), suggest ^{228}Ra in the liquid phase may derived from the same input as detrital ^{232}Th or it can be measured ^{228}Th is the origin of ^{228}Th in the detrital source itself.

In general, the obtained ^{228}Th/^{232}Th ratios less than one indicating most of the ^{228}Ra nuclides was leach out from the sediments to the overlying water as well described by Cochran (1982) and Ivanovich (1982). However, the trend of this ratio at St 3 exhibit that more points have greater values than its average ratio (0.92) that can be related to pH factor as the pH measured in this sediment core are higher (more alkali) than the others stations (Fig. 3) and profiles of ^{228}Th activities also reveal higher ^{228}Th at St 3. To confirm this phenomenon, statistical test was applied using correlation coefficient to all sub-samples ($n=40$) and the result is $r=0.615$ ($p<0.01$) between parameter of ^{228}Th activities versus pH measured. This indicates ^{228}Ra is trend to form complexes in sediments when the pH of sediment increased and more mobile in lower pH sediments condition.

Relationship thorium with other variables

A Pearson correlation coefficient test was applied to ascertain whether there are any significant relationship between thorium isotopes activities and others parameters such as Al, Fe, Mn, TC (total carbon). Al, Fe and Mn oxides play extremely important roles in the soils chemistry since they have significant effects on many soil chemical processes such as sorption because of their specific surface areas and reactivity (Sparks, 2003). Since there are fluctuation in other parameters and thorium activities, we will consider the combination of all samples obtain during this study were used in the testing. Using this approach, the partial correlation coefficient was defined as a measure of the strength of the linear relationship between two variables as shown in Table 3.

The r value for Al indicates a strong significant positive interactions with all thorium isotopes ($p<0.01$). Aluminum is known as a refractory element as obtained by Yeager and Santschi (2003) and as one of the main constituents of the earth's crust. During the weathering of primary rock minerals, the series of Al hydroxides of variables and composition, from $Al(OH)^{2+}$ to $Al(OH)_6^{3-}$ are formed (Kabata-Pendias and Pendias, 1984). These results suggest that the ^{232}Th, ^{230}Th and ^{228}Th nuclides were bound in the rock and refractory minerals and not adsorption onto the Al oxides. Significances between Th isotopes and Al are also presented by Yeager and Santschi (2003).

The r values for all discrete isotopes of Th with two variables, Fe and Mn, show a significant positive correlation with $p<0.01$ or $p<0.05$, respectively. However, the r value ($r=0.349$, $p<0.05$) for the relationship between ^{230}Th and Mn was slightly lower than the r values between ^{232}Th and

Table 4 Th isotopes measured in coals, bottom ash and fly ash that analyzed from different regions.

^{232}Th	^{230}Th (dpm/g)	^{228}Th	^{230}Th/^{232}Th (Ratio)	^{228}Th/^{232}Th (Ratio)	Procedure	Notice	Location	Reference
0.49	0.41	0.70	0.84	1.43	8 M HCl	Coal (washed)	Taken from power plant, Kapar	This study
2.7	2.79	4.68	1.03	1.73		Bottom ash		
0.10–6.49					Gamma spectrometry	Coal	Yatagan Thermal Power Plant, Muğla, Turkey	Baba (2002)
4.85–7.30						Fly ash		
7.24–9.14						Bottom ash		
0.73–3.88 (2.42)					Gamma spectrometry	Coal	Muğla, Turkey	Ayçik & Ercan (1997)
2.42–7.51 (4.36)						Fly ash		
0.221–1.55					INAA	Coal	Pakistan	Waheed et al., (2001)
0.41							Nigerian	
0.36–2.55							USA	
0.51–1.21					Gamma spectrometry	Coal	3 Lodz power stations, Poland	Bem et al., (2002)
2.85–5.49						Fly ash		
1.70–4.64						Bottom ash		

^{228}Th. This suggests the thorium isotope from ^{238}U decay series was less related with Mn compare Th isotopes from ^{232}Th decay series which are inversely obtained by Yeager and Santschi (2003). According to Cochran (1982), adsorption of thorium onto iron hydroxide coatings on particles occurred and increase of Mn concentration will enhance the scavenging of particles reactive nuclides like thorium. Extrinsic variable of TC displays significant negative correlation with ^{232}Th and ^{228}Th that TC containing organic as well as inorganic minerals. This supported by Mohamed et al., (1996) that said ^{232}Th decreased with increasing biogenic particles in the sediments. Figure 3 displays TC was enrich on the top of 3 cm depth at stations St 2 and St 3 that can be derived from the coal combustion where coals and bottom ash containing 58% and 22% of carbon, respectively. Selly (2000) also reported kerogen (coal) was the major constituent of the organic-rich mudrocks. However, the percentage of TC at all stations were only small amount from the measured TC in raw coal and bottom ash samples.

Thorium isotopes activities and ratios

^{232}Th and its granddaughter, ^{228}Th at Kapar area has greater activities than Redang Island, Malaysia (Table 2). However, the average activities of both isotopes were comparable and falls in range of others Malaysia's coastal area with ^{232}Th and ^{228}Th activities average of 7.32 ± 0.33 dpm/g and 6.80 ± 0.39 dpm/g, respectively. The ranged of ^{230}Th/^{232}Th and ^{228}Th/^{232}Th ratios exhibit less than unity or just a slightly higher than unity and the average ratio of ^{230}Th/^{232}Th was closed to the ratio of the earth's crust. In the previous study by Mohamed et al., (2002) at Kapar coastal, it surprisingly shows approximately 5 times higher of the both ratios and these may attribute from the different source of coal. The thorium isotopes will derive from the raw charcoal or from the bottom ash, the activities measured in coal and bottom ash (Table 4) were much lower than that obtained in the coastal sediments. These suggest that the operation from SSAAPS did not affects the activities of thorium radionuclide due to 1) the pre-wash of raw coal before it is consume, a process called beneficiation (Finkelman, 2003) that tends to remove useful organic compounds along with undesirable trace metals and 2) the utilities efficiency of modern equipment built-in with the power plant. This two stages taken by SSAAPS are from three stages can be made in order to mitigate the effects of coal combustion in the combustion process. However, this requires a further study in details at Kapar coastal has effected by the effluent from the coal-fired power plant operation. Moreover, Flues et al., (2002) study of soil samples in the vicinity of coal-fired power plant in Brazil reveal radionuclides concentration were only enhance for isotopes in ^{238}U-series (^{234}Th, ^{226}Ra and ^{210}Pb) and ^{40}K but no enhancement of ^{232}Th activity.

Conclusions

This study has shown a greatly disturbed sedimentary column which revealed by extremely high and rapid sediment mixing rate coefficient. This is mainly due to the physical factors such as dredging activity and hot water discharge. Radioisotopes of ^{232}Th, ^{230}Th and ^{228}Th display fluctuated distribution along the cores depth resulted from the sediments disturbance. Generally, ^{230}Th/^{232}Th and ^{228}Th/^{232}Th are less than one to its parents (^{234}U for ^{230}Th and ^{228}Ra for ^{228}Th) which were tending to leach out from the sediments to the solution phase. Significant positive or negative correlation coefficient obtained between thorium isotopes with variables such as Al, Fe, Mn, TC, pH and porosity. By comparison from the others site or coastal areas, thorium isotopes and ratios did not show apparent effect by the power station operation. However, this site requires further study in details to confirm weather it caused any concentration of radionuclides or not.

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