EnvironmentAsia
The international journal published by the Thai Society of Higher Education Institutes on Environment

Available online at www.tshe.org/EA
EnvironmentAsia 6(1) (2013) 66-73

Assessment Activity of ^{210}Po and ^{210}Pb in the Edible Tissues of Cultured Seabass (*Lates calcarifer*) at Peninsular Malaysia

Noorliza Zakaria, Afiza Suriani Sarimin, Asnor Azrin Sabuti and Che Abd Rahim Mohamed

School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.

Abstract

Analysis levels of ^{210}Po and ^{210}Pb were determined in the edible tissue of sea bass (*Lates calcarifer*) from 14 cages in the west and east coast Peninsular of Malaysia. The concentrations level in fish were found varies from 1.35 ± 0.22 to 6.20 ± 0.99 Bq/kg dry weight ^{210}Po and 3.30 ± 2.69 to 51.71 ± 19.26 Bq/kg dry weight ^{210}Pb. The level of this radionuclide was much related to the anthropogenic activities at the sampling locations neighbouring area, differences in metabolisms of fish and food intake pattern for each cage. Then the calculated daily intake value due to fish consumption was to be 7.69 mBq/d/person ^{210}Po and 35.90 mBq/d/person ^{210}Pb, which lower than those reported in others countries. In addition, the collective doses of ^{210}Po and ^{210}Pb were estimated to be 0.001mSv/year and 0.009 mSv/year, respectively. This suggests that the dose received by Malaysian due to consumption of fish is rather small, and did not deteriorate human's health and safe for consumption.

Keywords: ^{210}Po; ^{210}Pb; sea bass; daily intake; committed effective dose

1. Introduction

^{210}Po is extensively being studied in the marine environment because it represents the major natural source of internal irradiation for marine organisms (Cherry and Shannon, 1974; Carvalho, 1988; Brown *et al*., 2004). The radiotoxicity of ^{210}Po is connected with the fact that it emits alpha particles with a relatively high energy of about 5.3 MeV and that it is concentrated in the soft tissues, such as muscle, liver and others (Stewart *et al*., 2008). Alpha emitter is considered the most important potential internal radiation exposure of living tissue especially among the natural radionuclides occurring in the ocean. ^{210}Po is considered to be the most important contributor of radiation dose received by human via fish and shellfish consumption (Aarkrog *et al*., 1997). Several studies have been demonstrated that the natural alpha emitting radionuclide of ^{210}Po will accumulated to exceptionally high levels in tissues of a variety of marine organism, as well as above levels of the parent radionuclide ^{210}Pb (Carvalho and Fowler, 1997; Stepnowski and Skwarzec, 1994). Meanwhile, natural radionuclide of lead has also great importance because it is toxic for living organisms, involved in biological cycle and normally presents in highly concentration. This radionuclide is proven to be assimilating through the food chain, which they pose a threat for living organisms and man (Nonova *et al*., 2009; Ariffin and Mohamed, 2010). Therefore, in order to estimate radiological risk to the environment, a greater knowledge of the concentration of radionuclide in a number of reference organisms, the transfer path, the spatial and temporal variations in activities and the concentration factor and also determination of doses received and an evaluation of any possible effects (Brown *et al*., 2004).

Lates calcarifer or known as the white seabass in Asia Pasific is the most commonly cultured in Malaysia. Fish culturing was conducted in seawater, brackish water and freshwater had significantly increased the Malaysian economy. Malaysia also is the highest consumer of seafood in the Southeast Asian region due to term of per capita intake and percentage of protein (Alam and Mohamed, 2011). Measurement of natural background levels and estimation of dose to public in terms of health safety is essential, since these values form reference values for comparing radionuclide concentration due to anthropogenic activities. Some of the radionuclides such as ^{210}Po and ^{210}Pb assume to have greater importance due to their high accumulation potential in seafood (Feroz Khan and Godwin Wesley, 2009). Much less information about ^{210}Po and ^{210}Pb has been recorded in sea bass muscle despite of this fish is a popular fish extensively cultured in South East Asia region (Cheong, 1989). Therefore, a study regarding the ^{210}Po and ^{210}Pb concentration in edible muscle is very important in order to ensure the quality and health safety of this fish. The daily intake and radiation dose due to consumption of muscle are also the objective this study.

2. Material and Method

2.1. Sample and Sampling locations

Sampling was carried out on February 2010 to September 2010. These 53 samples were purchased from 14 cages (Fig. 1) in the west and east coast Peninsular Malaysia. Nowadays, urbanization and industrialization as come up rapidly in the east and west coast Peninsular Malaysia. The effluent discharges from this activities both treated and untreated will affect the aquaculture activity. The two combinations of two main types of fish feed used at every cage are moist feed or trash fish (e.g., Scombridae) and dry pellet. The average weight and length of the samples were taken and description of sampling site as shown in Table 1.

2.2. Analytical Method

The radiochemical separation method was used to estimate ^{210}Po and ^{210}Pb in the samples (Flynn, 1986; Harley, 1978). Briefly, the samples were dissected to obtain the muscle part and oven dried at 60ºC temperature. Then about 0.5g of the dried sample was taken and ^{209}Po of known activity and 20 mg of Pb carrier [$Pb(NO_3)_2$] was added as a yield tracer. A mixture of concentrated HNO_3, $HClO_4$, HCL acids and H_2O_2 were used for digestion (Yamamoto *et al*., 1994). Polonium was then spontaneously deposited onto polished and pre-cleaned silver foil (2.0 x 2.0 cm) in the 0.5M of HCL solution for a period of 3-4 hours at a temperature of 70-90ºC. The activities of ^{210}Po in samples were determined using the Alpha Spectrometry with a silicon-surface barrier detector by Canberra immediately after deposition process (Sabuti and Mohamed, 2011).

Next, the isotope of lead (^{210}Pb) was collected via the electro deposition process by forming lead sulphate ($PbSO_4$) precipitation. The precipitate was wrapped onto plastic disc and count for ^{210}Pb via ^{210}Bi beta activity using the gross alpha/beta counting system (model: Tennelec Series 5-XLB low background gas-flowing anti-coincidence alpha-beta counter) after one month to allow Bi ingrowths. Quality control procedure was applied using a fish standard reference material supplied by the IAEA-414 and the recovery was showed in Table 2.

3. Result and Discussion

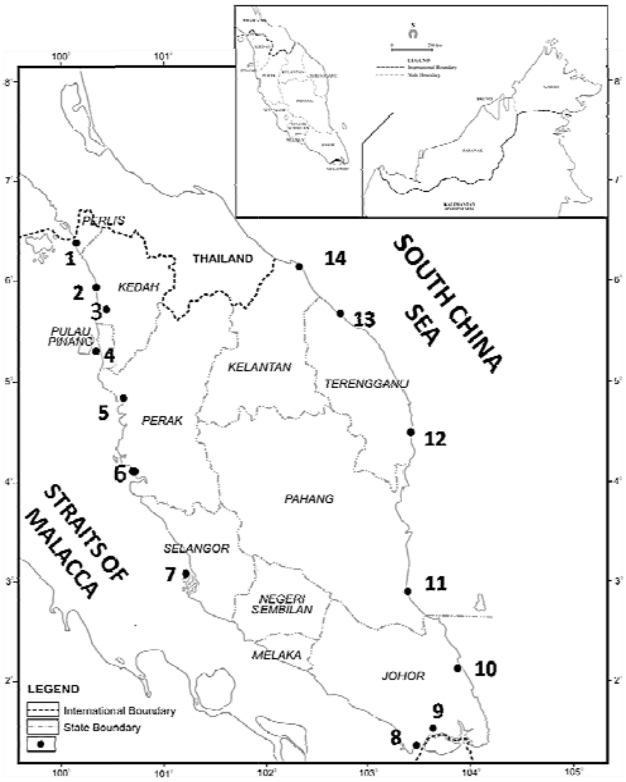

Figure 1. Map of Sampling Location

Table 1. Average length and average weight of samples with descriptions for all sampling locations

Station	Location	n	Sampling Date	Average Length (cm)	Average Weight (g)	Description
S1	Kuala Perlis	4	5-Aug-10	35.30 ± 1.97	667.50 ± 95.97	Rural area
S2	Merbok	4	5-Aug-10	39.03 ± 2.22	710.25 ± 129.09	Rural area
S3	Sg. Petani	4	5-Aug-10	45.40 ± 1.98	1275.00 ± 119.02	Near jetty and urbanization area
S4	Nibong Tebal	4	4-Aug-10	35.70 ± 0.54	653.00 ± 21.18	Near Juru industrial area
S5	Larut Matang	4	4-Aug-10	38.98 ± 0.88	702.50 ± 15.84	State mangrove reserve area
S6	Sg. Tambun	4	5-Aug-10	41.78 ± 1.58	886.00 ± 85.77	Near recreational area
S7	Port Klang	4	16-Sep-10	34.05 ± 0.56	740.00 ± 78.74	Urbanization area
S8	Gelang Patah	3	11-Feb-10	40.70 ± 1.64	1095.33 ± 207.04	Adjacent to Singapore urban area
S9	Sg. Danga	4	11-Feb-10	35.08 ± 0.59	514.25 ± 31.44	Near Danga Bay, recreational beach
S10	Sedili Kechil	3	12-Feb-10	33.65 ± 0.71	505.25 ± 47.07	Estuary of Sedili Kechil river, under state mangrove reserve area
S11	Pekan	3	12-Feb-10	35.23 ± 1.19	592.33 ± 43.36	Tributaries of Pahang river
S12	Paka	4	6-Aug-10	37.23 ± 0.42	602.75 ± 42.06	Near urbanization area
S13	Setiu	4	7-Aug-10	32.55 ± 1.13	493.25 ± 24.98	Mariculture area
S14	Tumpat	4	7-Aug-10	37.88 ± 1.79	717.75 ± 116.33	Near the boundaries of Thailand and recreational area
	Total (n)			**37.33 ± 1.72**	**725.37 ± 1.04**	

n – The number of samples

Note: Fish feed - combination of trash feed and dry pellet used at each sampling location

3.1. ^{210}Po and ^{210}Pb activity concentrations in the edible tissue of sea bass

The activity concentrations of ^{210}Po and ^{210}Pb in tissue ranged from 1.35 ± 0.22 to 6.20 ± 0.99 Bq/kg and 3.30 ± 2.69 to 51.71 ± 19.26 Bq/kg respectively. Average activity concentrations of ^{210}Po and ^{210}Pb for each cage are shown in Table 3. The value showed a wide range of concentrations with a greater accumulation of ^{210}Pb relative to ^{210}Po found in all samples. Theses variations in activity concentration are due to the differences in metabolisms and food intake pattern for each cage (Al-Masri *et al*., 2000; El Samad *et al*., 2000). Feeding practise with trash fish will increased pollution due to the proportion of feed wastage can be higher because the fish can break up upon entry into the water. Thus, this feeding style can lead the increases nutrients and organic in water (Blyth and Dodd, 2002). In addition, activity of ^{210}Po and ^{210}Pb in this species varies according to the sampling site can be assumed that accumulation influenced by environmental factor. The highest value of ^{210}Po was 5.30 ± 0.50 observed near the boundaries of Thailand and recreational area (S14) meanwhile the highest values of ^{210}Pb were 32.67 ± 11.54 at Juru industrial area (S4). Development of industries such as tourism, have a negative impact on fish cage near at S14. The direct waste from the hotel and resort near by might increase the nutrient and organic in water body of S14. According to Cherry and Heyraud (1981) ^{210}Po has a much higher affinity for organic matter in marine organisms compared to ^{210}Pb. El Samad *et al*. (2000) noted that the highest concentrations ^{210}Pb were found in industrialized areas whose effluents may increase the concentrations of naturally occurring radionuclides in the environment. Industrialization and urbanization area cause a lot of radioactive element extended to the river and directly through sea. Aysun Ugur *et al.* (2002) has studied the high level of ^{210}Po and ^{210}Pb observed in mussels could due to the extensive of coastal industrial source including petroleum and other chemical industries. The average activity concentration

Table 2. Result of ^{210}Pb(^{210}Po$^{\#}$) activity in Fish Reference Sample IAEA-414

Certified Value (Bq/kg d.w)	Measured Value (Bq/kg d.w)	Recovery (%)
1.8 - 2.5	1.08 ± 0.18	83.74

\# ^{210}Po is in equilibrium with ^{210}Pb at the time of measurement

Table 3. The average values of ^{210}Po and ^{210}Pb activity concentrations in fish (*Lates calcarifer*) muscle

Station	No. Samples	^{210}Po (Bq/kg)	^{210}Pb (Bq/kg)
S1	4	2.05 ± 0.33	6.16 ± 3.73
S2	4	2.48 ± 0.40	13.60 ± 5.30
S3	4	2.73 ± 0.44	16.72 ± 6.31
S4	4	1.74 ± 0.28	32.67 ± 11.54
S5	4	3.00 ± 0.48	23.06 ± 9.22
S6	4	4.20 ± 0.67	8.57 ± 3.98
S7	4	3.33 ± 0.53	19.31 ± 8.14
S8	3	3.03 ± 0.49	12.56 ± 7.29
S9	4	3.19 ± 0.51	13.86 ± 8.67
S10	3	4.65 ± 0.74	11.70 ± 7.26
S11	3	3.35 ± 0.54	15.95 ± 6.65
S12	4	2.46 ± 0.39	13.42 ± 5.96
S13	4	4.47 ± 0.72	11.60 ± 5.83
S14	4	5.30 ± 0.85	10.90 ± 5.46

of ^{210}Po and ^{210}Pb in fish, were comparable to those reported in other countries as shown in Table 4.

In general, concentration ^{210}Po in muscle was always higher than ^{210}Pb but in this study showed ^{210}Pb in muscle was higher than the ^{210}Po. This measurement agree with data in the literature such as *Euthynnus alletteratus* (Al-Masri *et al*., 2000), *Salvelinus namaycush* and *Coregonous clupeafornis* (Clulow *et al*., 1998), and *Nimipterus delagoae, Atule mate* and *Auxis thazard* (Zal U'yun *et al*., 2005). Generally, the wild fishes were used for previous studied compared cultured fish for this study. The wild fish inhabit natural environment and experience less influence from anthropogenic impact. These cultured fish extensively cultured along the estuaries and littoral zone of Malaysia coastal waters. Therefore, they have been exposed to the variation contamination either from land based or sea based source. In addition, the differences level of radioactivity could be due to differences in species, metabolism and feeding pattern (Al-Masri *et al*., 2000). Though the samples accumulate high level of ^{210}Pb, the variability in the accumulation reflected in the fish tissues is evidently due to the availability of ^{210}Pb in the environment (Hameed *et al*., 2004). But Hameed *et al*. (2004) noted also the direct absorption of radioisotopes by the gill membrane could be the reason for this higher

Table 4. Range/average of ^{210}Pb and ^{210}Po activity concentrations in fish muscle from different countries.

Location	Species	^{210}Po (Bq/kg)	^{210}Pb (Bq/kg)	References
Malaysia (Mean)	*Lates calcarifer*[a]	3.26	15.25	This study
Kemaman, Malaysia	m.s[b]	4.79-146.05	4.81-146.54	ZalU'yun *et al*., 2005
Besut, Malaysia	m.s[b]	7.93	7.96	ZalU'yun *et al*., 2005
Kuala Selangor, Malaysia	m.s[b]	0.10-11.77	0.13-4.00	Mohamed *et al*., 2006
Kapar, Malaysia	*Arius maculatus*[b]	0.06-5.64	-	Alam and Mohamed 2011
Lebanon	m.s[b]	0.22-47.82	1.31-45.00	El Samad *et al*., 2010
Syria	m.s[b]	0.27-27.48	0.05-0.38	Al-Masri *et al*., 2000
Japan	m.s[b]	0.6-26	0.04-0.54	Yamamoto *et al*., 1994
Australia	m.s[b]	0.9-44.1	-	Smith and Towler 1993
Portugal	m.s[b]	0.2-11	-	Carvalho, 1988
South Africa	m.s[b]	2.2-20.3	-	Cherry *et al*., 1994
America	m.s[b]	0.4-153.3	0.1-7.0	Noshkin *et al*., 1994

m.s – multi species
[a] Cage fish
[b] Wild fish

activity. In addition, the carnivorous feeding could also be attributed for this higher activity since ingestion is the dominant means by which radioactive material are accumulated in aquatic organisms agreed with previous studies (Raja and Hameed, 2010; Hameed *et al*., 2004). Lower concentrations of ^{210}Po in muscle are important, because human consume mostly the muscle of the fish. Thus, this accounts the low radiation dose (Iyengar *et al*., 1980). Regarding the fish size, there is no apparent relation between ^{210}Po or ^{210}Pb and weight or length by using statistical analysis. In this study it is clearly showed that the fish size could not affect the concentration of ^{210}Po and ^{210}Pb. Negative correlation ($r = -0.295, p < 0.05$) was found between concentration of ^{210}Po and ^{210}Pb.

3.2. Daily intake of ^{210}Po and ^{210}Pb via consumption of fish

Dietary intake of ^{210}Po and ^{210}Pb through the consumption of fish plays a major role in accumulation of ^{210}Po and ^{210}Pb in the human body. The daily intake of ^{210}Po and ^{210}Pb by the Malaysian adult population of 16.88 million (Ninth Malaysian Plan, 2005) through the fish consumer was calculated with the following equation;

Daily intake, (Bq/day/person) = [A x B x C] / [D x E] ------------- (1)

Where A is the activity of radionuclides in the muscle (Bq/kg), B is the annual production of aquaculture by cages reported by the Department of Fisheries Malaysia (2010), which was 24,236.31 ton, C is rate of edible part is the constant value edible part of fish (0.6), D is Malaysian population (16.88 million) and E is the time (365 days). An assessment of daily intake of ^{210}Po and ^{210}Pb was carried out to be 7.69 mBq/d/person and 35.9 mBq/d/person, respectively. This intake value was compared with other reported values given in Table 5. In general, the Malaysian population's consumption of seafood relatively low compared with other countries such as Japan. Thus, the daily intake of ^{210}Po and ^{210}Pb of Malaysian people also were relatively low than the other countries. From the reported values it was observed that intake values in present study is much less compared than other study; fish at Kuala Selangor, Malaysia by Mohamed *et al*. (2006) and Kapar coastal, Malaysia by Alam and Mohamed (2011). A comparatively higher value intake was observed on both previous studies because the source of the coal burning at the power plant. The lower intake value of this study may be due to lower annual fish cage production compare to the previous studies using the annual gross fish catch by fisherman. However, the daily intake for the Malaysian population was lower than that of the world reference value, which is 58000 Bq/d/person (IAEA, 1995).

3.3. Committed Effective Dose (CED) calculation.

Radiation dose deposition in human body due to consumption of seafood can be estimated by two methods (IAEA, 2006). The first method is based on the ^{210}Po and ^{210}Pb concentration in the seawater. The second method is based on the ^{210}Po and ^{210}Pb concentration in the edible tissue of the fish. Internal doses received through concentration of ^{210}Po and ^{210}Pb in the tissue of the fish for Malaysian were measured here. Dietary intakes of 7.69 mBq/d/person for ^{210}Po and 35.9 mBq/d/person for ^{210}Pb obtained were used in the calculation. The committed effective dose was calculated as follows:

Committed Effective Dose, CED (mSv/year) = A x B x C ---------- (2)

Where A is the daily intake of ^{210}Po or ^{210}Pb (mBq/d/person), and B is the ingestion dose coefficient (dose equivalent per intake of unit activity, Sv/Bq) reported by the International Commission on Radiological

Table 5. Daily intake of ^{210}Po and ^{210}Pb via consumption of fish muscle in different countries

Location	Daily intake (mBq/d/person)		References
	^{210}Po	^{210}Pb	
Malaysia	7.69	35.90	This study
Kuala Selangor, Malaysia	280	90	Mohamed *et al*., 2006
Kapar, Malaysia	199.86	-	Alam and Mohamed 2011
Japan	480-690	22-42	Yamamoto *et al*., 1994
Marshall Island	1900	230	Noshkin *et al*., 1994
Poland	42	1.1	Pietrzak-Flis *et al*., 1997
Poland	27	-	Skwarzec, 1997
Syria	6.46	0.24	Al-Masri *et al*, 2000

Table 6. Committed effective dose due to ^{210}Po and ^{210}Pb reported on other countries

Location	Committed Effective Dose (mSv/year)		References
	^{210}Po	^{210}Pb	
Malaysia	0.001	0.009	This study
Kapar Coastal, Malaysia	0.04	-	Alam and Mohamed, 2011
Lebanon	0.01	0.27	El Samad *et al*., 2010
Japan	0.05	0.05	Yamamoto *et al*., 1994
Japan	0.73	0.06	Tomoko *et al*., 2009
Syria	0.68	0.34	Al Masri *et al*., 2000
Ontario, Canada	0.08	0.39	Clulow *et al*., 1998

Protection (ICRP, 1994) to be 2.4 x 10-7 for ^{210}Po and 6.8 x 10-7 for ^{210}Pb and C is the exposure frequency (365 days/year).

The value of CED was calculate by applying the above dose conversion factor was to be 0.001 mSv/year ^{210}Po and 0.009 mSv/year ^{210}Pb, but low values of CED for ^{210}Po and ^{210}Pb are due to less intake of ^{210}Po and ^{210}Pb in consumption rates However, the Japanese people consume more fish and shellfish than European, American and Asian people. Therefore, the CED value for Japanese is much higher than those for European, American and Asian population (Table 6). Interestingly, the effective dose of ^{210}Po and ^{210}Pb are below the safety limit recommended by ICRP (1mSv/year ^{210}Po; 5mSv/year ^{210}Pb) (ICRP, 2007). This result can be explained by the contribution of ^{210}Po and ^{210}Pb from fish, which are consumed in low quantities by Malaysian and decrease the effective dose. Thus, the sea bass intake was considered to be safe for Malaysian.

4. Conclusion

This study provides a general view of ^{210}Po and ^{210}Pb activities in coastal area Peninsular of Malaysia. The concentration of ^{210}Po and ^{210}Pb found to be within in the range of other studies. On the basis of these findings, it was concluded that the ^{210}Po and ^{210}Pb activities in the edible parts of the sea bass would pose no health hazards for the consumers. The daily intake and committed effective dose of ^{210}Po and ^{210}Pb was calculated and found to be lower than IAEA and ICRP. Therefore, low radiation dose expected for Malaysian population through the consumption of ^{210}Po and ^{210}Pb in the analyzed fish.

Acknowledgement

The authors would like to thanks all the individuals and laboratory members involved in this research, especially Mr Mazren for his cordial help during sampling and laboratory works. This research is funded by the grants of Ministry of Science, Technology and Innovation (MOSTI) through the Science Fund grant No. 04-01-02-SF0117.

References

Aarkrog A, Baxter MS, Bettencourt AO, Bojanowski R, Bologa A, Charmasson S, Cunha I, Delfanti R, Duran E, Holm E, Jeffree R, Livingston HD, Mahapanyawong S, Nies H, Osvath I, Pingyu L, Povinec PP, Sanchez A, Smith JN, Swift D. A comparison of doses from ^{137}Cs and ^{210}Po in marine food, a major international study. Journal of Environmental Radioactitvity 1997; 1: 34.

Alam L, Mohamed CAR. Natural Radionclide of ^{210}Po in the edible seafood affected by coal-fired power plant industry in Kapar coastal area of Malaysia. Environmental Health 2011; 10: 43.

Al-Masri MS, Mamish S, Budeir Y, Nashwati A. ^{210}Po and ^{210}Pb concentration in fish consumed in Syria. Journal of Environmental Radioactivity 2000; 49: 345-53.

Ariffin NAN, Mohamed CAR. Natural radium isotopes in particulate and dissolved phases of seawater and rainwater at the west coast Peninsular Malaysia caused by coal-fired power plant. Environment Asia 2010; 3(2): 97-108.

Aysun Ugur, Gungor Yener, Asiye Bassari. Trace metals and ^{210}Po (^{210}Pb) concentration in mussels (*Mytilus galloprovincialis*) consumed at western Anatolia. Applied Radiation and Isotopes 2002; 57: 565-71.

Blyth PJ, Dodd RA. An economic assessment of current practice and methods to improve feed management of caged finfish in several SE Asia regions. Report prepared for APEC/NACA. NACA Bangkok. 2002; 21.

Brown JE, Jones SR, Saxen R, Thorring H, Vives I, Battle J. Radiation doses to organisms from natural radionuclides. Journal Radiological Protection 2004; 24: A63-A77.

Carvalho FP, Fowler SW. A double tracer technique to determine the relative important of water and food as a source of polonium-210 to marine prawns and fish. Marine Ecology Progress Series 1994; 103: 251-64.

Carvalho FP. ^{210}Po in marine organisms a wide range of natural dose domains. Radiation Protection Disometry 1988; 24 (14): 97-117.

Cheong L. Status of knowledge on farming of Seabass (*Lates calcarifer*) in South East Asia. *In*: Advances in Tropical Aquaculture, Tahiti. February 20–March 4, 1989; 9: 421–28.

Cherry RD, Heyraud M, Rindfuss R. Polonium in telecast fish and in marine mammals: Interfamily differences and possible association between polonium-210 and red muscle content. Journal of Environmental Radioactivity 1994; 24: 273-91.

Cherry RD, Heyraud M. Polonium-210 content of marine shrimp: variation with biological and environmental factors. Marine Biology 1981; 65: 165–75.

Cherry RD, Shannon LV. The alpha radioactivity of marine organisms. Atomic Energy Review 1974; 12: 3-454.

Clulow FV, Dave NK, Lim TP,Avadhanula R. Radionuclides (lead-210, polonium-210, thorium-230 and -232) and thorium and uranium in water, sediments and fish from lakes near the city of Elliot Lake, Ontario, Canada. Environmental Pollution 1998; 99: 199-213.

El Samad O, Baydoun R, El Jaid H. Activity concentration of Polonium-210 and Lead-210 in Lebanese fish. Lebanese Science Journal 2010; 11(2).

Feroz Khan M, Godwin Wesley S. Assessment of health safety from ingestion from natural radionuclides in seafood from tropical coast of India. Marine Pollution Bulletin 2009; 62: 399-404.

Flynn WW. The determination of low levels of polonium-210 in environmental materials. Analytical Chemistry 1986; 43: 221-27.

Hameed SM, Bukhari SA, Hameed SP. Study on the bioaccumulation of polonium-210 and lead-210 in the abiotic and biotic components of Palk Strait, South East Coast of India. *In*: 11th International Congress of the International Radiological Protection Association. Madrid, Spain. 2004; 111-15.

Harley JH. Manual of standard procedures, Environmental Measurement Laboratory. Department of Energy, USAEC Report HASL-300, New York; 1978.

IAEA, International Atomic Energy Agency, Sources of radioactivity in the marine environment and their relative contributions to overall dose assessment from marine radioactivity (MARDOS), IAEA-TECDOC-838, October; 1995.

IAEA, International Basic Safety Standards for Protection against Ionizing Radiations and for the Safety of Radiation Sources. Safety Series No. 115, IAEA, Vienna. 2003.

ICRP, Recommendations of the International Commision on Radiological Protection .ICRP Publication 30, Part 2 and supply. Oxford: Pergamon; 1980.

ICRP, Recommendations of the International Commision on Radiological Protection ICRP Publication 103. Annals ICRP 2007; 37: 2-4.

Iyengar MAR, Rajan MP, Ganapathy S, Kamath PR.Sources of natural radiation exposure in a low monazite environment. In:Proceedings of an International Symposium Held at Houston, Texas, USA, CONF-7804222, Natural Radiation Environment III 1980; 2: 1090-106.

Mohamed CAR, Tee LT, Zal U`yun WM, Zaharudin A, Masni MA. Activity concentration of ^{210}Po and ^{210}Pb in edible tissue of fish caught at Kuala Selangor, Malaysia. Malaysian Applied Biology 2006; 35(2): 67-73.

Ninth Malaysian Pelan: The economic planning unit. 2006: 2006-12.

Nonova TZ, Tosheva EA, Kies EA. Radioactive radium and lead isotopes determinations in biota samples. Journal of Radioanalytical and Nuclear Chemistry 2009; 282: 507–10.

Noshkin VE, William LR, Wong KM. Concentration of ^{210}Po and ^{210}Pb in the diet at the Marshal Island. Science Total Environment 1994; 155: 87-104.

Pietrzak-Flis Z, Chrzanowski E, Dembinska S. Intake of ^{226}Ra, ^{210}Po and ^{210}Pb with food in Poland. Science of the Total Environment 1997; 203: 157-65.

Quan W, Hongda Z, Tiqiang F, Qingfen L. Re-estimation of internal dose from natural radionuclides for Chinese adult men. Radiation Protection Dosimetry 2008; 130: 434-441.

Raja P,Hameed PS. Study on the distribution and bioaccumulation of natural radionuclides, ^{210}Po and ^{210}Pb in Parangipettai Coast, South East Coast of India. Indian Journal of Marine Science 2010; 39(3): 449-55.

Skwarzec B. Polonium, uranium and plutonium in the southern Baltic Sea. Ambio. 1997; 26(2): 113-17.

Sabuti AA, Mohamed, CAR. Natural Radioisotopes of Pb, Bi and Po in the Atmosphere of Coal Burning Area. EnvironmentAsia 2011; 4(2): 49-62

Smith JD, Towler PH. Polonium-210 in cartilaginous fishes (*Chondrichthyes*) from South Eastern Australia waters. Australian Journal of Marine Freshwater Research 1993; 44: 727-33.

Stepnowski P, Skwarzec B. Tissue and subcellular distribution of ^{210}Po in the crustacean saduria entomon in habiting the sourthen Baltic sea. Journal of Environmental Radioactivity 1999; 49: 195-99.

Stewart GM, Fower SW, Fisher NS. The bioaccumulation of U- and Th- series radionuclides in marine organisms. *In*: Radioactivity in the Environment (*Ed*: Baxter M). 2008; 13: 269-305.

Tomoko O, Tetsuya S, Yoko K, Takao M, Kaneaki S. Evaluation for Committed Effective Dose Due to Dietary Foods by the Intake for Japanese Adults. Journal Health Physics 2009; 44(1): 80-88.

Yamamoto M, Abe T, Kuwabara J, Komura K, Takazia Y. Po-210 and Pb-210 in marine organisms: intake levels for Japenese. Journal Radioanalytical Nuclear Chemistry 1994; 178: 81-90.

Zal U'yun WM, Zaharuddin A, Abdul Kadir I, Yii Mei W, Nor Faizal M, Jalal S, Kamarozaman I, Khairul Nizam R, Maziah M. Preliminaries study on the distributions of natural radionuclides in the east coast of peninsular Malaysia. Malaysian Journal of Analytical Sciences 2005; 9(2): 325-37.

Received 30 October 2012
Accepted 5 November 2012

Correspondence to
Professor Dr. Che Abd Rahim Mohamed
School of Environmental and Natural Resource Sciences,
Faculty of Science and Technology,
Universiti Kebangsaan Malaysia,
43600 Bangi,
Selangor,
Malaysia
Email: carmohd@ukm.my; mohamed6566@yahoo.com