Supplementary Materials

Ecological-health risks of potentially toxic metals in mangrove sediments near estuaries after years of piggery farming ban in Peninsular Malaysia

Chee Kong Yap[1]* and Khalid Awadh Al-Mutairi[2]

[1]Department of Biology, Faculty of Science, Universiti Putra Malaysia, 4340 UPM Serdang, Selangor, Malaysia;
[2]Department of Biology, Faculty of Science, University of Tabuk, Tabuk, P.O. Box 741, Saudi Arabia;
kmutairi@ut.edu.sa
* Correspondence: yapckong@hotmail.com; yapchee@upm.edu.my

Tables Legends

Table S1. Sampling information in the mangrove of Sepang Besar River (S1-S6), Sepang Kecil River (S7-S9) and Lukut River (L1-L5). Samplings were conducted on 1 December 2007, except for * on 5 May 2010.
Table S2. Heavy metals analysis recovery percentages of the certified reference materials (CRM).
Table S3. Comparisons between surface sediments from this study with those cited from sediment quality guidelines, and reference values.
Table S4. Definition, exposure factors, and reference values were used to estimate the intake values and health risks of potentially toxic metals in sediments collected from Peninsular Malaysia.
Table S5. Concentrations (mg/kg dry weight) of total Zn, percentages of four geochemical fractions (F1, F2, Fe, and F4), percentages of bioavailable fraction (Bio) and a non-bioavailable fraction (NonBio), Individual contamination factors (ICF), and risk assessment code (RAC), for Zn of surface sediments in Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR) mangrove ecosystems, based on nonresistant fraction as reference fraction or normalizer (-1), and based on background levels of the metals as reference metal or normalizer that were reported from Peninsular Malaysia (-2).
Table S6. Overall statistics of values of hazard quotient (HQ), and hazard index (HI), in the three exposure routes (ingestion= HQ_{ing}; inhalation= HQ_{inh}; dermal contact= HQ_{der}) of Zn, for both children (C) and adults (A) in the mangrove sediments collected from Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR).
Table S7. Concentrations (mg/kg dry weight) of total Cu, percentages of four geochemical fractions (F1, F2, Fe, and F4), percentages of bioavailable fraction (Bio) and a non-bioavailable fraction (NonBio), Individual contamination factors (ICF), and risk assessment code (RAC), for Cu of surface sediments in Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR) mangrove ecosystems, based on nonresistant fraction as reference fraction or normalizer (-1), and based on background levels of the metals as reference metal or normalizer that were reported from Peninsular Malaysia (-2).
Table S8. Overall statistics of values of hazard quotient (HQ), hazard index (HI), carcinogenic risk (CR_{inh}) in the three exposure routes (ingestion= HQ_{ing}; inhalation= HQ_{inh}; dermal contact= HQ_{der}) of Cu, for both children (C) and adults (A) in the mangrove sediments collected from Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR).
Table S9. Concentrations (mg/kg dry weight) of total Pb, percentages of bioavailable fraction (Bio) and non-bioavailable fraction (NonBio), Individual contamination factors (ICF), and risk assessment code (RAC), for Pb of surface sediments in Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR) mangrove ecosystems, based on nonresistant fraction as reference fraction or normalizer (-1), and based on background levels of the metals as reference metal or normalizer that were reported from Peninsular Malaysia (-2).
Table S10. Overall statistics of values of hazard quotient (HQ), hazard index (HI), carcinogenic risk (CR_{inh}) in the three exposure routes (ingestion= HQ_{ing}; inhalation= HQ_{inh}; dermal contact= HQ_{der}) of Pb, for both children (C) and adults (A) in the mangrove sediments collected from Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR).

Table S1. Sampling information in the mangrove of Sepang Besar River (S1-S6), Sepang Kecil River (S7-S9) and Lukut River (L1-L5). Samplings were conducted on 1 December 2007, except for * on 5 May 2010.

Site	Latitude	Longitude	Description of sampling site	Temp (°C)	Cond (µs/cm)	Salinity (ppt)	TDS (mg/L)	DO (mg/L)
SBR-1	02° 36.653′ N	101° 42.345′E	The prawn hatchery area and water was a bit muddy	27.99	34919	20.59	21.47	0.66
SBR-2	02° 36.980′N	101° 42.819′E	Mangrove area	27.54	34734	20.67	21.53	0.07
SBR-3	02° 36.260′ N	101° 42.133′E	A Jetty area, fishing hatchery, water was a little bit muddy	28.44	39303	23.25	23.97	1.45
SBR-4	02° 36.102′ N	101° 42.337′E	Mangrove area at the side of the river and Muddy water	28.01	36619	21.69	22.51	0.08
SBR-5	02° 35.933′ N	101° 42.826′E	Estuarine area, not far from sea and water little bit muddy	28.36	40491	24.07	24.07	0.08
SBR-6	02° 36.042′ N	101° 42.461′E	Clearwater, mangrove area at estuarine	27.87	36677	21.79	22.60	3.56
SBR-1*	101°42.779'E	2°36.913'N	Mangrove area near the industrial factory	31.20	48.68	31.59	NA	4.33
SBR-2*	101°42.261'E	2°36.200'N	Mangrove area	31.05	49.55	32.23	NA	5.19
SBR-3*	101°42.371'E	2°36.099'N	Mangrove area	31.27	48.77	31.65	NA	4.91
SKI-1	02° 37.198′ N	101° 41.235′E	The river was very muddy	29.40	13584	7.14	8.15	0.01
SKR-2	02° 37.201′ N	101° 41.239′E	Water was muddy	28.45	18647	10.26	11.37	-0.08
SKR-3	02° 36.890′ N	101° 41.026′E	River is muddy	29.50	20376	11.06	12.20	0.42
LR-1	02° 34.978′N	101° 47.607′E	The estuarine area nearby a construction site, boating	29.89	33343	18.81	19.82	2.27
LR-2	02° 34.979′ N	101° 47.668′E	Mangrove area	29.83	28452	15.82	16.93	2.23
LR-3	02° 34.847′ N	101° 47.795′E	Mangrove area	29.40	29706	16.73	17.81	2.06
LR-4	02° 34.853′ N	101° 47.882′E	Mangrove area nearby upstream	29.73	33140	18.75	19.76	2.09
LR-5	02° 34.737′ N	101° 48.033′E	Mangrove area nearby upstream, shipping, nearby construction recreational area	30.14	28093	15.50	16.63	0.07

Note: Temp= Temperature; Cond= Conductivity.

Table S2. Heavy metals analysis recovery percentages of the certified reference materials (CRM).

CRM	Cu	Pb	Zn
NSC DC73319 Soil China	85.0%	99.8%	99.7%
MESS - 3 NRC	93.1%	116%	82.8%
TH-1 Sediment Canada	92.9%	100%	110%
SRM 1547	NA	NA	115%
IAEA Soil-5	91.3%	116%	94.8%

NA - data not available.

Table S3. Comparisons of concentrations (mg/kg dry weight) of Zn, Cu and Zn between surface sediments from this study with those cited from sediment quality guidelines, and reference values.

	Zn	Cu	Pb	References
Sediment Quality Guidelines				
ISQV-low	200	65.0	75.0	Chapman *et al.* [1]
ISQV-high	410	270	218	Chapman *et al.* [1]
TEL (Threshold effect level)	124	18.7	30.2	Macdonald *et al.* [2]
PEL (Probable effect level)	271	108	112	Macdonald *et al.* [2]
ERL (Effect range low)	150	34.0	46.7	Long *et al.* [3]
ERM (Effects range median)	410	270	218	Long *et al.* [3]
Reference values				
Pre-industrial reference level	175	50.0	70.0	Hakanson [4]
Upper continental crust	71.0	25.0	17.0	Taylor and McLennan [5]
UCC (Upper Continental Crust)	67.0	28.0	17.0	Rudnick and Gao [6]
UCC (Upper Continental Crust)	52.0	14.3	17.0	Wedepohl [7]
Peninsular Malaysia background	-	3.55	-	Yap *et al.* [8]
Peninsular Malaysia background	-	-	19.48	Yap and Noorhaidah [9]
Peninsular Malaysia background	13.16	-	-	Yap *et al.* [10]

Note NA= not available.

Table S4. Definition, exposure factors, and reference values were used to estimate the intake values and health risks of potentially toxic metals in sediments collected from Peninsular Malaysia.

	Definition	Unit	Values		References
			Children	Adults	
IngR	Ingestion rate of sediment	mg/day	200	100	[11]
InhR	Inhalation rate of sediment	m^3/day	7.63	12.8	[12]
BW	Body weight of the exposed individual	kg	15.0	55.9	[13]
EF	Exposure frequency	days/year	350	350	[13]
ED	Exposure duration	years	6	24	[11]
AT	Average time	days	365 × ED	365 × ED	[14]
PEF	Particle emission factor	m^3/kg	1.36×10^9	1.36×10^9	[11]
SA	Exposed skin surface area	cm^2	1600	4350	[13]
AF	Skin adherence factor	mg/cm day	0.20	0.70	[15]
ABF	Dermal absorption factor	unitless	0.001	0.001	[16]
Cu RfD	Reference dose for ingestion	mg/kg day	4.00×10^{-2}	4.00×10^{-2}	[17]
Cu RfD	Reference dose for inhalation	mg/kg day	4.02×10^{-2}	4.02×10^{-2}	[17]
Cu RfD	Reference dose for dermal contact	mg/kg day	1.20×10^{-2}	1.20×10^{-2}	[17]
Pb RfD	Reference dose for ingestion	mg/kg day	3.50×10^{-3}	3.50×10^{-3}	[17]
Pb RfD	Reference dose for inhalation	mg/kg day	3.52×10^{-3}	3.52×10^{-3}	[17]
Pb RfD	Reference dose for dermal contact	mg/kg day	5.25×10^{-4}	5.25×10^{-4}	[17]
Zn RfD	Reference dose for ingestion	mg/kg day	3.00×10^{-1}	3.00×10^{-1}	[17]
Zn RfD	Reference dose for inhalation	mg/kg day	3.00×10^{-1}	3.00×10^{-1}	[17]
Zn RfD	Reference dose for dermal contact	mg/kg day	6.00×10^{-2}	6.00×10^{-2}	[17]

Table S5. Concentrations (mg/kg dry weight) of total Zn, percentages of four geochemical fractions (F1, F2, Fe, and F4), percentages of bioavailable fraction (Bio) and a non-bioavailable fraction (NonBio), Individual contamination factors (ICF), and risk assessment code (RAC), for Zn of surface sediments in Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR) mangrove ecosystems, based on nonresistant fraction as reference fraction or normalizer (-1), and based on background levels of the metals as reference metal or normalizer that were reported from Peninsular Malaysia (-2).

	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	45.52	2.10	22.90	30.06	28.91	25.00	63.51	1.39	2.10
Maximum	79.34	8.91	27.59	37.68	41.87	36.49	74.99	2.46	8.91
Mean	67.10	3.83	25.77	34.80	35.59	29.60	70.40	1.86	3.83
SE	6.11	1.28	0.83	1.31	2.41	1.92	1.91	0.20	1.28
Skewness	-0.83	-	-	-	-	-	-	-	-
Kurtosis	-0.80	-	-	-	-	-	-	-	-
SBR (N= 6)	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	18.10	0.56	8.03	18.38	39.27	8.59	65.76	0.67	0.56
Maximum	88.25	9.87	26.08	41.29	59.86	34.24	91.40	1.55	9.87
Mean	68.06	2.91	18.86	30.70	47.51	21.77	78.22	1.16	2.91
SE	10.49	1.42	2.94	3.06	3.43	3.92	3.93	0.15	1.42
Skewness	-1.44	-	-	-	-	-	-	-	-
Kurtosis	0.55	-	-	-	-	-	-	-	-
SKR (N= 3)	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	52.27	0.73	13.67	19.75	34.84	14.40	62.26	1.10	0.73
Maximum	98.97	6.44	31.30	37.91	47.70	37.74	85.60	1.87	6.44
Mean	69.55	3.71	24.84	29.77	41.68	28.56	71.45	1.44	3.71
SE	14.78	1.65	5.61	5.33	3.74	7.18	7.18	0.23	1.65
Skewness	0.68	-	-	-	-	-	-	-	-
Kurtosis	-1.50	-	-	-	-	-	-	-	-
SBR2010 (N= 3)	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	14.71	2.99	19.61	37.50	25.41	0.27	0.63	2.04	2.99
Maximum	26.47	7.83	34.10	42.11	32.93	0.37	0.73	2.94	7.83
Mean	19.99	4.97	26.81	39.75	28.47	0.32	0.68	2.56	4.97
SE	3.45	1.47	4.18	1.33	2.28	0.03	0.03	0.27	1.47
Skewness	0.35	-	-	-	-	-	-	-	-
Kurtosis	-1.50	-	-	-	-	-	-	-	-

Note: SE= standard error.

Table S6. Overall statistics of values of hazard quotient (HQ), and hazard index (HI), in the three exposure routes (ingestion= HQ_{ing}; inhalation= HQ_{inh}; dermal contact= HQ_{der}) of Zn, for both children (C) and adults (A) in the mangrove sediments collected from Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR).

	HQ_{ing}		HQ_{inh}		HQ_{der}		HI	
LR (N= 5)	C	A	C	A	C	A	C	A
Minimum	1.99×10^{-3}	2.67×10^{-4}	5.44×10^{-8}	2.45×10^{-8}	1.59×10^{-5}	4.06×10^{-5}	2.00×10^{-3}	3.08×10^{-4}
Maximum	3.47×10^{-3}	4.65×10^{-4}	9.49×10^{-8}	4.27×10^{-8}	2.77×10^{-5}	7.08×10^{-5}	3.49×10^{-3}	5.36×10^{-4}
Mean	2.93×10^{-3}	3.93×10^{-4}	8.02×10^{-8}	3.61×10^{-8}	2.35×10^{-5}	5.99×10^{-5}	2.96×10^{-3}	4.53×10^{-4}
SE	2.67×10^{-4}	3.58×10^{-5}	7.31×10^{-9}	3.29×10^{-9}	2.14×10^{-6}	5.45×10^{-6}	2.69×10^{-4}	4.13×10^{-5}
SBR (N= 6)	C	A	C	A	C	A	C	A
Minimum	7.91×10^{-4}	1.06×10^{-4}	2.16×10^{-8}	9.70×10^{-9}	6.33×10^{-6}	1.62×10^{-5}	7.97×10^{-4}	1.22×10^{-4}
Maximum	3.86×10^{-3}	5.17×10^{-4}	1.06×10^{-7}	4.75×10^{-8}	3.08×10^{-5}	7.88×10^{-5}	3.89×10^{-3}	5.96×10^{-4}
Mean	2.97×10^{-3}	3.99×10^{-4}	8.14×10^{-8}	3.66×10^{-8}	2.38×10^{-5}	6.07×10^{-5}	3.00×10^{-3}	4.60×10^{-4}
SE	4.59×10^{-4}	6.15×10^{-5}	1.26×10^{-8}	5.65×10^{-9}	3.67×10^{-6}	9.37×10^{-6}	4.62×10^{-4}	7.09×10^{-5}
SKR (N= 3)	C	A	C	A	C	A	C	A
Minimum	2.28×10^{-3}	3.06×10^{-4}	6.25×10^{-8}	2.81×10^{-8}	1.83×10^{-5}	4.67×10^{-5}	2.30×10^{-3}	3.53×10^{-4}
Maximum	4.32×10^{-3}	5.80×10^{-4}	1.18×10^{-7}	5.33×10^{-8}	3.46×10^{-5}	8.83×10^{-5}	4.36×10^{-3}	6.69×10^{-4}
Mean	3.04×10^{-3}	4.08×10^{-4}	8.31×10^{-8}	3.74×10^{-8}	2.43×10^{-5}	6.21×10^{-5}	3.06×10^{-3}	4.70×10^{-4}
SE	6.46×10^{-4}	8.67×10^{-5}	1.77×10^{-8}	7.97×10^{-9}	5.17×10^{-6}	1.32×10^{-5}	6.51×10^{-4}	9.99×10^{-5}
SBR2010 (N= 3)	C	A	C	A	C	A	C	A
Minimum	6.43×10^{-4}	8.62×10^{-5}	1.76×10^{-8}	7.92×10^{-9}	5.14×10^{-6}	1.31×10^{-5}	6.48×10^{-4}	9.94×10^{-5}
Maximum	1.16×10^{-3}	1.55×10^{-4}	3.16×10^{-8}	1.42×10^{-8}	9.25×10^{-6}	2.36×10^{-5}	1.17×10^{-3}	1.79×10^{-4}
Mean	8.75×10^{-4}	1.17×10^{-4}	2.39×10^{-8}	1.07×10^{-8}	6.99×10^{-6}	1.78×10^{-5}	8.82×10^{-4}	1.35×10^{-4}
SE	1.52×10^{-4}	2.02×10^{-5}	4.10×10^{-9}	1.84×10^{-9}	1.20×10^{-6}	3.07×10^{-6}	1.53×10^{-4}	2.33×10^{-5}
SBR[1]	2.40×10^{-2}	3.22×10^{-3}	6.58×10^{-7}	2.96×10^{-7}	1.92×10^{-4}	4.91×10^{-4}	2.42×10^{-2}	3.72×10^{-3}
SBR[2]	2.63×10^{-2}	3.53×10^{-3}	7.20×10^{-7}	3.24×10^{-7}	2.10×10^{-4}	5.37×10^{-4}	2.65×10^{-2}	4.07×10^{-3}
SKR[2]	4.02×10^{-3}	5.39×10^{-4}	1.10×10^{-7}	4.95×10^{-8}	3.21×10^{-5}	8.21×10^{-5}	4.05×10^{-3}	6.21×10^{-4}
LR[3]	9.13×10^{-3}	1.23×10^{-3}	2.50×10^{-7}	1.12×10^{-7}	7.31×10^{-5}	1.87×10^{-4}	9.21×10^{-3}	1.41×10^{-3}
SBR[4]	1.84×10^{-2}	2.47×10^{-3}	5.03×10^{-7}	2.27×10^{-7}	1.47×10^{-4}	3.76×10^{-4}	1.85×10^{-2}	2.84×10^{-3}

Note: SE= standard error; SBR[1]= based on the maximum level of Zn (550 mg/kg dry weight) reported by Ismail and Ramli [18]; SBR[2]= based on the maximum level of Zn (602 mg/kg dry weight) reported by Saed *et al.* [19]; SKR[2]= based on the maximum level of Zn (91.96 mg/kg dry weight) reported by Saed *et al.* [19]; LR[3]= based on the maximum level of Zn (209 mg/kg dry weight) reported by Ismail and Safahieh [20]; SKR[4]= based on the maximum level of Zn (421 mg/kg dry weight) reported by Yap *et al.* [21].

Table S7. Concentrations (mg/kg dry weight) of total Cu, percentages of four geochemical fractions (F1, F2, Fe, and F4), percentages of bioavailable fraction (Bio) and a non-bioavailable fraction (NonBio), Individual contamination factors (ICF), and risk assessment code (RAC), for Cu of surface sediments in Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR) mangrove ecosystems, based on nonresistant fraction as reference fraction or normalizer (-1), and based on background levels of the metals as reference metal or normalizer that were reported from Peninsular Malaysia (-2).

	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	9.37	0.48	0.13	31.68	55.40	0.77	98.69	0.49	0.48
Maximum	20.06	0.98	0.55	43.52	67.08	1.27	99.19	0.81	0.98
Mean	12.80	0.77	0.35	35.66	63.20	1.12	98.86	0.59	0.77
SE	1.98	0.09	0.08	2.11	2.09	0.09	0.09	0.06	0.09
Skewness	0.98	-	-	-	-	-	-	-	-
Kurtosis	-0.54	-	-	-	-	-	-	-	-
SBR (N= 6)	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	5.23	0.12	0.81	23.22	65.37	1.12	93.89	0.34	0.12
Maximum	22.73	0.69	5.43	30.15	74.72	6.11	98.82	0.53	0.69
Mean	13.46	0.44	2.10	27.72	69.72	2.54	97.44	0.44	0.44
SE	2.54	0.10	0.68	0.99	1.30	0.73	0.73	0.03	0.10
Skewness	0.18	-	-	-	-	-	-	-	-
Kurtosis	-1.00	-	-	-	-	-	-	-	-
SKR (N= 3)	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	7.96	1.15	0.12	29.44	64.85	1.63	96.56	0.48	1.15
Maximum	13.48	1.52	1.93	33.21	67.60	3.44	98.48	0.54	1.52
Mean	10.08	1.39	0.92	31.18	66.53	2.31	97.70	0.50	1.39
SE	1.72	0.12	0.53	1.10	0.85	0.57	0.58	0.02	0.12
Skewness	0.64	-	-	-	-	-	-	-	-
Kurtosis	-1.50	-	-	-	-	-	-	-	-
SBR2010 (N= 3)	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	2.71	0.59	1.06	17.16	42.69	0.02	0.89	0.34	0.59
Maximum	22.97	7.55	2.96	55.67	75.00	0.11	0.98	1.34	7.55
Mean	9.84	4.70	2.02	36.68	56.66	0.07	0.93	0.86	4.70
SE	6.57	2.11	0.55	11.12	9.58	0.03	0.03	0.29	2.11
Skewness	0.70	-	-	-	-	-	-	-	-
Kurtosis	-1.50	-	-	-	-	-	-	-	-

Note: SE= standard error.

Table S8. Overall statistics of values of hazard quotient (HQ), hazard index (HI), carcinogenic risk (CR_{inh}) in the three exposure routes (ingestion= HQ_{ing}; inhalation= HQ_{inh}; dermal contact= HQ_{der}) of Cu, for both children (C) and adults (A) in the mangrove sediments collected from Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR).

	HQ_{ing}		HQ_{inh}		HQ_{der}		HI	
LR (N= 5)	C	A	C	A	C	A	C	A
Minimum	3.07×10^{-3}	4.12×10^{-4}	8.40×10^{-8}	3.80×10^{-8}	1.64×10^{-5}	4.18×10^{-5}	3.09×10^{-3}	4.54×10^{-4}
Maximum	6.57×10^{-3}	8.82×10^{-4}	1.79×10^{-7}	8.10×10^{-8}	3.51×10^{-5}	8.95×10^{-5}	6.61×10^{-3}	9.72×10^{-4}
Mean	4.19×10^{-3}	5.63×10^{-4}	1.14×10^{-7}	5.14×10^{-8}	2.24×10^{-5}	5.71×10^{-5}	4.22×10^{-3}	6.20×10^{-4}
SE	6.50×10^{-4}	8.72×10^{-5}	1.77×10^{-8}	8.03×10^{-9}	3.46×10^{-6}	8.85×10^{-6}	6.53×10^{-4}	9.60×10^{-5}
SBR (N= 6)	C	A	C	A	C	A	C	A
Minimum	1.71×10^{-3}	2.30×10^{-4}	4.70×10^{-8}	2.10×10^{-8}	9.14×10^{-6}	2.33×10^{-5}	1.72×10^{-3}	2.53×10^{-4}
Maximum	7.45×10^{-3}	9.99×10^{-4}	2.03×10^{-7}	9.10×10^{-8}	3.97×10^{-5}	1.01×10^{-4}	7.49×10^{-3}	1.10×10^{-3}
Mean	4.41×10^{-3}	5.92×10^{-4}	1.20×10^{-7}	5.40×10^{-8}	2.35×10^{-5}	6.01×10^{-5}	4.44×10^{-3}	6.52×10^{-4}
SE	8.34×10^{-4}	1.12×10^{-4}	2.27×10^{-8}	1.02×10^{-8}	4.45×10^{-6}	1.14×10^{-5}	8.38×10^{-4}	1.23×10^{-4}
SKR (N= 3)	C	A	C	A	C	A	C	A
Minimum	2.61×10^{-3}	3.50×10^{-4}	7.10×10^{-8}	3.20×10^{-8}	1.39×10^{-5}	3.55×10^{-5}	2.62×10^{-3}	3.86×10^{-4}
Maximum	4.42×10^{-3}	5.93×10^{-4}	1.20×10^{-7}	5.40×10^{-8}	2.36×10^{-5}	6.02×10^{-5}	4.44×10^{-3}	6.53×10^{-4}
Mean	3.30×10^{-3}	4.43×10^{-4}	9.00×10^{-8}	4.03×10^{-8}	1.76×10^{-5}	4.50×10^{-5}	3.32×10^{-3}	4.88×10^{-4}
SE	5.62×10^{-4}	7.54×10^{-5}	1.52×10^{-8}	6.89×10^{-9}	3.00×10^{-6}	7.66×10^{-6}	5.65×10^{-4}	8.31×10^{-2}
SBR2010 (N= 3)	C	A	C	A	C	A	C	A
Minimum	8.88×10^{-4}	1.19×10^{-4}	2.42×10^{-8}	1.09×10^{-8}	4.74×10^{-6}	1.21×10^{-5}	8.93×10^{-4}	1.31×10^{-4}
Maximum	7.53×10^{-3}	1.01×10^{-3}	2.05×10^{-7}	9.23×10^{-8}	4.01×10^{-5}	1.03×10^{-4}	7.57×10^{-2}	1.11×10^{-3}
Mean	3.23×10^{-3}	4.33×10^{-4}	8.78×10^{-8}	3.95×10^{-8}	1.72×10^{-5}	4.41×10^{-5}	3.24×10^{-2}	4.76×10^{-4}
SE	2.15×10^{-3}	2.89×10^{-4}	5.87×10^{-8}	2.64×10^{-8}	1.15×10^{-5}	2.95×10^{-5}	2.17×10^{-2}	3.18×10^{-4}
SBR[1]	2.20×10^{-1}	2.95×10^{-2}	5.98×10^{-6}	2.69×10^{-6}	1.17×10^{-3}	2.99×10^{-3}	2.21×10^{-1}	3.25×10^{-2}
SBR[2]	1.88×10^{-1}	2.52×10^{-2}	5.12×10^{-6}	2.31×10^{-6}	1.00×10^{-3}	2.56×10^{-3}	1.89×10^{-1}	2.78×10^{-2}
SBR[3]	1.70×10^{-1}	2.28×10^{-2}	4.62×10^{-6}	2.08×10^{-6}	9.05×10^{-4}	2.31×10^{-3}	1.71×10^{-1}	2.51×10^{-2}
SBR[2]	1.90×10^{-2}	2.54×10^{-3}	5.16×10^{-7}	2.32×10^{-7}	1.01×10^{-4}	2.58×10^{-4}	1.91×10^{-2}	2.80×10^{-3}
LR[4]	3.04×10^{-2}	4.08×10^{-3}	8.28×10^{-7}	3.73×10^{-7}	1.62×10^{-4}	4.14×10^{-4}	3.06×10^{-2}	4.49×10^{-3}
SKR[5]	5.28×10^{-2}	7.08×10^{-3}	1.44×10^{-6}	6.47×10^{-7}	2.81×10^{-4}	7.19×10^{-4}	5.30×10^{-2}	7.80×10^{-3}

Note: SE= standard error. Note: SBR[1]= based on the maximum level of Cu (670 mg/kg dry weight) reported by Ismail and Ramli [18]; SBR[2]= based on the maximum level of Cu (574 mg/kg dry weight) reported by Saed *et al.* [19]; SKR[3]= based on the maximum level of Cu (518 mg/kg dry weight) reported by Hossain [22]; SKR[2]= based on the maximum level of Cu (57.86 mg/kg dry weight) reported by Saed *et al.* [19]; LR[4]= based on the maximum level of Cu (92.8 mg/kg dry weight) reported by Ismail and Safahieh [20]; SKR[5]= based on the maximum level of Cu (161 mg/kg dry weight) reported by Yap *et al.* [21].

Table S9. Concentrations (mg/kg dry weight) of total Pb, percentages of bioavailable fraction (Bio) and non-bioavailable fraction (NonBio), Individual contamination factors (ICF), and risk assessment code (RAC), for Pb of surface sediments in Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR) mangrove ecosystems, based on nonresistant fraction as reference fraction or normalizer (-1), and based on background levels of the metals as reference metal or normalizer that were reported from Peninsular Malaysia (-2).

	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	28.93	2.43	0.27	17.11	74.31	3.07	91.43	0.29	2.43
Maximum	47.37	4.21	4.65	21.91	77.62	8.57	96.93	0.35	4.21
Mean	40.33	3.28	1.63	19.05	76.03	4.91	95.09	0.32	3.28
SE	3.19	0.34	0.78	0.89	0.61	1.00	1.00	0.01	0.34
Skewness	-0.81	-	-	-	-	-	-	-	-
Kurtosis	-0.60	-	-	-	-	-	-	-	-
SBR (N= 6)	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	18.99	1.78	2.86	15.32	49.93	4.86	71.13	0.26	1.78
Maximum	41.25	7.21	22.88	29.51	79.13	28.87	95.09	1.00	7.21
Mean	28.26	4.33	7.33	21.98	66.35	11.67	88.32	0.55	4.33
SE	2.98	0.88	3.15	2.25	4.63	3.66	3.66	0.12	0.88
Skewness	0.77	-	-	-	-	-	-	-	-
Kurtosis	0.03	-	-	-	-	-	-	-	-
SKR (N= 3)	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	20.02	1.90	1.09	2.94	66.12	5.63	91.38	0.13	1.90
Maximum	32.47	5.00	3.94	28.25	88.44	8.56	94.37	0.51	5.00
Mean	25.30	3.81	2.86	19.20	74.07	6.68	93.27	0.37	3.81
SE	3.72	0.97	0.89	8.15	7.20	0.94	0.95	0.12	0.97
Skewness	0.49	-	-	-	-	-	-	-	-
Kurtosis	-1.50	-	-	-	-	-	-	-	-
SBR2010 (N= 3)	Total	F1	F2	F3	F4	Bio	NonBio	ICF	RAC
Minimum	25.61	3.33	10.10	31.37	44.70	0.15	0.85	0.87	3.33
Maximum	31.99	5.28	11.46	39.92	53.52	0.15	0.85	1.24	5.28
Mean	28.78	4.37	10.74	36.05	48.85	0.15	0.85	1.06	4.37
SE	1.84	0.57	0.39	2.50	2.56	0.00	0.00	0.11	0.57
Skewness	0.02	-	-	-	-	-	-	-	-
Kurtosis	-1.50	-	-	-	-	-	-	-	-

Table S10. Overall statistics of values of hazard quotient (HQ), hazard index (HI), carcinogenic risk (CR_{inh}) in the three exposure routes (ingestion= HQ_{ing}; inhalation= HQ_{inh}; dermal contact= HQ_{der}) of Pb, for both children (C) and adults (A) in the mangrove sediments collected from Lukut River (LR), Sepang Besar River (SBR) and Sepang Kecil River (SKR).

	HQ_{ing}		HQ_{inh}		HQ_{der}		HI	
LR (N= 5)	C	A	C	A	C	A	C	A
Minimum	1.07×10^{-1}	1.44×10^{-2}	2.95×10^{-6}	1.33×10^{-6}	1.16×10^{-3}	2.95×10^{-3}	1.08×10^{-1}	1.73×10^{-2}
Maximum	1.75×10^{-1}	2.35×10^{-2}	4.83×10^{-6}	2.17×10^{-6}	1.89×10^{-3}	4.83×10^{-3}	1.77×10^{-1}	2.84×10^{-2}
Mean	1.49×10^{-1}	2.00×10^{-2}	4.11×10^{-6}	1.85×10^{-6}	1.61×10^{-3}	4.11×10^{-3}	1.51×10^{-1}	2.42×10^{-2}
SE	1.18×10^{-2}	1.58×10^{-3}	3.25×10^{-7}	1.46×10^{-7}	1.27×10^{-4}	3.25×10^{-4}	1.19×10^{-2}	1.91×10^{-3}
SBR (N= 6)	C	A	C	A	C	A	C	A
Minimum	7.03×10^{-2}	9.43×10^{-3}	1.94×10^{-6}	8.71×10^{-7}	7.59×10^{-4}	1.94×10^{-3}	7.11×10^{-2}	1.14×10^{-2}
Maximum	1.53×10^{-1}	2.05×10^{-2}	4.20×10^{-6}	1.89×10^{-6}	1.65×10^{-3}	4.21×10^{-3}	1.54×10^{-1}	2.47×10^{-2}
Mean	1.05×10^{-1}	1.40×10^{-2}	2.88×10^{-6}	1.30×10^{-6}	1.13×10^{-3}	2.88×10^{-3}	1.06×10^{-1}	1.69×10^{-2}
SE	1.10×10^{-2}	1.48×10^{-3}	3.04×10^{-7}	1.37×10^{-7}	1.19×10^{-4}	3.04×10^{-4}	1.12×10^{-2}	1.79×10^{-3}
SKR (N= 3)	C	A	C	A	C	A	C	A
Minimum	7.41×10^{-2}	9.95×10^{-3}	2.04×10^{-6}	9.18×10^{-7}	8.00×10^{-4}	2.04×10^{-3}	7.49×10^{-2}	1.20×10^{-2}
Maximum	1.20×10^{-1}	1.61×10^{-2}	3.31×10^{-6}	1.49×10^{-6}	1.30×10^{-3}	3.31×10^{-3}	1.22×10^{-1}	1.94×10^{-2}
Mean	9.37×10^{-2}	1.26×10^{-2}	2.58×10^{-6}	1.16×10^{-6}	1.01×10^{-3}	2.58×10^{-3}	9.47×10^{-2}	1.52×10^{-2}
SE	1.38×10^{-2}	1.85×10^{-3}	3.78×10^{-7}	1.70×10^{-7}	1.48×10^{-4}	3.79×10^{-4}	1.39×10^{-2}	2.23×10^{-3}
SBR2010 (N= 3)	C	A	C	A	C	A	C	A
Minimum	9.48×10^{-2}	1.27×10^{-2}	2.61×10^{-6}	1.17×10^{-6}	1.02×10^{-3}	2.61×10^{-3}	9.59×10^{-2}	1.53×10^{-2}
Maximum	1.18×10^{-1}	1.59×10^{-2}	3.26×10^{-6}	1.47×10^{-6}	1.28×10^{-3}	3.26×10^{-3}	1.20×10^{-1}	1.92×10^{-2}
Mean	1.06×10^{-1}	1.43×10^{-2}	2.93×10^{-6}	1.32×10^{-6}	1.15×10^{-3}	2.93×10^{-3}	1.08×10^{-1}	1.72×10^{-2}
SE	6.70×10^{-3}	9.24×10^{-4}	1.88×10^{-7}	8.66×10^{-8}	7.51×10^{-5}	1.88×10^{-4}	6.96×10^{-3}	1.13×10^{-3}
SBR[1]	1.72×10^{-1}	2.31×10^{-2}	4.74×10^{-6}	2.13×10^{-6}	1.86×10^{-3}	4.74×10^{-3}	1.74×10^{-1}	2.78×10^{-2}
SBR[2]	1.90×10^{-1}	2.55×10^{-2}	5.22×10^{-6}	2.35×10^{-6}	2.05×10^{-3}	5.23×10^{-3}	1.92×10^{-1}	3.07×10^{-2}
SKR[2]	3.50×10^{-2}	4.69×10^{-3}	9.62×10^{-7}	4.33×10^{-7}	3.77×10^{-4}	9.63×10^{-4}	3.53×10^{-2}	5.65×10^{-3}

Note: SE= standard error. SBR[1]= based on the maximum level of Pb (46.5 mg/kg dry weight) reported by Ismail and Ramli [18]; SBR[2]= based on the maximum level of Pb (51.24 mg/kg dry weight) reported by Saed *et al.* [19]; SKR[2]= based on the maximum level of Pb (9.44 mg/kg dry weight) reported by Saed *et al.* [19];.

References

1. Chapman, P.M.; Allard, P.J.; Vigers, G.A. Development of Sediment Quality Values for Hong Kong Special Administrative Region: A Possible Model for Other Jurisdictions. *Mar. Pollut. Bull.* **1999**, *38*, 161–169, doi:10.1016/S0025-326X(98)00162-3.
2. Macdonald, D.D.; Carr, R.S.; Calder, F.D.; Long, E.R.; Ingersoll, C.G. Development and Evaluation of Sediment Quality Guidelines for Florida Coastal Waters. *Ecotoxicology* **1996**, *5*, 253–278, doi:10.1007/BF00118995.
3. Long, E.R.; Macdonald, D.D.; Smith, S.L.; Calder, F.D. Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. *Environ. Manage.* **1995**, *19*, 81–97, doi:10.1007/BF02472006.
4. Hakanson, L. An Ecological Risk Index for Aquatic Pollution Control.a Sedimentological Approach. *Water Res.* **1980**, *14*, 975–1001, doi:10.1016/0043-1354(80)90143-8.
5. Taylor, S.R.; McLennan, S.M. The Geochemical Evolution of the Continental Crust. *Rev. Geophys.* **1995**, *33*, 241–265, doi:https://doi.org/10.1029/95RG00262.
6. Rudnick, R.L.; Gao, S. 3.01 - Composition of the Continental Crust. In *Treatise on Geochemistry*; Holland, H.D., Turekian, K.K., Eds.; Pergamon: Oxford, 2003; pp. 1–64 ISBN 978-0-08-043751-4.

7. Wedepohl, K.H. The Composition of Earth's Upper Crust, Natural Cycles of Elements, Natural Resources. In *Elements and Their Compounds in the Environment*; John Wiley & Sons, Ltd, 2004; pp. 2–16 ISBN 978-3-527-61963-4.
8. Yap, C.K.; Arifin, N.; Tan, S.G. Relationships of Copper Concentrations between the Different Soft Tissues of Telescopium Telescopium and the Surface Sediments Collected from Tropical Intertidal Areas. *Int. J. Chem.* **2013**, *5*, 8–19, doi:10.5539/ijc.v5n1p8.
9. Yap, C.K.; Noorhaidah, A. Gill and Digestive Caecum of Telescopium Telescopium as Biomonitors of Pb Bioavailability and Contamination by Pb in the Tropical Intertidal Area. *Sains Malays.* **2011**, *40*, 1075–1085.
10. Yap, C.K.; Noorhaidah, A.; Tan, S.G. Zn Concentrations in the Different Soft Tissues of Telescopium Telescopium and Their Relationships with Zn Speciation by Sequential Extraction in Surface Sediments: A Statistical Multiple Linear Stepwise Regression Analysis. In *Gastropods: Diversity, Habitat, and Genetics*; Branchi, A.M., Fields, J.N., Eds.; Nova Science Publishers Inc.: New York, NY, USA, 2011; pp. 127–148 ISBN 978-1-61324-695-5.
11. US EPA *Baseline Human Health Risk Assessment Vasquez Boulevard and I-70 Superfund Site Demver, Co*; US Environmental Protection Agency: United States of America, 2001;
12. Li, Z.; Ma, Z.; van der Kuijp, T.J.; Yuan, Z.; Huang, L. A Review of Soil Heavy Metal Pollution from Mines in China: Pollution and Health Risk Assessment. *Sci. Total Environ.* **2014**, *468–469*, 843–853, doi:10.1016/j.scitotenv.2013.08.090.
13. BQTSB (Beijing Quality and Technology Supervision Bureau) Environmental Site Assessment Guideline; DB11/T 656-2009 2009.
14. US EPA Human Health Evaluation Manual. In *Risk Assessment Guidance for Superfund*; Office of Emergency and Remedial Response, U.S. Environmental Protection Agency: Washington DC, United States, 1989; Vol. 1 ISBN EPA/540/1-89/002.
15. Barnes, D.G.; Dourson, M.; Dourson, M.; Preuss, P.; Barnes, D.G.; Bellin, J.; Derosa, C.; Engler, R.; Erdreich, L.; Farber, T.; et al. Reference Dose (RfD): Description and Use in Health Risk Assessments. *Regul. Toxicol. Pharmacol.* **1988**, *8*, 471–486, doi:10.1016/0273-2300(88)90047-5.
16. Chabukdhara, M.; Nema, A.K. Heavy Metals Assessment in Urban Soil around Industrial Clusters in Ghaziabad, India: Probabilistic Health Risk Approach. *Ecotoxicol. Environ. Saf.* **2013**, *87*, 57–64, doi:10.1016/j.ecoenv.2012.08.032.
17. Qing, X.; Yutong, Z.; Shenggao, L. Assessment of Heavy Metal Pollution and Human Health Risk in Urban Soils of Steel Industrial City (Anshan), Liaoning, Northeast China. *Ecotoxicol. Environ. Saf.* **2015**, *120*, 377–385, doi:10.1016/j.ecoenv.2015.06.019.
18. Ismail, A.; Ramli, R. Trace Metals in Sediments and Molluscs from an Estuary Receiving Pig Farms Effluent. *Environ. Technol.* **1997**, *18*, 509–515, doi:10.1080/09593331808616566.
19. Saed, K.; Ismail, A.; Omar, H.; Kusnan, M. Accumulation of Heavy Metals (Zn, Cu, Pb, Cd) in Flat-Tree Oysters Isognomon Alatus Exposed to Pig Farm Effluent. *Toxicol. Environ. Chem.* **2002**, *82*, 45–58, doi:10.1080/713746657.
20. Ismail, A.; Safahieh, A. Copper and Zinc in Intertidal Surface Sediment and Telescopium Telescopium from Lukut River, Malaysia. *Coast Mar Sci* **2005**, *29*, 111–115.
21. Yap, C.K.; Ismail, A.; Ching, H.L.; Tan, S. Interpretation of Copper and Zinc Contamination in the Aquatic Environment of Peninsular Malaysia with Special Reference to a Polluted River, Sepang River. *Wetl. Sci.* **2007**, *5*, 311–321.
22. Hossain, M.; Othman, S.; Bujang, J.S.; Lim, M.T. Distribution of Copper in the Sepang Mangrove Reserve Forest Environment, Malaysia. *J. Trop. For. Sci.* **2001**, *13*, 130–139.