MSD Publications
Research is creating new knowledge

Research International Journal of Energy & Environmental Sciences

Research Article

Heavy Metals in Rock Oyster *Saccostrea cucullata* Collected from Sungai Tapai and Pantai Lido, Peninsular Malaysia: An Insight from Health Risk Assessment

Chee Kong Yap[1]*, Wing Sam Lo[1], Wan Hee Cheng[2], Rosimah Nulit[1], Mohd Hafiz Ibrahim[1], Shih Hao Tony Peng[3], Chee Wah Yap[4], Moslem Sharifinia[5], Alireza Riyahi Bakhtiari[6] and Salman Abdo Al-Shami[7]

[1]Department of Biology, Faculty of Science, University Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.

[2]Inti International University, Persiaran Perdana BBN, Nilai, Negeri Sembilan, Malaysia.

[3]All Cosmos Bio-Tech Holding Corporation, PLO650, Jalan Keluli, Pasir Gudang Industrial Estate, 81700 Pasir Gudang, Johor, Malaysia.

[4]MES SOLUTIONS, 22C-1, Jalan BK 5A/2A, Bandar Kinrara, 47100 Puchong, Selangor, Malaysia.

[5]Shrimp Research Center, Iranian Fisheries Science Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Bushehr, Iran.

[6]Department of Environmental Sciences, Faculty of Natural Resources and Marine Sciences, Tarbiat Modares University, Noor, Mazandaran, Iran.

[7]Indian River Research and Education Center, IFAS, University of Florida, Fort Pierce, FL 34945, USA.

***Address for Correspondence:** Chee Kong Yap, Department of Biology, Faculty of Science, University Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia. Email: yapckong@hotmail.com; yapchee@upm.edu.my

Received: 27 May 2020; **Accepted:** 25 July 2020; **Published:** 29 July 2020

Citation of this article: Yap CK, Lo WS, Cheng WH, Nulit R, Ibrahim MH, et al. (2020) Heavy Metals in Rock Oyster *Saccostrea cucullata* Collected from Sungai Tapai and Pantai Lido, Peninsular Malaysia: An Insight from Health Risk Assessment. Rea Int Journal of Energy Environmental sci. 1(1): 005-010. DOI: 10.37179/rijees.000002.

Keywords: Oyster, Saccostrea cucullata, heavy metals, Malaysia.

Introduction

The rock oyster, *Saccostrea cucullata* is a filter-feeder bivalve (Tack and Polk, 1996) that lives on trunks and roots of mangroves and rocky substrate (Tack *et al*., 1992). In general, oysters are the accumulators of heavy metals (Yap et al., 2011a) and hyper accumulators for Zn (Silva et al., 2006; Yap et al., 2011b; Wang and Lu, 2017).

Numerous studies on heavy metals in the oysters are reported in the literature. In Malaysia, bioaccumulation of heavy metals in oysters was reported by Najiah *et al.* (2008) and Lim *et al.* (1995, 1998) on *Crassaostrea iredalei*; Saed *et al.* (2004) on *Isognomon alatus* and Lim *et al.* (1995,1998) on *C. belcheri*. Studies on the uses of oysters as biomonitors of heavy metal contamination were reported from Natal Brazil (Silva *et al*., 2006), and US coast (O'connor and Lauenstein, 2006).

The distributions of heavy metals in the different organs or tissues of intertidal molluscs have been well reported in the literature. These published studies included the green-lipped mussel *Perna viridis* (Yap *et al*., 2012, 2006; Yap, 2018), clam *Polymesoda erosa* (Yap *et al*., 2014a), mangrove snail *Nerita lineata* (Yap and Cheng, 2013; Yap *et al*., 2014), cockle *Anadara granosa* (Yap and Lo, 2013), and mudflat snail *Telescopium* (Yap *et al*., 2013) and rock oyster *S. cucullata* (Yap *et al*., 2010).

However, all these citations never discussed the human health risk assessment (HHRA) using Target Hazard Quotient (THQ) in the specific organ or tissues investigated. All of the above interpretations of results were focused on metal bio availabilities and bio monitoring points of view (Rainbow, 1995). The objective of the present study is to determine the HHRA of Cd, Cu, Fe, Ni, Pb and Zn in the edible soft tissues of *S. cucullata* collected from Sg. Tapai and Pantai Lido in 2008.

Materials and Methods

About 25-30 of the oysters, *S. cucullata* from Sg. Tapai (Kelantan; sampled on 13 May 2008) and Pantai Lido (near Danga Bay, Johor; sampled on 3 May 2008) (Figure 1) was used for the metal analysis. The sampling sites description and some *in-situ* surface water parameters are given in (Table 1).

The identification of the oyster species was based on the book authored by Takashi (2000), and the Malaysia Fisheries Directory (2005) by Department of Fisheries Malaysia. The shell lengths (cm) of the oysters ranged from 2.82-5.54 and 6.92-9.49 for Sg. Tapai and Pantai Lido, respectively.

The oyster shell widths (cm) ranged from 3.30-6.10 and 7.63-10.6 for Sg. Tapai and Pantai Lido, respectively. The oyster shell heights (cm) ranged from 1.08-2.27 and 3.13-4.76 for Sg. Tapai and Pantai Lido, respectively.

The total soft tissue wet weight and dry weight of the two populations ranged from 0.84-4.11g (mean: 2.24 g) and 0.11-0.91g (mean: 0.42 g), respectively. Therefore, the conversion factor (0.42/2.24) of 0.19 was used to convert the dry weight into wet weight basis. The water contents of the two populations ranged from 77.0-87.5% (mean: 81.3%).

The oysters were dissected from the shells, and they were pooled into muscle, mantle, gill and remainder. The samples were dried at 60°C until constant dry weights. They were digested in concentrated HNO_3 (Analar grade, BDH 69%). They were placed in a hot-block digester for 1 hour (40°C) and increased to 140°C for at least 3 hours (Yap *et al*., 2003a). After dilution and filtration, they were determined

Table 1: Sampling details and some water parameters for all sampling sites.

No.	Sampling Site (GPS)	Description	Temp	Cond	Sal	DO
1.	Sg. Tapai (6°12'45.76"N, 102°08'38.02"E)	Recreational beach and agricultural area	30.1 ± 0.001	40419 ± 2.39	23.2 ± 0.001	1.20 ± 0.001
2.	Pantai Lido (Sg. Danga) (N 01° 28.001' N; 103° 43.618' E)	Urban and agricultural areas	30.5 ± 0.001	30815 ± 4.01	17.0 ± 0.001	2.14 ±0.001

Note: Temp (°C) = Temperature; Cond= Conductivity (μs/cm); DO= Dissolved oxygen (mg/L).

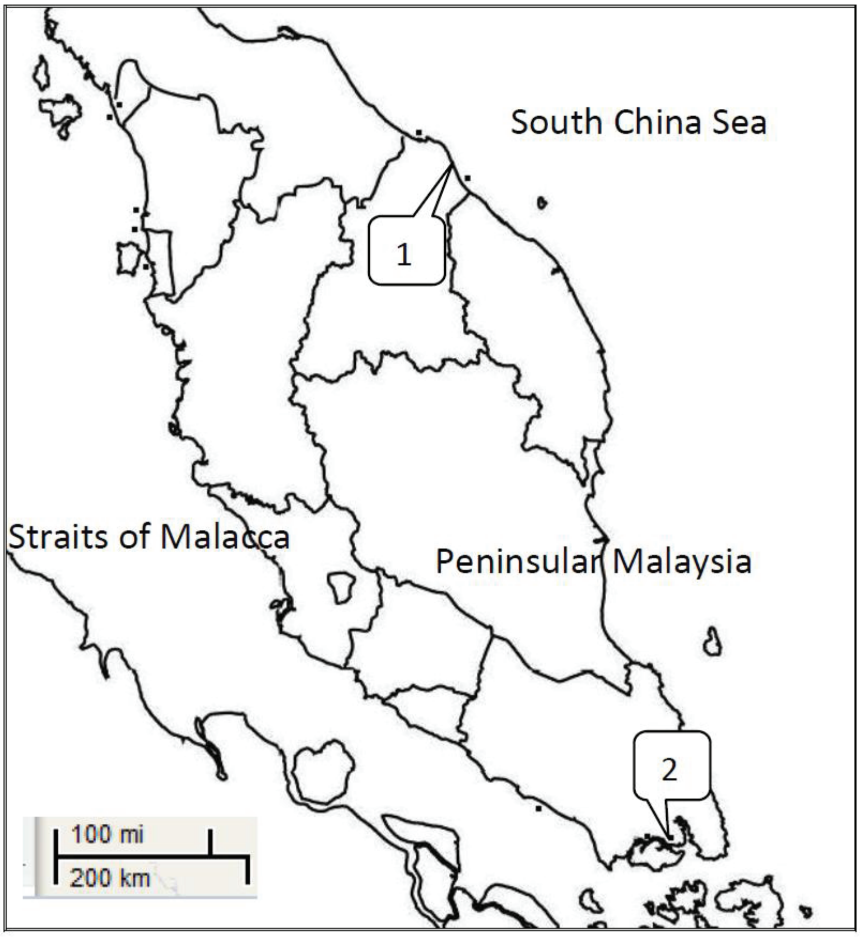

Figure 1: Map showing the sampling sites for *Saccostrea cucullata* in Peninsular Malaysia (1 = Sg. Tapai; 2= Pantai Lido).

for Cd, CU, Fe, Ni, Pb and Zn by using an air-acetylene flame Atomic Absorption Spectrophotometer (AAS) Perkin-Elmer Model Analyst 800.

For quality control and quality assurance, all glassware and equipment used were acid-washed. Besides, procedural blanks and quality control samples made from standard solutions for all the six metals were analyzed to check for sample accuracy. The metal percentages of recoveries for the metals were between 80-110%. The analytical procedures for the samples were also checked with the Certified Reference Material (CRM) dogfish liver (DOLT-3, National Research Council Canada). The recoveries for the CRM were satisfactory being between 89-103%.

Health Risk Assessment

To assess a once-or long-term potential hazardous exposure to the six heavy metals through consumption of oysters (USEPA, 1989), the Estimated Daily Intake (EDI) and THQ values were calculated by using the following formulas:

EDI= (Mc x consumption rate)/body weight

THQ= EDI/RfD

Where Mc is the metal concentration (mg/kg) in the oyster soft tissue (converted wet weight); body weight for Malaysian adult was 62 kg and consumption rate as 41g/day for Malaysian adults (Nurul Izzah *et al.*, 2016). The metal concentrations in µg/g dry weight were converted into wet weight basis by using a conversion factor of 0.19 for the four different edible soft tissues of oysters.

The oral reference dose (RFD) was used to compare with the EDI (µg/kg wet weight/day) of metals in the oysters. The RFD (µg/kg wet weight/day) values used in this study were Cd: 1.00; Cu: 40.0; Fe: 700, Ni: 20 and Zn: 300, provided by the EPA's Integrated Risk Information System online database (IRIS) (IRIS, 2014). Since RFD for Pb was not available according to the EPA's IRIS (IRIS, 2014). The present study employed the RFD as 3.50 µg/kg wet weight/day, as suggested by a former study by USEPA (2000, 2008).

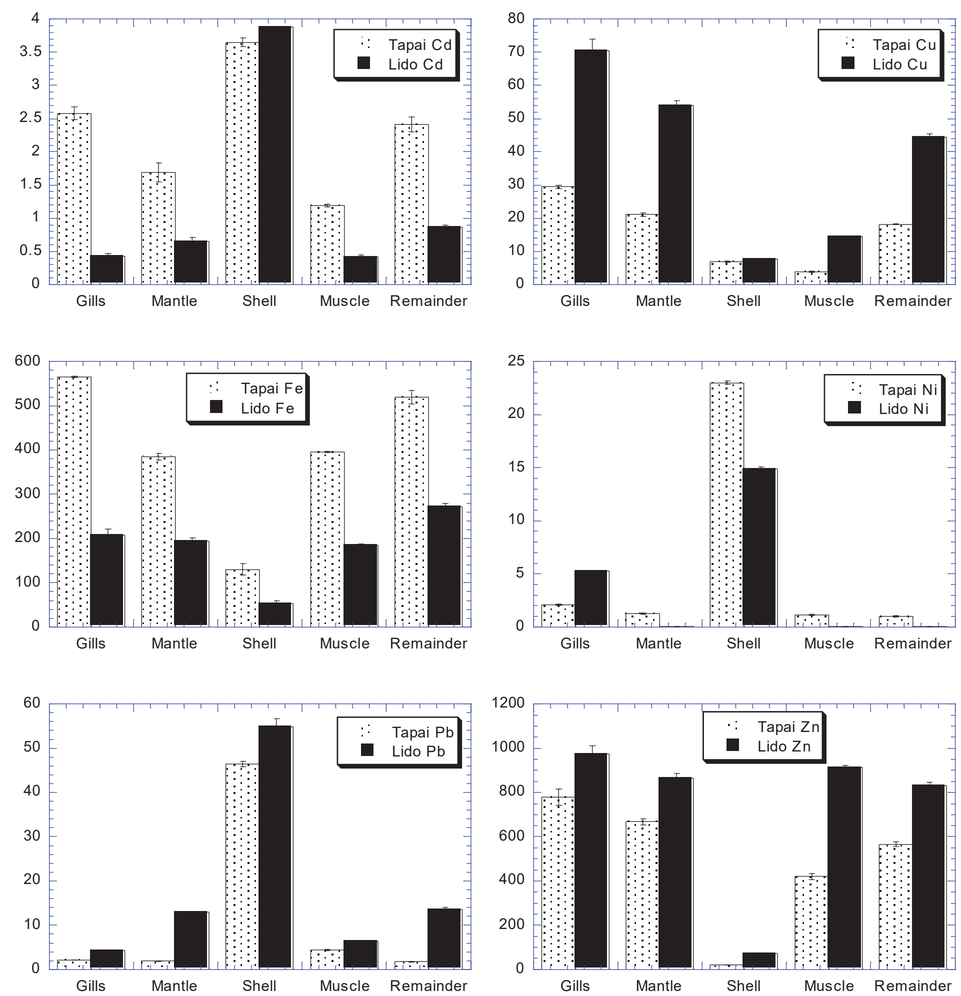

Figure 2: Heavy metal concentrations (mean ± SE, µg/g dw) in the different parts of oyster collected from Pantai Lido and Sg. Tapai.

Table 2: Values of Estimated Daily Intake (EDI) and Target Hazard Index (THQ) in the oysters collected from Sg. Tapai and Pantai Lido.

	Cd		Cu		Fe		Ni		Pb		Zn	
Tapai	EDI	THQ	EDI	THQ	EDI	THQ	EDI	THQ	EDI	THQ	EDI	THQ
Gills	0.32	0.32	3.71	0.09	70.9	0.10	0.26	0.013	0.27	0.08	98.0	0.33
Mantle	0.21	0.21	2.65	0.07	48.4	0.07	0.16	0.008	0.24	0.07	83.9	0.28
Muscle	0.15	0.15	0.48	0.01	49.8	0.07	0.14	0.007	0.55	0.16	52.8	0.18
Remainder	0.30	0.30	2.29	0.06	65.2	0.09	0.13	0.006	0.22	0.06	71.1	0.24
Lido	EDI	THQ	EDI	THQ	EDI	THQ	EDI	THQ	EDI	THQ	EDI	THQ
Gills	0.05	0.05	8.85	0.22	26.1	0.04	0.66	0.033	0.53	0.15	122	0.41
Mantle	0.08	0.08	6.78	0.17	24.4	0.03	0.01	0.001	1.63	0.47	109	0.36
Muscle	0.05	0.05	1.81	0.05	23.1	0.03	0.01	0.001	0.81	0.23	115	0.38
Remainder	0.11	0.11	5.58	0.14	34.2	0.05	0.01	0.001	1.71	0.49	104	0.35

Note: The metal concentrations in mg/kg dry weight were converted into wet weight basis by using a conversion factor of 0.19 for the four different soft tissues.

Results and Discussion

The heavy metal concentrations in the shells and four different edible soft tissues of the two oyster populations are presented in Figure 2. Based on the edible soft tissues (gills, mantle, muscle and remainder), the metal concentrations (μg/g dw) ranged from 0.42-2.58 for Cd, 3.81-70.4 for Cu, 184-565 for Fe, 0.08-5.28 for Ni, 1.73-13.6 for Pb, and 420-975.

Except for Pb, gills were found to record the highest Cd level among all the soft tissues. The remainder was found to have the highest Pb level. When compared to other soft tissues, shells recorded the highest levels of Cd, Ni and Pb, while the lowest levels of Fe and Zn in the shells.

In general, oyster accumulated the highest levels of Zn in comparison to Cd, Cu, Fe, Ni, and Pb. This is supported by the study reported for *S. cucullata* collected from Penang coastal waters (Yap *et al.*, 2010). Abhilash *et al.* (2013) assessed the levels of Zn, Cu, Fe, Pb and Ni in *S. cucullata*, around Port Blair, India. Zinc was found to be the highest concentrated trace metal in all the five stations, probably due to the role of several Zn metalloenzymes in the oyster shell mineralization (Abhilash *et al.*, 2013).

Zn is believed to be accumulated from the solute phase proportionally to the ambient Zn concentrations (Chong and Wang, 2000). This could be due to its high assimilation efficiency, and low rate constants of loss (Luoma and Rainbow, 2005).

According to Szefer *et al.* (2007), oysters are known to be exceptional accumulators of Zn and Cu. Similar elevated Zn levels in the oysters can be found in the literature for *S. cucullata* (Blackmore, 2001), pearl oysters (*Pinctada radiata*) (Gokoglu *et al.* (2006), and flat-tree oyster *I. alatus* (Saed *et al.*, 2004).

In general, higher concentrations of Cu, Pb and Zn were found in the Pantai Lido population than Sg. Tapai population (Figure 2). Meanwhile, generally higher concentrations of Cd, Fe and Ni were found in the different parts of oyster from Sg. Tapai than Pantai Lido population. This indicated that Pantai Lido had higher bio availabilities of Cu, Pb and Zn than Sg. Tapai while Sg.

Tapai had higher bio availabilities of Cd, Fe and Ni than Pantai Lido population. By referring to the sampling site description, Pantai Lido is an urban, aquaculture area besides being a boat jetty and potentially receiving municipal wastes (Yap *et al.*, 2006), while, Sg. Tapai is a recreational beach and agricultural area. Heavy metal bio availabilities found in these locations could be due to the anthropogenic activities found in the sites.

From the present study, the metal concentrations (μg/g dry weight) in the oyster muscles from the two populations ranged from 420-912 for Zn, 3.81-14.4 for Cu, and 4.39-6.42 for Pb. Chakraborty and Mitra A (2017) reported the metal concentrations (μg/g dry weight) muscles of *S. cucullata* collected from Sagar Island, West Bengal, ranging from 187-217 for Zn, 102-133 for Cu, and 13.1-17.9 for Pb. Lee *et al.*

(2015) suggested that the adductor muscle of *Atrina japonica* displayed an essential role in the energy loading. Uddin *et al.* (2007) reported that the weight loss of the muscle of scallop during the spawning was related to energy storage. Baik *et al.* (2001) reported that the adductor muscle of *A. japonica had higher* glycogen content than those in the visceral mass.

Values of EDI and THQ for the six metals in the two populations are given in Table 2. Overall, the values of EDI ranged from 00.05-0.32 for Cd, 0.48-8.85 for Cu, 23.1-70.9 for Fe, 0.01-0.66 for Ni, 0.22-1.71 for Pb, and 52.8-122 for Zn. The values of THQ for all the six metals are all below 1.0.

This means that the daily consumption of oysters collected from Sg. Tapai and Pantai Lido would not likely result in adverse health effects during a lifetime in a human population (Bogdanovic *et al.*, 2014). This also indicated that the two oyster populations from the six sites are safe, with no non-carcinogenic effects of the six metals, for consumption at least based the sampling period.

Conclusion

This study determined the concentrations of six heavy metals in the shells and four edible soft tissues of *S. cucullata* collected from Sg. Tapai and Pantai Lido obtained in 2008. Higher bio availabilities of Cu, Pb and Zn to *S. cucullata* were found in the Pantai Lido population; meanwhile, Sg. Tapai had higher bio availabilities of Cd, Fe and Ni to the oyster population.

For HHRA, the THQ values of all the six metals are below than 1.0. These values indicated that the edible soft tissues of oysters would cause no non-carcinogenic risk of Cd, Cu, Fe, Ni, Pb and Zn to the consumers. Therefore, rock oysters are safe to be consumed based on the samples collected in 2008.

Acknowledgement

The financial support provided through the Research University Grant Scheme (RUGS), [Vote no: 91229], by University Putra Malaysia is highly acknowledged.

References

1. Abhilash KR, Gireeshkumar TR, Venu S, Raveendran TV (2013) Bio concentration of trace metals by *Saccostrea cucullata* (von Born 1778) from Andaman waters. *Ind. J. Geo-Mar. Sci* 42: 326-330. Link: https://bit.ly/2DcPRxq
2. Baik SH, Kim KJ, Chung EY, Choo JJ, Park KH (2001) Seasonal variations in biochemical components of the visceral mass and adductor muscle in the pen shell, *Atrina pectinata*. *Fish. Aquat. Sci* 4: 18–24. Link: https://bit.ly/2D8G1MY
3. Blackmore G (2001) Interspecific variation in heavy metal body concentrations in Hong Kong marine invertebrates. *Environ. Pollut* 114: 303-311. Link: https://bit.ly/39wqimQ
4. Bogdanovic T, Ujevic I, Sedak M, Listes E, Simat, et al. (2014) As, Cd, Hg and Pb in four edible shellfish species from breeding and harvesting areas along the eastern Adriatic Coast, Croatia. *Food Chem* 146: 197–203. Link: https://bit.ly/2PbVvmd
5. Chakraborty S, Mitra A (2017) Concentrations of heavy metals in edible dominant oyster (*Saccostrea cucullata*) inhabiting Sagar Island, West Bengal. *J. Fisheries Livest. Prod* 5: 238. Link: https://bit.ly/2OY457Z
6. Chong K, Wang WX (2000) Assimilation of cadmium, chromium, and zinc by the green mussel *Perna viridis* and the clam *Ruditapes philippinarum*. *Environ. Toxicol. Chem* 19: 1660-1667. Link: https://bit.ly/3f2QTsZ
7. Department of Fisheries Malaysia (2005) *Malaysia Fisheries Directory, 2005-06*. Acean Medialine (M) Sdn. Bhd 56-57. Link: https://bit.ly/2WW5mAv
8. Gokoglu N, Gokoglu M, Yerlikaya P (2006) Seasonal variations in proximate and elemental composition of pearl oyster (*Pinctada radiata*, Leach, 1814) *J Sci Food Agric* 86: 2161–2165. Link: https://bit.ly/3f3mWZN
9. (2014) IRIS (Integrated risk information system) US Environmental Protection Agency. Link: https://bit.ly/3hJkzgf
10. Lee YJ, Choi KS, Lee DS, Lee WC, Park HJ, et al. (2015) The role of the adductor muscle as an energy storage organ in the pen shell *Atrina japonica* (Reeve, 1858) *J. Molluscan Stud* 81: 502–511. Link: https://bit.ly/39HOdQB
11. Lim PE, Lee CK, Din Z (1995) Accumulation of heavy metals by cultures oysters from Merbok Estuary, Malaysia. *Mar. Pollut. Bull.* 31: 420-423. Link: https://bit.ly/2WX9nVm
12. Lim PE, Lee CK, Din Z (1998) The kinetics of bioaccumulation of zinc, copper, lead and cadmium by oysters (*Crassostrea iredalei* and *C. belcheri*) under tropical field conditions. *Sci. Tot. Environ* 216: 147-157. Link: https://bit.ly/2D8Sb8A
13. Luoma SN, Rainbow PS (2005) Why is metal bioaccumulation so variable? Biodynamic as a unifying concept. *Environ. Sci. Tech* 39: 1921-1931. Link: https://bit.ly/3jIpdx4
14. Najiah M, Nadirah M, Lee KL, Lee SW, Wendy W, et al. (2008) Bacteria flora and heavy metals in cultivated oyters *Crassostrea iredalei* of Setiu Wetland, East Coast Peninsular Malaysia. *Vet. Res. Comm* 32: 377-381. Link: https://bit.ly/3g2nkZK
15. Nurul Izzah A, Wan Rozita WM, Tengku Rozaina TM, Cheong YL, Siti Fatimah D, et al. (2016) Fish consumption pattern among adults of different ethnics in Peninsular Malaysia. *Food Nutr. Res* 60: 32697. Link: https://bit.ly/2X1DKdr
16. O'Connor TP, Lauenstein GG (2006) Trends in chemical concentrations in mussels and oysters collected along the US coast: Update to 2003. *Mar. Environ. Res* 62: 261-285. Link: https://bit.ly/2WXAIH4
17. Rainbow PS (1995) Bio monitoring of heavy metal availability in the marine environment. *Mar. Pollut. Bull* 31: 183-192. Link: https://bit.ly/30OU6r4
18. Silva CAR, Smith BD, Rainbow PS (2006) Comparative biomonitors of coastal trace metal contamination in tropical South America. *Mar. Environ. Res* 61: 439-455. Link: https://bit.ly/39uIs8y
19. Szefer P, Ikuta K, Kushiyama S, Frelek K, Geldon J (2007) Distribution of Trace Metals in the Pacific Oyster, *Crassostrea gigas,* and Crabs from the East Coast of Kyushu Island, Japan. *Bull. Environ. Contam. Toxicol* 58: 108-l14. Link: https://bit.ly/2CUu2CG
20. Tack JF, Polk P (1996) The uptake of colloidal melanin from seawater by marine bivalves. *Mar. Ecol.* 17: 543-548. Link: https://bit.ly/3g3XF2X
21. Tack JF, Vanden BE, Polk P (1992) Ecomorphology of *Saccostrea cucullata* (Born, 1778) (Ostreidae) in mangrove creek (Gazi, Kenya). *Hydrobiol* **247**: 109-117. Link: https://bit.ly/39ud2z4
22. Takashi O (2000) *Marine molluscs in Japan* Tokai University, Japan. Tokai University Press, Japan. Link: https://bit.ly/2Ehtoj2
23. Uddin MJ, Park KI, Kang DH, Park YJ, Choi KS (2007) Comparative reproductive biology of Yezo scallop, *Patinopecten yessoensis*, under two different culture systems on the east coast of Korea. *Aquacul* 265: 139–147. Link: https://bit.ly/2BzvmKP
24. (1989) USEPA (US Environmental Protection Agency) Guidance manual for assessing human health risks from chemically contaminated, fish and shellfish. EPA-503/8-89-002. USEPA, Washington DC. Link: https://bit.ly/3fbA4w9
25. (2000) USEPA (US Environmental Protection Agency) Risk-Based Concentration Table. Philadelphia PA: USEPA, Washington, DC. Link: https://bit.ly/2CTSGDv
26. (2008) USEPA (US Environmental Protection Agency) Integrated Risk Information System. CRC. Link: https://bit.ly/3hKWOop
27. (1990) USFDA (Food and Drug Administration of the United States) US Food and Drug Administration Shellfish Sanitation Branch, Washington, D.C. Link: https://bit.ly/30Olwx3
28. Wang WX, Lu G (2017) Heavy Metals in Bivalve Mollusks. 553-594 Link: https://bit.ly/3jMgGZR
29. Yap CK, Noorhaidah A, Tan SG, Soo (2013) Relationships of copper concentrations between the different soft tissues of *Telescopium* and the surface sediments collected from tropical intertidal areas. *Int. J. Chem* 5: 8-19. Link: https://bit.ly/2X1DXNJ
30. Yap CK (2018) Selected organs of marine mussels as accurate biomonitors of metal bioavailability and contamination in the coastal waters: Challenges. *EC Phamacol Toxicol.* 6: 528-534. Link: https://bit.ly/2WZPOfs
31. Yap CK, Cheng WH (2013) Distributions of heavy metal concentrations in different tissues of the mangrove snail *Nerita lineata*. *Sains Malays* 42: 597–603. Link: https://bit.ly/3f1IKGo
32. Yap CK, W.S Lo (2013) Metal concentrations in Anadara granosa collected from intertidal mudflats on the west coast of peninsular Malaysia. *J. Sust. Sci. Manage.* 8: 11-21. Link: https://bit.ly/2WXLdKu
33. Yap CK, Edward FB, Tan SG (2014) Concentrations of heavy metals in different tissues of the bivalve *Polymesoda erosa*: Its potentials as a biomonitor and food safety concern. *Pertanika J. Trop. Agric. Sci.* 37: 19 – 38. Link: https://bit.ly/304yrMh
34. Yap CK, Ismail A, Tan SG (2003) Mercury concentrations of the surface sediment of the intertidal area along the west coast of Peninsular Malaysia. *Toxicol. Environ. Chem* 85: 13-21. Link: https://bit.ly/3jL8MQn

DOI: 10.37179/rijees.000002.

35. Yap CK, Ismail A, Edward FB, Tan SG, Siraj SS (2006) Use of different soft tissues of *Perna viridis* as biomonitors of bioavailability and contamination by heavy metals (Cd, Cu, Fe, Pb, Ni and Zn) in a semi-enclosed intertidal water, the Johore Straits. *Toxicol. Environ. Chem.* 88: 683-695. Link: https://bit.ly/30KCZ9K

36. Yap CK, Mohd Nasir S, Edward FB, Tan SG (2012) Anthropogenic inputs of heavy metals in the east part of the Johore Straits as revealed by their concentrations in the different soft tissues of *Perna viridis* (L.). *Pertanika J. Trop. Agric. Sci.* 35: 827–834. Link: https://bit.ly/2WZq2b0

37. Yap CK, Mohd Ruszaidi S, Cheng WH (2010) Different tissues of rock oyster *Saccostrea cucullata* as biomonitors of trace metal bioavailability's in the Penang coastal waters, Malaysia. *Res. J. Chem. Environ* 14: 17-21. Link: https://bit.ly/39xTgCW

38. Yap CK, Azmizan AR, Hanif MS (2011) Bio monitoring of trace metals (Fe, Cu and Ni) in the mangrove area of Peninsular Malaysia, using different soft tissues of flat-tree oyster *Isognomon alatus. Wat. Air Soil Poll* 218: 19-36. Link: https://bit.ly/3hGI7mc

39. Yap CK, Azmizan AR, Hanif MS, Tan SG (2011) Use of different tissues of flat-tree oyster *Isognomon alatus* as biomonitors of bioavailabilities and contamination by Zn in the mangrove area of Peninsular Malaysia. *J. Sust. Sci. Manage* 6: 230-239. Link: https://bit.ly/2D5TuoG