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# Correlations between Speciation of Zn in Sediment and Zn Concentrations in Different Soft Tissues of the Gastropod Mollusc *Telescopium telescopium* Collected from Intertidal Areas of Peninsular Malaysia

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## ABSTRACT

The aim of this study was to relate the Zn level in the different tissues of *Telescopium telescopium* to the Zn levels of surface sediment of the gastropod habitat. Zn concentrations were determined in the different soft tissues (foot, cephalic tentacle, mantle, muscle, gill, digestive caecum and remaining soft tissues) of *T. telescopium* and in the sediments collected from 17 intertidal areas of Peninsular Malaysia, where the snails were collected. Total Zn concentrations and speciation of Zn of the surface sediment were correlated with the Zn concentrations measured in the different soft tissues of *T. telescopium*. The results showed that significant ($p < 0.01$) correlations were observed between Zn concentrations in mantle, muscle, gill, and remaining soft tissues with non-resistant Zn in sediment; Zn concentration in gill with resistant Zn in sediment; mantle, muscle, gill, and remaining soft tissues with acid reducible Zn in sediment; gill and remaining soft tissues with oxidisable-organic Zn in sediment. The pattern of Zn distribution showed that digestive caecum of *T. telescopium* in all 17 sites always contained the highest concentration of Zn, except for Kuala Sg. Ayam. Therefore, the present results generally supported the use of different soft tissues of *T. telescopium* as a more accurate biomonitoring organ for Zn, besides the total soft tissues.

**Keywords: *Telescopium telescopium*, different soft tissues, intertidal area, Peninsular Malaysia**

## INTRODUCTION

During the past few years, studies on the distributions, concentrations, and functions of heavy metals in gastropod tissues have been stimulated by several factors. The accumulation of several heavy metals, especially by aquatic organisms, has drawn attention to their essential role in many life processes, e.g. Zn is particularly involved in enzyme functions and respiratory functions (Spronk *et al*., 1971). Several researchers (Bu Olayan and Thomas, 2001; Conti and Cecchetti, 2003; Dang *et al*., 2005; Ireland and Wootton, 1977; Shiber and Shatila, 1978; Taylor and Maher, 2003; Walsh *et al*., 1995) have reported the use of whole soft tissues of snails for biomonitoring studies. These researchers have investigated heavy metal concentrations in the whole soft tissues of gastropod molluscs but no emphasis has been given to the different soft tissues of gastropods. Some of the gastropods that inhabit rocky shores or sediments fulfil most of the requirements of good biomonitors (Raibows *et al*., 1990); however, it is important that they accumulate metals in proportion to metal availabilities in the environment (Ying *et al*., 1993). In addition to that, Ying *et al*. (1993)

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suggested that in the case of sediment-dwelling gastropods, only the bioavailability fraction of metals in sediment can have an impact on accumulation. Nevertheless, bioavailability is not the only factor which influences the metal concentrations in marine organisms (Bryan and Hummertsone, 1986; Rainbow *et al*., 1990; Rainbow, 1997), the physiological differences between the different soft tissues and metal-fractionation in sediment are also influential. Other studies (Luoma and Bryan, 1978; Luoma, 1983; Yap *et al*., 2002; Ying *et al*., 1993) have examined various molluscs species and demonstrated significant correlations between metal concentrations in organisms and metal concentrations extracted from the sediment by various extractants. Therefore, this present study focussed on the correlation between the total concentrations of Zn in different soft tissues in snails and fractionated heavy metals in sediment.

In general, Zn concentrations in sediments and tissues of aquatic organisms are usually elevated in the vicinity of smelters and other point sources of Zn, and decrease with increasing distance (Ward *et al*., 1986). Moreover, sediment acts as an important reservoir for heavy metals which leads to the following question: to what extent are sediment-bound metals available for uptake by living organisms? (Mountouris *et al*., 2002). In most circumstances, the major part of the anthropogenic metal load in the sea and sea bed sediments and organisms has a terrestrial source from mining and intensive aquaculture and municipal wastewaters, untreated effluents, harbour activities, urban and agricultural runoff along major rivers, estuaries and bays (Dalman *et al*., 2006).

Many organisms, including plankton, molluscs and fish, can act as biomonitors by accumulating pollutant metals as a function of the metal concentrations in their environment (Foulkes, 1990). *Telescopium telescopium* (Family: Potamididae) is focused in this study because it fulfils most of the recommended criteria for a good biomonitor including sedentary lifeform, accumulative of metal concentrations, easy sampling and wide geographical distribution (Kang *et al*., 1999; Yap *et al*., 2006: 2007). For this study, the samples of sediment and the snails, *T. telescopium* were collected from 17 intertidal areas of Peninsular Malaysia. These were analyzed for Zn concentrations in an attempt to recognize subtle pollution effects and anthropogenic influences. The objective of this study was to correlate the Zn levels in the different tissues of T. telescopium and the Zn levels in the surface sediments.

## MATERIALS AND METHODS

### *Sampling and Sample Preparation*

The description of each site is given in Table 1. Snails were collected from 17 geographical sites along the south western intertidal area of Peninsular Malaysia (*Fig. 1*). Stations shown on the map were chosen because the west coast of Peninsular Malaysia receives many industrial and domestic effluents from the surrounding areas. The samples were kept in an ice chest and brought to the laboratory. About 6-21 individual snails from each station were used for the analysis. The mean length and width of the shell of the snails were measured. As in the previous collections, the snails were not kept in the laboratory in any attempt to purge contents, and this was to avoid the possibility of contamination. Therefore, they potentially contained gut contents, but were considered to represent only a small proportion of the total body metal content (Rainbow, 1987: 1998; Rainbow and Blackmore, 2001), given the characteristics of snails as particularly strong trace metal accumulators.

### *Metal Analyses*

About 9-15 individuals of *T. telescopium* from each site were dissected and pooled into seven different soft tissues, namely foot, cephalic tentacle, mantle, muscle, gill, digestive caecum, and remaining soft tissues (‘rest’).

All the snails and sediment samples were dried at 80 °C for 72 h until constant dry weights were achieved. Three replicates of each different part of soft tissues and shells of snails were

TABLE 1
The description of sampling sites

| No of sites | N | Date | GPS | Sampling sites | Height Min | SE Max | Width Min | SE Max |
|---|---|---|---|---|---|---|---|---|
| 1. | 9 | 12th January 2007 | N 04º 55' 89.6"<br>E 100º 26' 79.1" | Kuala Gula (KG) | 8.60<br>8.03 | 0.11<br>9.33 | 4.28<br>3.98 | 0.07<br>4.91 |
| 2. | 13 | 25th February 2006 | N 04° 14' 44.3"<br>E 100° 41' 35.6" | Kg Setiawan (KS) | 6.58<br>5.82 | 0.14<br>7.08 | 3.18<br>2.95 | 0.04<br>3.41 |
| 3. | 6 | 25th February 2006 | N 04° 14' 53.8"<br>E 100° 42' 09.1" | Kg Deralik (KD) | 5.65<br>4.51 | 0.15<br>6.67 | 3.24<br>2.78 | 0.07<br>3.75 |
| 4. | 8 | 27h February 2006 | N 04° 16' 46.0"<br>E 100° 39' 50.2" | J. Permaisuri Bainun (JPB) | 5.35<br>4.62 | 0.07<br>5.84 | 2.83<br>2.45 | 0.04<br>3.05 |
| 5. | 8 | 16th August 2006 | N 03º 0' 22.94"<br>E 101º 18' 22.5" | Pulau Indah (PI) | 8.98<br>8.55 | 0.13<br>9.48 | 4.52<br>4.38 | 0.05<br>4.69 |
| 6. | 10 | 24th February 2006 | N 03° 13' 14.6"<br>E 101° 18' 19.5" | Kg Pantai Jeram (KPJ) | 7.81<br>6.85 | 0.12<br>8.35 | 3.71<br>3.42 | 0.04<br>3.94 |
| 7. | 21 | 20th March 2006 | N 03° 10' 20.0"<br>E 101° 18' 1.4" | Sg Janggut (SJ) | 8.35<br>8.02 | 0.08<br>8.81 | 4.56<br>4.01 | 0.12<br>5.26 |
| 8. | 10 | 7th January 2006 | N 02º 36' 19.41"<br>E 101º 42' 11.51" | Sg Sepang Besar (SB) | 4.96<br>4.73 | 0.06<br>5.29 | 2.89<br>2.75 | 0.06<br>3.25 |
| 9. | 9 | 15th September 2006 | N 02º 35' 57.52"<br>E 101º 42' 31.41" | Bagan Lalang (BL) | 7.64<br>7.31 | 0.06<br>7.94 | 3.72<br>3.39 | 0.05<br>3.95 |
| 10. | 10 | 18th August 2006 | N 02º 36' 4.11"<br>E 101º 41' 7.79" | Sg Sepang Kecil (SK) | 8.41<br>7.27 | 0.17<br>8.96 | 3.89<br>3.63 | 0.07<br>4.25 |
| 11. | 12 | 28th April 2006 | N 02° 34' 49.2"<br>E 101° 49' 34.4" | Kuala Lukut Besar (KLB) | 8.74<br>7.55 | 0.16<br>10.74 | 4.73<br>3.9 | 0.09<br>5.28 |
| 12. | 6 | 28th April 2006 | N 02° 33' 42.2"<br>E 101° 48' 00.2" | Kuala Lukut Kecil (KLK) | 9.20<br>8.83 | 0.08<br>9.47 | 4.68<br>4.21 | 0.21<br>5.93 |
| 13. | 17 | 29th April 2006 | N 01° 52' 21.0<br>E 102° 44' 16.5 | Sg Balang Laut, Muar (SBL) | 7.83<br>7.53 | 0.07<br>7.97 | 3.90<br>3.63 | 0.08<br>4.15 |
| 14. | 15 | 29th April 2006 | N 01° 45' 12.5"<br>E 102° 55' 45.4 | Kuala Sg Ayam, Batu Pahat (KSA) | 7.15<br>6.37 | 0.13<br>7.83 | 3.51<br>2.93 | 0.07<br>3.82 |
| 15. | 11 | 29th April 2006 | N 01° 41' 07.2<br>E 103° 05' 54.6" | Pantai Punggur, Pontian (PP) | 8.47<br>7.95 | 0.14<br>8.98 | 4.16<br>3.98 | 0.04<br>4.35 |
| 16. | 11 | 30th April 2006 | N 01° 26' 05.8"<br>E 101° 56' 02.4" | Kg Pasir Puteh, Johor Baharu (KPP) | 9.03<br>8.56 | 0.13<br>9.66 | 4.82<br>4.56 | 0.04<br>4.97 |
| 17. | 8 | 15th December 2006 | N 06º 12' 55.21"<br>E 102º 14' 14.21" | Tumpat, Kelantan (T) | 7.30<br>6.62 | 0.18<br>8.15 | 3.08<br>2.96 | 0.04<br>3.29 |

then digested in concentrated nitric acid (BDH: 69%). The dried sediment samples were crushed using a mortar and pestle and sieved through a 63 µm aperture stainless steel sieve and were shaken vigorously to produce homogeneity (Yap *et al*., 2002). For the analyses of the total Zn concentrations in the sediment samples, three replicates were analyzed using direct aqua-regia method (Yap *et al*., 2006). About 1 g of each dried sample was digested in a combination of concentrated $HNO_3$ (AnalaR grade; BDH 69%) and $HClO_4$ (AnalaR grade; BDH 60%), in the

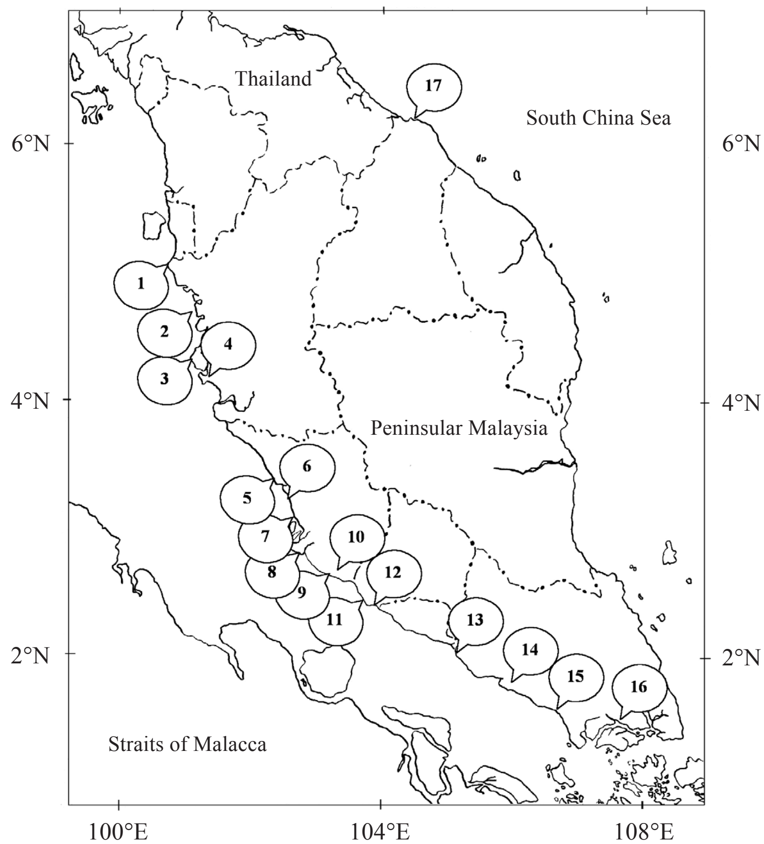


*Fig. 1: Map showing 17 sampling locations (in numbers) of the intertidal areas of Peninsular Malaysia (the names of all sampling sites in numbers are given in Table 1)*

ratio of 4:1. The snail and sediment samples were put into a hot-block digester first at a low temperature (40 °C) for 1 hr and they were fully digested at 140 °C for at least 3 hrs (Yap *et al*., 2002). Geochemical fractions of Zn in the sediments were obtained using the modified SET (Sequential Extraction Technique) described by Badri and Aston (1983). The four fractions 'easily, freely or leachable or exchangeable (EFLE)', 'acid reducible', 'oxidisable-organic' and resistants were employed (Yap *et al*., 2002). Two replicates for each fraction were analyzed. In the four fractions considered, the extraction solutions and the conditions employed are as follows:

(1) EFLE: About 10g of sample was continuously shaken for 3 hours with 50 ml 1.0 M ammonium acetate ($NH_4CH_3COO$), pH 7.0, and at room temperature.

(2) 'Acid reducible': the residue from (1) was continuously shaken for 3 hours with 50 ml 0.25M hydroxylammonium chloride ($NH_2OH$•HCl) acidified to pH 2 with HCl, at room temperature.

(3) 'Oxidisable – organic': The residue from (2) was first oxidized with 30 % $H_2O_2$ in a water bath at 90 °C – 95 °C. After cooling, the metal released from the organic complexes was continuously shaken for 3 hours with 1.0M ammonium acetate ($NH_4CH_3COO$) acidified to pH 2.0 with HCl at room temperature.

(4) 'Resistant': The residue from (3) was digested in a combination of concentrated nitric acid (AnalaR grade, BDH 69 %) and perchloric acid (AnalaR grade, BDH 60 %) as performed in the direct aqua-regia method.

The prepared samples were then analyzed for Zn using an air-acetylene flame Atomic Absorption Spectrophotometer (AAS) Perkin Elmer Model A- Analyst 800. The sample concentrations are presented as µg/g dry weight (dw).

*Quality Assurance*

To avoid possible contamination, all the glassware and equipment used were acid-washed. To check for contamination, procedural blanks were analyzed after every five sample (Yap *et al.*, 2006). Meanwhile, the quality control samples, made from standard solutions of Zn, were analyzed in every sample to check for the metal recoveries. The accuracy of the digestion analysis procedure was evaluated by the analysis of NIST 1566a Oyster tissue, NRCC Dolt-1 Dogfish liver and MESS-3 Marine sediment, as depicted in Table 2.

## STATISTICAL ANALYSIS

The data were analyzed using SPSS 15.0, i.e. the coefficient of correlation (r) between variables; Pearson's correlation was performed to determine the relationship of different soft tissues of snail and metals concentration in sediment based on untransformed data. Analysis of variance (ANOVA) was used to calculate the interaction of different soft parts and sampling location on the metals concentrations of snail, *T. telescopium*. The ANOVA analysis revealed significant differences for the factor 'sampling locations' on the Zn concentrations of the sediment and snail bodies (different soft parts). The hierarchy of the mean values and relationship to homogeneous subsets (mean values within are not significantly different) were determined with Student-Newman-Keuls test. Homogeneous subsets are marked with letters (a-j) (Table 3). All the statistical tests were performed at the significance level of $P < 0.05$.

## RESULTS AND DISCUSSION

The concentrations of Zn in all geochemical fractions in the surface sediments are given in Table 5 and *Fig. 2*. The Zn concentration in the sediment collected from Kuala Sg. Ayam (297.46 ± 0.81µg/g dw) was significantly higher compared to the other sites ($P < 0.05$). However, the resistant fraction for Zn from Kuala Sg. Ayam was the dominant fraction. It is assumed that the Zn concentrations in the sediment derived greatly from the geochemical background rather than anthropogenic inputs. With respect to the Zn concentrations of the surface sediments from Kg. Pasir Puteh, Kuala Lukut Besar, and Sepang Kecil, the Zn non- resistant fraction (EFLE, acid reducible, and oxidisable-organic) was found to contain more than 70%, and these sites are most likely to be influenced by the untreated domestic effluent. Henkin *et al.* (1984) classified Zn as a typical indicator of industrial and domestic wastes.

The highest concentration of EFLE fraction of Zn was found at Kg. Pasir Puteh, which was significantly higher ($P < 0.05$) than the other sites. Kuala Sg. Ayam showed the highest

TABLE 2
Comparison of Zn concentration between measured values by using AAS and CRM values

| | Dogfish | Mussel | Sediment |
|---|---|---|---|
| Measured | 100.26 | 129.21 | 145.03 |
| CRM | 86.60 | 137.00 | 159.00 |
| Recovery (%) | 115.77 | 94.31 | 91.21 |

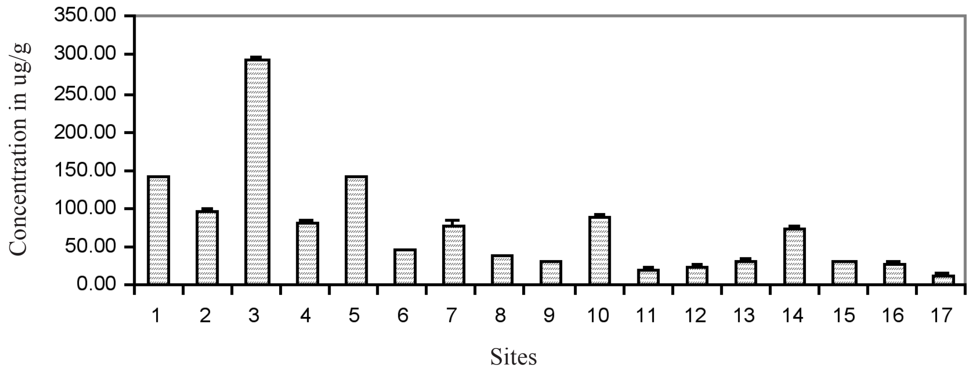


*Fig. 2: Mean Zn concentration of sediment collected from 17 intertidal area of Peninsular Malaysia*

level of acid reducible fraction, oxidisable-organic fraction, and resistant fractions of Zn in sediment.

The concentrations of Zn in digestive caecum, gill, muscle, and foot were commonly higher than those in the sediment. For example, Zn in the digestive caecum of gastropods from Bagan Lalang averaged three times higher when compared to the total Zn concentration in the sediment. In addition to that, digestive caecum were always found to accumulate high concentrations of Zn in the 17 sampling locations (Table 5), except for the population from Kuala Sg. Ayam in which the gill accumulated higher concentrations of Zn. Other tissues such as cephalic tentacle, remaining soft tissues, and gill showed low concentrations of Zn, but not in any consistent pattern. Based on the findings of the present study, some important points can be noted. According to Deb and Fukushima (1999), metals may be in high concentrations in the gills, intestine and digestive glands of gastropod. These organs have relatively high potential for metal storage and accumulation (Altindag and Yigit, 2005). Unlike this report, Zn concentrations in foot, mantle, and muscle did not show significant difference, but Zn found in the gill and digestive caecum of *T. telescopium* was markedly higher ($P < 0.05$) than other different soft tissues because as an essential trace element, Zn is known to act as an enzyme cofactor in over 200 enzymes with important biological functions regulating many physiological processes including DNA synthesis, behavioural response, and reproduction (Vallee and Auld, 1990). The high level of Zn in the digestive caecum could be related to its functions in biochemical mechanism within a particular tissue, regardless of the environmental exposures of the organisms to the metals (Turoczy *et al*., 2001) and physiological differences between those different soft tissues rather than proximity to human activity or other environmental variables (Park and Presley, 1997). In general, the accumulation and storage of trace metals (e.g. Zn) in common biomonitors, such as bivalve and gastropod molluscs, are strongly associated with the level and metal binding capacity of metallothioneins or other detoxificatory systems in their tissues (Roesijadi, 1992; Dallinger *et al*., 2004a, b; Yap *et al*., 2006).

Table 3 shows that the highest Zn concentrations were found in the foot from Jambatan Permaisuri Bainun, followed by Kuala Sg. Ayam and Sg Janggut. The foot from Kg. Pasir Puteh recorded the lowest Zn concentration but the gastropods from this particular site recorded the highest concentrations of Zn in mantle, muscle and remaining soft tissues. For gill, the highest concentrations were found from Kuala Sg. Ayam, followed by Kg. Setiawan and Kg Pasir Puteh, while Bagan Lalang recorded the highest Zn concentration in digestive caecum, followed by Sg. Janggut and Sg. Balang Laut.

TABLE 3
Mean Zn concentrations (µg/g dry weight) in the different soft tissues of *Telescopium telescopium* collected from 17 intertidal areas of Peninsular Malaysia

| No | Site | Foot | | | CT | | | Mantle | | | Muscle | | | Gill | | | REST | | | DC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SE | | Mean | SE | | Mean | SE | | Mean | SE | | Mean | SE | | Mean | SE | | Mean | SE | |
| 1. | KPP | 49.22 | ± 1.74 | a | 36.81 | ± 0.97 | a | 105.57 | ± 1.17 | h | 133.39 | ± 2.27 | f | 144.48 | ± 2.58 | h | 246.57 | ± 5.49 | h | 282.59 | ± 6.33 | c,d |
| 2. | PP | 82.48 | ± 4.56 | c,d,e | 63.37 | ± 0.57 | c | 71.69 | ± 1.94 | c,d,e | 78.19 | ± 3.62 | b,c,d | 72.99 | ± 4.26 | f | 30.92 | ± 0.10 | a,b | 194.55 | ± 3.51 | a,b |
| 3. | KSA | 91.21 | ± 1.11 | e | 71.78 | ± 0.82 | e,f | 80.49 | ± 6.92 | e,f,g | 87.61 | ± 7.23 | d,e | 402.78 | ± 11.58 | j | 77.13 | ± 1.84 | f | 180.08 | ± 6.74 | a,b |
| 4. | SBL | 70.68 | ± 1.10 | b,c | 51.27 | ± 1.45 | b | 63.98 | ± 2.52 | b,c | 50.08 | ± 1.29 | a,b | 19.86 | ± 0.81 | a | 62.69 | ± 1.49 | d,e | 284.02 | ± 2.76 | c,d |
| 5. | KLK | 84.90 | ± 0.69 | d,e | 66.43 | ± 4.42 | c,d,e | 82.12 | ± 0.87 | f,g | 88.60 | ± 1.32 | d,e | 26.75 | ± 0.43 | a,b | 71.51 | ± 3.39 | e,f | 211.18 | ± 1.26 | a,b,c |
| 6. | KLB | 82.60 | ± 1.50 | c,d,e | 71.17 | ± 2.23 | d,e,f | 84.72 | ± 3.40 | f,g | 87.98 | ± 1.24 | d,e | 40.30 | ± 0.89 | b,c | 67.94 | ± 1.13 | d,e,f | 201.29 | ± 8.01 | a,b |
| 7. | SB | 69.66 | ± 1.72 | b,c | 60.93 | ± 3.71 | c | 68.58 | ± 1.93 | c,d | 80.58 | ± 1.60 | b,c,d,e | 74.12 | ± 0.28 | f | 99.34 | ± 4.63 | g | 220.56 | ± 2.57 | a,b,c,d |
| 8. | BL | 71.06 | ± 1.02 | b,c | 50.96 | ± 2.19 | b | 58.09 | ± 0.40 | a,b | 69.44 | ± 0.64 | b | 48.22 | ± 1.02 | c,d | 26.33 | ± 1.56 | a | 394.69 | ± 66.04 | e |
| 9. | SK | 64.42 | ± 0.31 | b | 63.39 | ± 0.10 | c,d,e | 75.23 | ± 1.74 | d,e,f | 84.86 | ± 0.79 | c,d,e | 35.57 | ± 1.12 | a,b,c | 59.61 | ± 1.68 | d | 243.86 | ± 0.79 | b,c,d |
| 10. | KPJ | 61.75 | ± 1.01 | b | 50.27 | ± 0.20 | b | 50.66 | ± 3.07 | a | 52.51 | ± 4.26 | a | 55.11 | ± 2.04 | d,e | 23.23 | ± 1.60 | a | 144.78 | ± 0.50 | a |
| 11. | SJ | 91.15 | ± 1.28 | e | 64.68 | ± 1.85 | c,d,e | 78.93 | ± 1.41 | d,e,f | 84.94 | ± 1.93 | c,d,e | 70.46 | ± 0.65 | e,f | 31.27 | ± 1.14 | a,b | 292.54 | ± 5.01 | d |
| 12. | PI | 77.32 | ± 0.85 | c,d | 64.61 | ± 2.11 | c,d,e | 68.76 | ± 1.32 | c,d | 83.87 | ± 0.43 | c,d,e | 70.19 | ± 3.55 | e,f | 38.37 | ± 0.99 | b | 170.21 | ± 2.80 | a,b |
| 13. | KD | 78.82 | ± 1.67 | c,d,e | 62.46 | ± 1.38 | c,d | 61.36 | ± 0.75 | a,b,c | 73.85 | ± 1.69 | b,c | 61.45 | ± 2.01 | d,e,f | 31.49 | ± 2.30 | a,b | 277.97 | ± 2.43 | c,d |
| 14. | KS | 79.10 | ± 0.82 | c,d,e | 71.24 | ± 1.65 | e,f,g | 58.71 | ± 2.08 | b | 91.15 | ± 2.15 | e | 175.80 | ± 9.60 | i | 22.76 | ± 1.35 | a | 215.86 | ± 2.73 | a,b,c,d |
| 15. | JPB | 126.29 | ± 9.45 | f | 75.25 | ± 0.33 | f | 71.10 | ± 0.27 | c,d,e | 87.12 | ± 1.41 | d,e | 93.87 | ± 3.31 | g | 46.27 | ± 3.61 | c | 272.18 | ± 4.45 | c,d |
| 16. | KG | 84.62 | ± 0.38 | d,e | 70.86 | ± 0.52 | d,e,f | 89.13 | ± 0.46 | g | 75.26 | ± 2.93 | b,c | 94.20 | ± 0.73 | g | 50.03 | ± 0.74 | c | 194.97 | ± 2.23 | a,b |
| 17. | T | 71.88 | ± 1.27 | b,c | 53.50 | ± 0.28 | b | 70.19 | ± 1.00 | c,d | 70.75 | ± 0.17 | b | 23.67 | ± 1.55 | a | 70.00 | ± 0.03 | e,f | 278.83 | ± 2.59 | c,d |

Objects indicated with different alphabet: $p < 0.05$, objects indicated with same alphabet: $p > 0.05$ (the same alphabet showed that the means do not differ from one another, $p > 0.05$). Homogeneous subsets resulting from one-way ANOVA and Student Newman Keuls test ($p < 0.05$) are donated with letters $^{a-j}$

These findings are similar with the ones found in the previous study by Yap *et al*. (2007) on *Perna viridis*. According to Wang and Rainbow (2005), the uptake of Zn by marine invertebrates is also dependent on the excretion of accumulated Zn in their bodies. On the other hand, the Zn uptake from the solute phase was proportional to the ambient Zn concentration (Wang *et al*., 1996; Chong and Wang, 2000). Wang and Wong (2003) also found that in *Perna viridis*, regulation was mainly achieved by a change in the Zn assimilation from the dietary phase which might dominate the overall Zn accumulation in mussels. However, the accumulation and tissue distribution of Zn in various organs of the *T. telescopium* should be investigated to elucidate the suitability of this snail as a biomonitor of Zn pollution through experimental field or laboratory work.

The correlations between different geochemical fractions of Zn in sediment and Zn in the different soft tissues of *T. telescopium* are shown in Table 2. Significant correlations were also found between Zn in mantle (r = 0.595, P < 0.01)), muscle (r = 0.768, P < 0.01) and remaining soft tissues (r = 0.910, P < 0.01) and EFLE fraction of Zn (Table 4). Zinc found in mantle, muscle, gill, and remaining soft tissues was found to be significantly correlated with acid reducible fraction (r = 0.374, 0.516, 0.695 and 0.627, P < 0.01) (Table 4). Significant correlations were also found between Zn in gill, and remaining soft tissues and oxidisable- organic fraction of Zn (r = 0.390, 0.462, P < 0.01). Zn in gill was also found to be significantly correlated with the resistant fraction of Zn in the sediment. For Zn in digestive caecum of *T. telescopium,* no significant correlation (P > 0.05) was found among the EFLE, acid-reducible and oxidisable-organic fractions, except for negative correlation (r = -0.296, P < 0.05) with the resistant fraction of Zn in sediment. The general trend of Zn concentrations in different soft tissues was digestive caecum > gill > muscle > foot > mantle > remaining soft tissues > cephalic tentacle, which is probably the result of both exposure and ability to regulate Zn. The data presented in Table 3 show that the digestive caecum accumulated the highest concentration of Zn as compared to other tissues (P < 0.05). Even though the digestive caecum always accumulated higher concentrations of Zn in 16 sampling locations out of 17, the Zn levels in this digestive caecum did not significantly correlate with any of the sedimentary fractions of Zn. This could be due to the bioavailability of Zn to the digestive caecum not reflecting the Zn contamination of the sampling sites, as represented by the surface sediments (Yap *et al*., 2002). A strong correlation (P < 0.01) between Zn in mantle,

TABLE 4
Pearson correlation coefficients between EFLE, acid reducible, oxidisable-organic and resistant of Zn concentration in sediment with different parts of soft tissues correlations

| | EFLE | AR | OO | Resistant | Foot | CT | Mantle | Muscle | Gill | REST | DC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AR | 0.649** | 1 | | | | | | | | | |
| OO | 0.359** | 0.751** | 1 | | | | | | | | |
| Resistant | 0.020 | 0.670** | 0.772** | 1 | | | | | | | |
| Foot | -0.455** | -0.274 | -0.172 | 0.124 | 1 | | | | | | |
| CT | -0.539** | -0.214 | -0.190 | 0.149 | 0.730** | 1 | | | | | |
| Mantle | 0.595** | 0.374** | 0.259 | 0.106 | -0.034 | -0.024 | 1 | | | | |
| Muscle | 0.768** | 0.516** | 0.200 | 0.059 | -0.056 | -0.035 | 0.729** | 1 | | | |
| Gill | 0.225 | 0.695** | 0.390** | 0.741** | 0.183 | 0.252 | 0.219 | 0.349* | 1 | | |
| REST | 0.910** | 0.627** | 0.462** | 0.110 | -0.420** | -0.514** | 0.707** | 0.714** | 0.192 | 1 | |
| DC | 0.107 | -0.144 | -0.219 | -0.296* | -0.031 | -0.369** | -0.043 | 0.031 | -0.244 | 0.097 | 1 |

*Note*: Data based on 17 sites of intertidal area of Peninsular Malaysia. Level of significance ** P< 0.01 level and *P < 0.05 level

TABLE 5
Order of Zn concentrations in the different soft tissues of *T. telescopium* from each sampling location

| No. | Sites | Patterns | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Kg Pasir Puteh | DC | > | REST | > | Gill | > | Muscle | > | Mantle | > | Foot | > | CT |
| 2. | Pantai Punggur | DC | > | Foot | > | Muscle | > | Gill | > | Mantle | > | CT | > | REST |
| 3. | Kuala Sg Ayam | Gill | > | DC | > | Foot | > | Muscle | > | REST | > | Mantle | > | CT |
| 4. | Sg Balang Laut | DC | > | Foot | > | Mantle | > | REST | > | CT | > | Muscle | > | Gill |
| 5. | Kuala Lukut Kecil | DC | > | Muscle | > | Foot | > | Mantle | > | REST | > | CT | > | Gill |
| 6. | Kuala Lukut Besar | DC | > | Muscle | > | Mantle | > | Foot | > | CT | > | REST | > | Gill |
| 7. | Sepang Besar | DC | > | REST | > | Muscle | > | Gill | > | Mantle | > | Foot | > | CT |
| 8. | Bagan Lalang | DC | > | Foot | > | Muscle | > | Mantle | > | CT | > | Gill | > | REST |
| 9. | Sepang Kecil | DC | > | Muscle | > | Mantle | > | Foot | > | CT | > | REST | > | Gill |
| 10. | Kg Pantai Jeram | DC | > | Foot | > | Gill | > | Muscle | > | Mantle | > | CT | > | REST |
| 11. | Sg Janggut | DC | > | Foot | > | Muscle | > | Mantle | > | Gill | > | CT | > | REST |
| 12. | Pulau Indah | DC | > | Muscle | > | Foot | > | Mantle | > | Gill | > | CT | > | REST |
| 13. | Kg Deralik | DC | > | Foot | > | Muscle | > | CT | > | Gill | > | Mantle | > | REST |
| 14. | Kg Setiawan | DC | > | Gill | > | Muscle | > | Foot | > | CT | > | Mantle | > | REST |
| 15. | J P. Bainun | DC | > | Foot | > | Gill | > | Muscle | > | CT | > | Mantle | > | REST |
| 16. | Kuala Gula | DC | > | Gill | > | Mantle | > | Foot | > | Muscle | > | CT | > | REST |
| 17. | Tumpat | DC | > | REST | > | Muscle | > | Mantle | > | Foot | > | CT | > | Gill |

muscle, gill, and remaining soft tissues and non-resistant sedimentary fraction (total of EFLE, acid reducible fraction, and oxidisable organic fraction) was found, suggesting that *T. telescopium* is a good biomonitor of Zn contamination besides Zn bioavailability. Other studies (Luoma and Bryan, 1978; Luoma, 1983; Ying *et al*., 1993; Yap *et al*., 2002) have examined various mollusc species and demonstrated significant correlations between metal concentrations in organisms and metal concentrations extracted from the sediment by various extractants.

## CONCLUSIONS

Significant ($p < 0.05$) correlations between Zn concentrations in different soft tissues of *T. telescopium* (mantle, muscle, gill, and remaining soft tissues) and some geochemical fractions of Zn in the sediment were found. These results suggest that selected soft tissues of *T. telescopium* could be used as biomonitoring organs for Zn pollution in the intertidal area of Peninsular Malaysia. However, further validation is still required based on the field and laboratory studies. Furthermore, biochemical and molecular studies should be conducted in future in order to establish *T. telescopium* as a good biomonitor of Zn for intertidal area in Malaysia.

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