Concentration, distribution and correlation of heavy metals in Asian Moon Scallop (*Amusium pleuronectes*) and sea water from Indragiri River estuary

B Amin¹*, I Lestari²

¹Department of Marine Science, Faculty of Fisheries and Marine Science, University of Riau
²The Ministry of Marine Affairs and Fisheries of Riau Province, Pekanbaru 28293, Indonesia

*Email: bintalamin@gmail.com

**Abstract.** A study on the concentration, distribution and correlation of heavy metals Pb, Cd, Cu and Zn in seawater and asian moon scallop (*Amusium pleuronectes*) from Indragiri river estuary has been conducted on April 2018. Samples were collected from six stations representing inner and outer part of the estuary and the analysis of heavy metal was carried out by using AAS Shimadzu AA-7000. The results of the study showed that the average concentration of Pb, Cd, Cu and Zn in surface seawater and scallop were 0.0744, 0.0038, 0.0302, 0.1761 mg/L and 0.3100, 0.5300, 7.8669, 43.1069 µg/g, respectively. The concentrations of heavy metals between stations were significantly different (p<0.05), but no difference found between outer and inner part of the estuary (p>0.05). Heavy metal concentrations in seawater and scallop were positively correlated, except for Pb. The tolerable intake of metals as PTWI (Provisional Tolerable Weekly Intake) was calculated presented. Although the concentrations of all metals were still lower than many reported areas in Indonesian coastal waters, further intensive study is needed in order to determine the toxic metals in the scallop, and not only to report levels of contaminants but also important to compare them with health criteria values. Continuous environment monitoring programs should also be implemented to keep and protect the sustainability of the estuary.

1. **Introduction**

Pollution of coastal areas may come from both natural and anthropogenic activities. Most of anthropogenic activities which can be activities of individuals, households, industry, agriculture, livestock, plantations, fisheries, and others will eventually ended up its waste both directly and indirectly into the river flow and ended up into the sea and often results in river and coastal pollution. Declining water quality due to pollution, such as what occurs in rivers and coastal areas, can change the community structure of aquatic organisms that live in it [1].

Complex activities that occur along the river and in the estuary of the Indragiri River are thought to result in the entry of pollutants including heavy metals. Increased levels of heavy metals in seawater will cause heavy metals that were originally needed for various metabolic processes, especially those of essential metals, can turn toxic to marine organisms. Besides being toxic, heavy metals will also accumulate in sediments and biota through the process of gravity and biomagnification. The spread of pollutants, especially heavy metals in waters with deposition processes will affect the life cycle of...
aquatic animals, especially molluscs from bivalve groups [2, 3]. The higher the metal content in the waters, the higher the heavy metal content that accumulates in the body of the organism [4-7].

The Indragiri River Estuary waters receive wastes from various anthropogenic activities, namely household and industries, aquaculture activities and fishing vessel fleet activities and unfortunately there is still no clear information about the concentration of heavy metals in this area of important fishing ground for the local fishermen, especially for scallops (*Amusium pleuronectes*). Therefore this study is necessary to provide initial data on the concentration, distribution and correlation of heavy metals in seawater, sediment and scallops in the Indragiri River Estuary, Riau Province.

2. Materials and Methods

The research was conducted in March - April 2018 by collecting samples of seawater and scallops (*A. pleuronectes*) from six stations located in the waters of the Indragiri River Estuary, Riau Province (Figure 1). The selection of the sampling stations was determined purposively which represent the condition of the Indragiri River Estuary as described in Table 1.

![Figure 1. Map of Indragiri river estuary and the sampling stations](image)

All statistical analyses of data were carried out using SPSS statistical package programs version 17 and graphs were plotted with Microsoft EXCEL 2007. Data were tested for the basic assumptions of normality and homogeneity of variance in exploratory data analysis in SPSS 17. The correlation between concentration of heavy metals in water and scallop was analysed by using simple linear regression, whilst independent sample t-test was used to evaluate the differences between concentration of heavy metals at the inner part of the estuary (stations 1, 2, 3) with the outer part of the estuary (stations 4, 5, 6) [8]. The safety limit of consuming scallop was carried out according to the Provisional Tolerable Weekly Intake (PTWI) standard [9]. Environmental parameters measured in the present study were temperature, pH, salinity, transparency, current velocity and dissolved oxygen (DO).

| Station | Sampling position | Remark |
|---------|------------------|--------|
| 1       | 0°14′50.33″S    | 103°37′40.32″T | Mangrove area with little anthropogenic activities |
| 2       | 0°14′23.80″S    | 103°37′40.32″T | Residential area |
Seawater samples for analysis of heavy metals were collected from the surface, middle, and near the bottom at each sampling station which were then homogenized in 500 ml PE plastic bottles and then filtered using 0.45 µm Whatman filter paper. Samples were preserved with concentrated nitric acid (HNO₃) to obtain pH of ≤ 2 (1 ml per 500 ml sample), then placed into the cool box before being transferred to the laboratory for further analysis. Fifteen (15) individuals of the relatively same size of A. pleuronectes were collected from each station, put into labelled plastic bags and placed into a prepared cool box.

In the laboratory, the scallops were washed and its soft tissues were separated from the shell, and then dried in an oven at 80°C for 24 hours or until it reaches a constant weight, then cooled and weighed. As much as 1 g of each sample (from three individuals) was weighted digested in 10 ml of concentrated HNO₃ by putting them in hot plate at low temperatures (40°C) for 1 hour and continued at high temperatures (140°C) for ± 3 hours [10]. The samples were then cooled and added with double distilled water to the volume of 50 ml and filtered with 0.45 µm filter paper and ready for analysis of the metal concentrations (Pb, Cd, Cu and Zn) using AAS Shimadzu AA-7000.

3. Results and Discussion

Indragiri Hilir Regency is part of Riau Province which is located between 0°36'NL - 1°07'SL and 102°30' EL - 104°10 EL. The regency has an area of around 11,605.97 Km², the estuary of the Indragiri Hilir River is used by the surrounding communities as an area of boat transportation and fishing activities. The fishing community uses the estuary and its surroundings to catch fish and shellfish. This area is affected by tides that occur twice a day (semi diurnal). The results of measurements of water quality can be seen in Table 2.

Table 2. Measurement of water quality parameters

| Parameter       | Unit | Station 1 | Station 2 | Station 3 | Station 4 | Station 5 | Station 6 | Average | Standard*) |
|-----------------|------|-----------|-----------|-----------|-----------|-----------|-----------|---------|-------------|
| Temperature     | °C   | 31.6      | 30.1      | 30.4      | 31.5      | 31.5      | 30.4      | 30.9    | Dev. 3     |
| Transparency    | Cm   | 13        | 12.5      | 12.5      | 11.5      | 12.5      | 13        | 12.5    | -           |
| Current speed   | m/s  | 0.33      | 0.33      | 0.25      | 0.40      | 0.25      | 0.33      | 0.3     | -           |
| Salinity        | °/00 | 17        | 18        | 19        | 20        | 20        | 20        | 19.0    | -           |
| pH              |      | 7.45      | 7.45      | 7.45      | 7.65      | 7.65      | 7.65      | 7.65    | 7 – 8.5    |
| DO              | mg/l | 11.4      | 4.5       | 4.3       | 4.4       | 5         | 4.8       | 5.7     | > 5         |

*Standard of PP No. 82 - 2001

The results of water quality parameters measurement indicated that the waters of the Indragiri River estuary are still within the permissible limits in accordance with Kep. No. 51/MENKLH/2004 concerning Sea Water Quality Standards (Attachment III: Quality Standards for Marine Biota) except DO which is 0.2 smaller than permissible permits Kep. No. 51/MENKLH/2004, at stations 2, 3, 4 and 6.
### 3.1 Concentration of Pb, Cd, Cu and Zn in Sea Water

The concentrations of Pb, Cd, Cu and Zn in sea water at each station from the Indragiri River estuary vary as seen in Table 3. The highest Pb concentration was found at Station 2 (0.0884 mg/L) while the lowest was found at Station 6 (0.0687 mg/L). This is presumably caused by Pb contamination from various activities that occur in the nearby densely populated residential area and water transportation and fishing boat activities that produces a lot of wastes. Activities in coconut processing industry and other anthropogenic activities might contribution to additional wastes in the waters, compared to station VI which is located far from anthropogenic activities. It was stated by Kinnear and Gray [11] that lead (Pb) contained in nature can enter the waters through deposition and dropping of dust containing Pb derived from burning leaded petrol, erosion, and industrial waste. Soluble metal cations are deposited by anions such as sulfate, chloride, fluoride, bicarbonate or carbonate in seawater.

At station 1 Cd was the highest concentrations found while in station 4 the highest concentration was Cu and Zn. High concentration of Cd in station 1, presumably because of anthropogenic activity in the upstream of Indragiri river that contributes wastes such as from coconut processing industry and coconut plantation areas which generally use fertilizers and pesticides. Other sources might come from fishing boats which are generally coated with paint to protect the corrosion process. The high concentration of heavy metals at station 4 for Cu and Zn is suspected the nature of Cu and Zn which is easily bound by particles of other compounds, both in the form of organic matter. At station IV, which is a shipping lane, it is also assumed that the wastes originating from the waters around the Singkep islands and Jambi coast carried by boat and ships passing through Berhala Strait. Darmono [12] stated that sources of Cu and Zn were generally divided into: 1) naturally derived from lava rock and mud, (2) derived from human activities such as: electrode production, chemical batteries, and also in metal mining wastewater and iron steel industry. Zinc is also used in the production of paints, ceramic materials, glass, lamps, pesticides and fertilizers.

| Station | Pb       | Cd       | Cu       | Zn       |
|---------|----------|----------|----------|----------|
| 1       | 0.0697 ± 0.0018 | 0.0047 ± 0.0002 | 0.0321 ± 0.0003 | 0.1809 ± 0.0007 |
| 2       | 0.0884 ± 0.0018 | 0.0029 ± 0.0005 | 0.0310 ± 0.0095 | 0.1978 ± 0.0011 |
| 3       | 0.0739 ± 0.0018 | 0.0045 ± 0.0000 | 0.0290 ± 0.0082 | 0.1353 ± 0.0039 |
| 4       | 0.0697 ± 0.0018 | 0.0042 ± 0.0006 | 0.0328 ± 0.0000 | 0.2422 ± 0.0001 |
| 5       | 0.0759 ± 0.0018 | 0.0031 ± 0.0005 | 0.0300 ± 0.0072 | 0.1483 ± 0.0011 |
| 6       | 0.0687 ± 0.0000 | 0.0033 ± 0.0009 | 0.0265 ± 0.0071 | 0.1518 ± 0.0010 |
| Average | 0.0744 ± 0.0015 | 0.0038 ± 0.0004 | 0.0302 ± 0.0054 | 0.1761 ± 0.0013 |
Figure 2. Concentration of Pb, Cd, Cu and Zn in water (A) and scallop (B) in inner part (blue) and outer part (orange) of the Indragiri River estuary.

Figure 2 showed metal concentrations in the inner part (station 1, 2 and 3) and outer part of the estuary (station 4, 5 and 6). The highest average metal concentration in water in each region is Zn and the lowest concentration is Cd. The statistical analysis results showed that Pb, Cd, Cu, and Zn between regions in inner part of estuary (stations 1, 2, 3) and outer part of estuary (stations 4, 5, 6) were not significantly different (p > 0.05). This was suspected because the source of wastes from upstream to downstream comes from the same source, namely from domestic activities, coconut processing industry, transportation facilities, fishing boat/ports, so that it is suspected that the metal containing wastes were accumulated at the bottom of the Indragiri River estuary.

3.2 Concentration of Pb, Cd, Cu and Zn in scallop (A. pleuronectes)

The concentrations of Pb, Cd, Cu and Zn in scallops (A. pleuronectes) at each station is presented in Table 4 and Figure 3. Table 4 showed that the highest concentrations of Pb and Zn were found in Station IV. This station is affected by tidal cycle where metal accumulation can be easily deposited in the sediment where scallop and other bivalve lived. At this area there are also many boats/ships passing through that carry oil reserves for refueling fishermen boats in this region. The complex activities that occur in the surrounding Indragiri River estuary is suspected to result in the entry of pollutants such as heavy metals [2] to this area.

The highest Cd and Cu concentration in scallop was found at station I, this is presumably due to accumulation process through food chain occurs when those organism filtered the water and particles containing heavy metals which originating from various anthropogenic activities occurred along the upstream area of Indragiri river. Those activities include coconut plantations which generally use fertilizers and pesticides, as well as waste disposal from domestic activities in the upstream part which takes place continuously. So that when plankton being filtered by scallop (as a filter feeder), it also accumulates metal particles in their body as mentioned by Connell and Miller [13].

| Station | Mean concentration ± Std. Dev. (µg/g) |
|---------|-------------------------------------|
| Pb      | Cd        | Cu        | Zn        |
| 1       | 0.1800 ± 0.0000 | 0.7100 ± 0.0300 | 9.0550 ± 0.0705 | 39.9417 ± 0.1075 |
| 2       | 0.3000 ± 0.2078 | 0.4983 ± 0.0076 | 7.6400 ± 0.0173 | 44.2267 ± 0.0275 |
| 3       | 0.1800 ± 0.0000 | 0.4850 ± 0.0250 | 8.1633 ± 0.0431 | 41.5833 ± 0.0775 |
| 4       | 0.4800 ± 0.3747 | 0.5267 ± 0.0225 | 7.7517 ± 0.0144 | 46.5233 ± 0.2475 |
| 5       | 0.3600 ± 0.0000 | 0.5333 ± 0.0076 | 6.8583 ± 0.0437 | 42.7983 ± 0.1950 |
### 3.3 Relationships between Pb, Cd, Cu, and Zn in sea water and scallop (*A. pleuronectes*)

The results of simple linear regression test on the relationship between metal concentration in sea water and scallop from Indragiri River estuary showed positive relationships for Cd, Cu, and Zn, whereas Pb showed negative relationship as seen in Figure 3. Concentration of heavy metals in sea water varies depending on type and amount of waste disposal, the level of waste treatment and season [2]. High concentration of heavy metals in water will usually be followed by an increase in heavy metals concentration in the body of the biota. Therefore, polluted water will caused an increasing metal concentration in biota living in the environment including scallop which are sessile animals which take their food by filtering particles, organic matter and living things that are suspended in water. From the results of the study it can be seen that the relationship between metal concentration in sea water and the scallop in Indragiri River estuary shows positive relationship for Cd, Cu, and Zn, but negative relationship for Pb. Both relationships were considered as weak correlation (r <0.05) for Pb, Cd, Cu and moderate relationship (r = 0.65) for Zn.

![Figure 3](image)

**Figure 3.** Relationship between heavy metal concentrations in sea water with scallop

### 3.4 Safety limit for human consumption

Scallop (*A. pleuronectes*) is consumed by many people not only around Indragiri River estuary but also in other parts of the world. Calculation was conducted to determine the safe limit for consumption of scallop from the Indragiri River estuary by referring to PTWI (Provisional Tolerable Weekly Intake). The standard value of Pb is 0.025 mg/kg body weight per week, Cd is 0.007 mg/kg body weight per week, Cu is 3.5 mg/kg body weight per week, and Zn is 7 mg/kg body weight per week. The calculation of safe consumption limits was based on conversion suggested by Thomson [14] with a ratio of 1: 4. The result of the calculations is shown in Table 5.
Table 5. Safety limits for consumption of scallops (*A. pleuronectes*) in the Indragiri River estuary

| Metal | Conc. in w.w (µg/g) | PTWI for 70 kg b.w (µg/kg) | Safety limit (kg/week) |
|-------|---------------------|-----------------------------|------------------------|
| Pb    | 0.0775              | 1.750                       | 22.5806                |
| Cd    | 0.1325              | 490.000                     | 3.6981                 |
| Cu    | 1.9667              | 245.000                     | 124.5719               |
| Zn    | 10.7767             | 490.000                     | 45.4683                |

Based on the calculation of safe limits for human consumption, it can be seen that the safe limit for consumption of scallop from Indragiri River estuary based on Pb is 22.5806 kg/week, Cd 3.6981 kg/week, Cu 124.5719 kg/week, and Zn 45.4683 kg/week for 70 kg of adult body weight. Although it can be said that it is still safe, supervision in the consumption of scallop from Indragiri river estuary needs to get attention and not to exceed the permitted limit.

4. Conclusions

Water quality parameters around Indragiri River estuary are still in the range of tolerable level for the life of aquatic organisms. Concentration of Cu and Zn in scallop was higher than that of Pb and Cd. The highest and lowest concentrations of Pb, Cd, Cu, and Zn in sea water and scallop between stations vary, but in general the highest concentration of metals found is at around residential areas. Based on PTWI calculations, consumption of scallop (*A. pleuronectes*) from Indragiri River estuary is still safe and feasible since its not exceeding the prescribed safe limits. Further research is needed to have better understanding on the exact sources of the metals in this area. Continuous monitoring is also needed to maintain the environmental sustainability of natural resources in the Indragiri River estuary.

Acknowledgements

The authors express their gratitude to all those who contributes helps in collecting and analyzing the samples in this study as well as to the anonymous reviewers for their thoughtful comments.

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