Bio-concentration factors of copper (Cu) and lead (Pb) in seagrass and some fish from coast Batam, Riau Islands, Indonesia

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Abstract. Heavy metals pollution in aquatic environment has a significant adverse effect for biota especially invertebrates, fishes and also humans. Lead is toxic even at low concentration, whereas copper toxicity requires high concentration. The bioconcentration factors (BCFs) of heavy metals in seagrass and some fishes from coast Batam, Riau Islands, Indonesia were studied. Tissues from Enhallus accoroides, Siganus sp, Sphyraena sp, Caesionidae sp and Chaetodontidae sp were collected from six locations and the bioconcentration factors separately determined. The concentration of Cu in samples still meets with the permissible limit. However the concentration of Pb in four species of fishes were exceed the permissible limit. The BCFs study revealed the ability of fishes and seagrass to accumulate Cu and Pb. Level of Cu in seagrass tissues obtained higher than Pb. As demonstrated in BCFs study, the accumulation of Cu in fish was decreasing as follows: Siganus sp>Sphyraena sp>Chaetodonidae sp>Chaesionidae sp. The accumulation of Pb in fish was decreasing respectively as follow: Sphyraena sp>Chaetodontidae sp>Siganus sp> Chaesionidae sp.

1. Introduction
The coasts Batam, Riau Islands as one of the busiest area in South East Asia have been received waste discharges from two sources, land and sea as well as natural and anthropogenic sources. Various human activities, shipping activities, and industries potentially contain hazardous substances which are harmful to both human health and marine ecosystem. Heavy metals are the most important pollutants which cause considerable harm to environment when they exceed certain concentrations [1]. The contamination of the aquatic system with heavy metals from natural and anthropogenic sources has become a global problem which poses threats to ecosystems and natural communities [2,3].

Heavy metals are deemed serious pollutants due to their toxicity, persistence [1], and non-biodegradable in the environment [4,5]. In another side, heavy metals taken up by marine organisms can move to the higher trophic levels and enter the human food chain through the contamination seafood [6]. According to [2], the increasing pollution by heavy metals has a significant health effects to invertebrates, fishes, and humans. Fishes can accumulate heavy metal in their body through absorption while the humans can be exposed to heavy metals through their meal [7]. Exposure of heavy metals has liked to several human diseases such as development retardation or malformation, kidney damage, cancer, abortion, effect on intelligence and behavior, and event death [5].

Heavy metals such as lead (Pb), copper (Cu) and cadmium (Cd) are of interest because of their toxicity. Cadmium and lead are toxic at low level, whereas copper is toxic at high concentration [6]. The increasing of activity around coast Batam by shipyard industries and transportations has an impact to level of cadmium, copper and lead in water, sediment, angel fish [7] and seagrass [8].

Metal accumulation is a tool to identify the impact of heavy metals in aquatic ecosystems because it shows the adverse of effect on the organism [7]. The metals are separated into two categories: essential and non-essential. The essential elements such as Fe, Cu, Zn and Mn have defined biological
functions in organism whereas non-essential element such as Pb, Cd, Cr, As, and Hg are not involved in any metabolic mechanism [9].

Levels of heavy metals in biota are fluctuating, influenced by age, size, level of trophic, species, and feeding behavior [10]. Seagrass and fish are good accumulators of heavy metals. In another side, fish have good of nutritive and economical values [11] so that the consumers may be exposed to heavy metal toxicity if bioaccumulation results due to regular consumption [12]. Despite the many studies carried out in heavy metals, scanty information is available on the bioconcentration factors of heavy metals in biota from coast Batam. Consequently, the current work was carried out to determine the BCF values of seagrass (E. accoroides) and some fishes species from coast Batam in order to know whether or not the metals are bio-accumulated in the tissues of the seagrass and fishes so as to protect the consumers from exposure to the heavy metal toxicity as a result of regular consumption.

2. Materials and Methods

2.1 Sampling method

The fresh fish samples were collected from 6 sites (Tanjung Pinggir, Sekupang, Tanjung Riau, Marina Beach, Tanjung Uncang and Sagulung) distributed along the west side of coast Batam (See Table 1). The fish samples (Table 1) were collected by using traps that were planted in the sea bottom. The fishes were kept in an ice box and then transported to the laboratory until dissection took place. The water samples were collected from the bottom water (depth 2-2.5m). Samples were collected from the marine used Van Dorn horizontal water sampler into polyethylene bottles and transported to laboratory. 20-25 specimens of seagrass were collected from each location. The seagrass removed from the seawater, washed with tap water, kept in a plastic bag, and transported to the laboratory.

Table 1. Seagrass and fish species collected from the sampling sites

| Sampling sites   | E. accoroides | Siganus sp | Sphyraena sp | Chaesionidae sp | Chaetodontidae sp |
|------------------|---------------|------------|--------------|-----------------|-------------------|
| Tanj. Pinggir    | +             | +          | +            | -               | +                 |
| Sekupang port    | +             | +          | +            | +               | -                 |
| Tanj. Riau       | +             | +          | +            | -               | +                 |
| Marina Beach     | +             | +          | +            | +               | +                 |
| Tanj. Uncang     | +             | +          | +            | +               | +                 |
| Sagulung         | +             | +          | +            | +               | -                 |

Figure 1. Sampling location
a. Sample treatment
Water samples were acidified with nitric acid until pH 2 then filtered with Whatman filter paper. The filtrate collected into 50 ml volume and ready to be analyzed using atomic absorption spectrophotometer.

The fish meat samples were separated using Dolphin surgical equipment. Seagrass and fish samples were dried using an oven Kirrin model KBO-250 RA at 105°C until constant weight. Five grams of the smooth samples was added 5 ml of nitric acid and heated for 30 minutes or until a clear liquid was obtained. The mixture was filtered using Whatman filter paper. The filtrate obtained then added aquadest up to 50 ml volume and ready to be analyzed.

2.2 Heavy metals analysis
The determination of copper and lead were performed as describe by [7].

2.3 Data analysis
Bioconcentration factors were analyzed based on metal concentration in water and on tissues of seagrass and fish. BCF analysis performed to determine the accumulated level of Cu and Pb in seagrass and fish tissues. BCF of heavy metals in the samples calculated as [9]:

\[ BCF = \frac{C_{\text{biota}}}{C_{\text{ambient medium}}} \]

Where \( C_{\text{biota}} \) is the heavy metals concentration in the biota and \( C_{\text{ambient medium}} \) for fish is the heavy metals concentration in water while for seagrass is both of heavy metals concentration in water and sediment.

3. Result and Discussion
3.1 Distribution of heavy metals
The result of distribution of heavy metals and the permission standard guidelines are shown in Table 2. In this study, the level of heavy metals varied in all different components. Level of Cu and Pb in sediment obtained greater than their level in seawater. The level of metals in sediments in the coastal area can be elevated due to high inputs from natural as well as anthropogenic sources [13]. Heavy metals have a high tendency to bind to suspended matter and through sedimentation. According to [4], the metal content of sediment was controlled by organic matter and Fe contents. It was supported by a factor of activity degree (pH) that was alkaline and normal temperature range resulted in insoluble Pb and deposited on sediments [14]. Sediments can act as source and sink for nutrients and heavy metals depending upon the physicochemical condition. Hence, sediments are potential secondary sources of contaminants in aquatic ecosystems [15]. The present study found that the levels of Cu and Pb in sediments still meet the level of heavy metals in USEPA standard for a category not polluted. However, levels of Cu and Pb in seawater have exceeded the permissible limit set by Indonesia Ministry of Environment.

Based on this study, the level of Cu and Pb in seagrass obtained greater than fish samples. The levels of Pb in seagrass was exceeded the permissible limit for food and seafood specified in SNI 7378, 2009 and FAO standard’s 2003. However, the content of Cu still meets the FAO’s standard that is 30 mg/kg. In addition, the level of Cu in all species of fishes ranged from 0.225 to 1.4033 mg/kg. The highest level of Cu in fish samples was found in Sphyraena sp. However, this value still meets the standard of FAO. Lead is the second element (after arsen) of top 20 list of the most poisoning heavy metals [1]. The levels of Pb in all species of fish have exceeded the permissible limit in SNI 7378, 2009 and FAO, 2003. It was ranged from 1.6325 to 3.1075 mg/kg. The highest level of Pb obtained for Siganus sp. Thus, it is revealed that there is a potential high risk to health if the peoples consume the fishes caught in this area.
Table 2. Concentration of heavy metals in seawater, sediment, seagrass and fish collected from coast Batam, Indonesia

| Samples   | Heavy metals (mg/kg) | Reference |
|-----------|----------------------|-----------|
|           | Cu                   | Pb        |
| Seawater  | Mean 0.0423          | 0.0403    |
|           | Sd 0.0032            | 0.0040    |
| Sediment  | Mean 11.5472         | 12.9592   |
|           | Sd 10.6384           | 5.1429    |
| *E. accoroides* | Mean 24.8983     | 10.7333   |
|           | Sd 12.8629           | 4.3628    |
| *Siganus sp* | Mean 0.3950       | 3.1075    |
|           | Sd 0.2040            | 1.6099    |
| *Sphyraena sp* | Mean 1.4033      | 1.6950    |
|           | Sd 1.7579            | 0.7991    |
| *Caesionidae sp* | Mean 0.2250    | 1.6325    |
|           | Sd 0.2899            | 0.7275    |
| *Chaetodontidae sp* | Mean 0.5800    | 1.6700    |
|           | Sd 0.3869            | 0.8242    |
| Permission limit in food and seafood in Indonesia (SNI 7378, 2009) | - | 0.3 | [8] |
| Permission standard limit in food (FAO, 2003) | 30 | 0.5 | [16] |
| Permission limit in seawater (Indonesia Ministry of Environment No. 5, 2004) | 0.008 | 0.008 | [7] |
| Standard Quality Sediment (USEPA) | 25 | 30.2 | [4] |

replication (n) = 6

3.2 Bioconcentration factor (BCF) of heavy metals in seagrass and fish

In the present study, BCF_{b/w} refers to the ratio of the heavy metals concentration in biota and seawater, while the BCF_{b/s} refers to the ratio of the heavy metals concentration in biota and sediment. Bioconcentration is the accumulation of the contaminant by aquatic organisms through non-dietary uptake routes, e.g., from the soluble phase [17]. The results of BCF from the present investigation are shown in Table 3.

Table 3. The BCF values of the heavy metals of fishes and seagrass from coast Batam, Indonesia

| Samples   | BCF_{b/w} | BCF_{b/s} | BCF range | Category BCF^a |
|-----------|-----------|-----------|-----------|----------------|
|           | Cu        | Pb        |           |                |
| *Siganus sp* | 9.33      | 77.10     | >1000     | Very high      |
| *Sphyraena sp* | 33.17     | 42.06     | 100-1000  | High           |
| *Caesionidae sp* | 5.32     | 40.51     | 30-100    | Moderate       |
| *Chaetodontidae sp* | 13.71    | 41.44     | <30       | Low            |
| *E. accoroides* | 588.61    | 266.34    | 2.16 0.82 |                |

^aPotipat et al., 2015

Level of heavy metals in fish closely related to the disposal waste near the fish live. Intake heavy metals by fish depending on ecological requirements, metabolisms, and other factors such as salinity, water pollution level, food and sediment [18]. According to [19], accumulation rate of heavy metals in fishes depends on the characteristic of chemical compounds, concentration and species of fish. The *Siganus sp*, *Sphyraena sp*, *Caesionidae sp* and *Chaetodontidae sp* were chosen because of their abundance in the sampling area and represented for calculation of the BCFs. If the values of BCF greater than 1.00 it is indicated that the metals were highly bio-accumulated and bio-magnified [12]. From this investigation, all species of fishes obtained in the moderate categories for Pb, and low categories for Cu, except *Sphyraena sp* in moderate category.
The result of BCF_{bw} and BCF_{bs} showed the ability of \textit{E.accoroides} to accumulate heavy metals. This study found that \textit{E.accoroides} is at high BCF category for Cu and Pb in water, but low BCF category for Cu and Pb in sediment. It is revealed that \textit{E.accoroides} is a good accumulator for Cu and Pb from seawater. The BCF value for Cu obtained higher than Pb. Copper is the essential element of some enzymes for organisms [20] and serve as micronutrients for cellular metabolism [8]. According to [20], the great level of Cu intake via seafood consumption can cause adverse health problems such as liver and kidney damage, but not carcinogenic to humans and animals.

4. Conclusion
The result of this study found that the distribution of the essential element (Cu) in seawater, sediment and fishes from coast Batam, Riau Islands, Indonesia lower than the non-essential element (Pb), except seagrass (\textit{E.accoroides}). The BCF obtained for Cu and Pb were higher than 1.00 revealed that the Cu and Pb were highly bio-accumulated and bio-magnified in the tissue of fishes and seagrass. Cu has higher BCF than Pb in \textit{E.accoroides}. In another side, the BCFs of Cu in all of the fish species were lower than Pb. The accumulation of Cu in fish was decreasing as follows: \textit{Siganus sp}>\textit{Sphyraena sp}>\textit{Chaetodontidae sp}>\textit{Chaesionidae sp} as demonstrated in the BCF study. The accumulation of Pb in fish was decreasing respectively as follows: \textit{Sphyraena sp}>\textit{Chaetodontidae sp}>\textit{Siganus sp}>\textit{Chaesionidae sp}.

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