Bioaccumulation and translocation of chromium on crabs and mangroves in Mati River estuary, Bali, Indonesia

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Abstract. Conditions of waters and sediments of the Mati River estuary which is contaminated by chromium (Cr) raise questions about the condition of living biota. Mangroves and crabs as dominant organisms are generally appropriate indicators for analyzing the bioaccumulation of Cr in Mati River estuary. This study aimed to analyze content, bioaccumulation and translocation of Cr in mangroves and crabs in Mati River estuary. Cr content was analyzed by Inductively Coupled Plasma Emission (ICPE) method. Measurement of Cr on mangroves was done in roots, leaves, and litter, whereas in crabs were done on muscles and gills. The results showed that Cr was higher in mangroves than in crabs, presumably because of the ability of mangroves to absorb heavy metals in sediments. There was a variation of Cr in mangroves part, consecutive from the highest to the lowest content in the litter, leaf, and root. The highest Cr concentration in litter was suspected because one of the mangrove adaptations is to expend heavy metals from itself. The accumulation of Cr on mangroves was much higher than in crabs because the mangrove interacts directly with sediment which is the main source of Cr. The translocation factor of Cr on mangroves and crabs was very effective between body parts.
Key Words: heavy metal, body part, organism, depuration, effective.

Introduction. Heavy metal chromium (Cr) is the 17th highest heavy metal abundance in the earth crust (Avudainayagam et al 2003) and has the 7th highest abundance in the world (Nriagu & Pacyna 1988). Cr is one of the metals that have toxic properties in plants (Shanker et al 2005) and animals (Velma et al 2009). When Cr enters the body of aquatic organisms, will disrupt the enzyme's work and accumulate for a period of time until the organism dies (Aslam & Yosafzai 2017). In addition, Cr can be deposited through the food chain and when settled on the body parts of living organisms, it can be toxic (Mulyani 2004). Furthermore, Biachi et al (1983) also explained that in the long term, Cr can cause the damage of DNA structure until mutations occur. It also carcinogen (cancer-causing), teratogen (inhibits fetal growth) and mutagen (Schiavon et al 2008).

Cr pollution increases every year (Babula et al 2008). This contamination is due to the high use of Cr for tanning processes (Mwegoha & Lema 2016), water corrosion inhibitors, and dyes in the textile and ceramic industries (Avudainayagam et al 2003). According to Pratiwi (2010) Cr waste in the textile industry was generated on the activities of starching, cooking, coloring, printing and finishing process. Those produced will be higher when the human activities increase (Aminiyan et al 2016).

The Mati River is one of the rivers in Bali, Indonesia with heavy polluted condition (Arida 2008) where textile and screen printing industry in the River Basin develops. Waste from the textile and screen printing industries increases the heavy metal content including Cr that goes into waters and sediments (Kant 2012). The results of research conducted by Dirgayusa et al (2017) indicated that Cr content in the waters and sediments in the Mati River estuary exceeded the threshold set by the Indonesian government. That high content, directly or indirectly, will affect the Cr content in biota that living in the estuary of Mati River estuary such as mangroves and crabs.

Ecologically, one of the mangroves functions is as absorber of heavy metal pollution (Dudani et al 2017). Previous research showed that species in mangrove ecosystems such as the *Avicennia marina* had the ability to absorb Cr from their habitat (Kannan et al 2016; Suwandewi et al 2013). The presence of high Cr content in sediment and water will cause high absorption of Cr by mangrove. Mangroves have the ability to accumulate metals in their bodies especially in parts of roots, leaves and stems (Kannan et al 2016). The heavy metal content in the organism can move through the food chain process (Zhuang et al 2009). Along with the food chain, Cr which is absorbed by mangroves will move to other biota that use mangrove as a food source, such as crabs that consumes litter of mangroves that fall into the sediment. When consuming litter, not only the nutrients contained in the litter will enter and be absorbed by the crab body, but all other contents contained in the litter including Cr. The aimed of this research were to analyze content, bioaccumulation and translocation of Cr in mangrove and crabs in Mati River estuary.

Material and Method

Study sites. This study was conducted from June to August 2016 in Mati River estuary, Bali, Indonesia. This location is close to Ngurah Rai International Airpot and part of Ngurah Rai Forest Park area (Tahura Ngurah Rai). This location is also used for ecotourism and crab cultivation. The location of the study and the distribution of sampling points (Figure 1) are arranged by dividing as follows: 5 mangrove and crab sampling points in left side estuary and 5 point sampling in the right side.

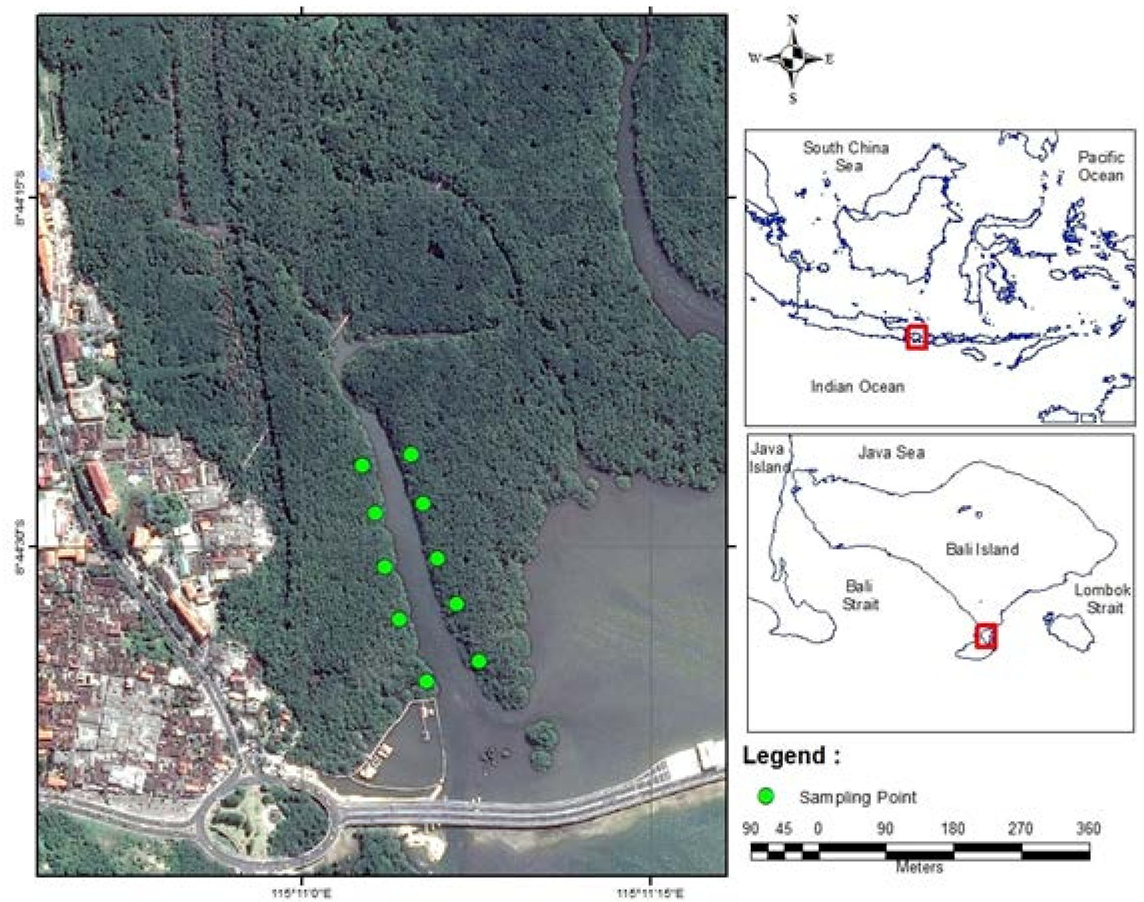

Figure 1. Mangroves and crabs sampling locations.

Crabs and mangroves samples collection. Mangroves sampling was done during low tide condition to facilitate the sampling process. Part of mangroves which was used in this research was litters, leaves and roots. The mangrove samples were taken directly by a using cutting tool (each around 100 g). Samples obtained were inserted into a plastic bag and stored in cool box. The mangroves as object were a tree at breast height. Crabs samples in this research were crabs that live in the mangrove location. Crabs were captured using traditional trap. Traps were installed during low tide conditions and left for 24 hours. The sampled crab characteristics: no defects and weight range between 75-100 g (consumption size). Gills and muscle of crabs were taken to measure Cr content.

Measurement of Cr. Each sample of crabs and mangroves from the field was weighed, then dried in oven and weighed again to find dry samples (ranging from 5 g). The samples were then processed using wet destruction igestion following Kapungwe (2013). Wet destruction was done by adding 25 mL of HNO_3 to 1 g of dried sample. The mixture was then heated at 100^{o}C, and then cooled. The cold mixture was added with 10 mL of distilled water and 10 mL of $HClO_3$ and reheated until the mixture was clear. Sample preparation follows APHA (2012). Chromium content measurement was performed using Inductively Coupled Plasma Emission (ICPE) 9000 Spectroscopy (detection limit 0.001) and results were expressed in mg kg^{-1}.

Analysis. Bioaccumulation determination based on Bioaccumulation Concentration Factor (BCF) is the ratio of Cr in organisms (C_o) and sediments (C_s) (Gobas 1993):

$$BCF = C_o/C_s$$

C_s in this study was taken from Dirgayusa et al (2017). Translocation Factor (TF) value was performed to determine the ability of plants to transect metal from roots to all parts of the plants (MacFarlane et al 2007). TF is determined according to Nugrahanto et al (2014):

$$TF = \frac{Cr\ in\ leaf}{Cr\ in\ root} \qquad TF = \frac{Cr\ in\ litter}{Cr\ in\ leaf}$$

$$TF = \frac{Cr\ in\ gill}{Cr\ in\ litter} \qquad TF = \frac{Cr\ in\ meat}{Cr\ in\ gill}$$

Results and Discussion. Cr measurements on crabs and mangroves showed varied result. Cr content in crabs ranged from undetectable to 9.12 mg kg^{-1}, whereas in mangroves from 7.42 to 20.88 mg kg^{-1}. The results showed that the average Cr content in mangroves was higher than in crabs (Figure 2). This is may be due to differences in the ability of mangroves to absorb heavy metals in sediments. According to Heriyanto & Subiandono (2011) and Purwiyanto (2012) some types of mangrove have better ability to absorb heavy metals such as *Rhizophora apiculata*, *Avicennia marina*, and *Ceriops tagal*. *A. marina* is an example of mangrove species that very difficult to absorb lead (Pb) (Macfarlane & Burchett 2001), even in some cases it is not absorbing at all (Baker 1981). Higher content of Cr in mangroves than crabs were also suspected due to the high concentration of Cr in sediment, according to Dirgayusa et al (2017). Cr content in Mati River estuary sediment was 34.9 mg kg^{-1}. In addition, the low Cr content in crabs was thought to be due to the depuration process in metabolism.

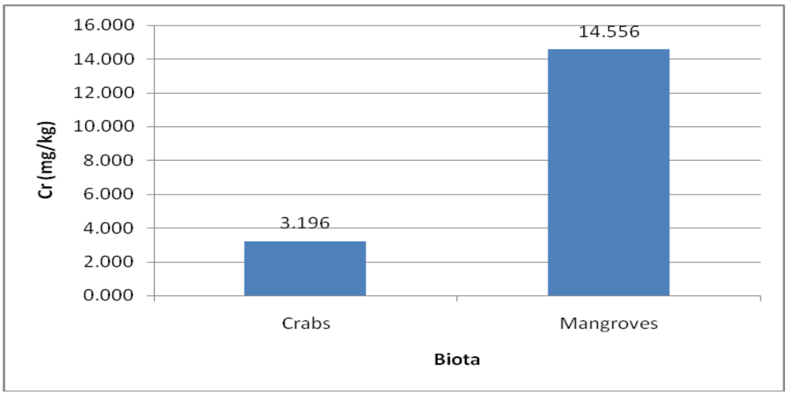

Figure 2. Cr content in biota at Mati River estuary.

Cr content in roots, leaves and litter ranged from <0.001-22.16 mg kg^{-1}, <0.001-25.07 mg kg^{-1}, and <0.001-31.61 mg kg^{-1} respectively. The average Cr content on each mangroves part shows that the root has the lowest content, followed by leaf and litter having the highest content (Figure 3 left panel).

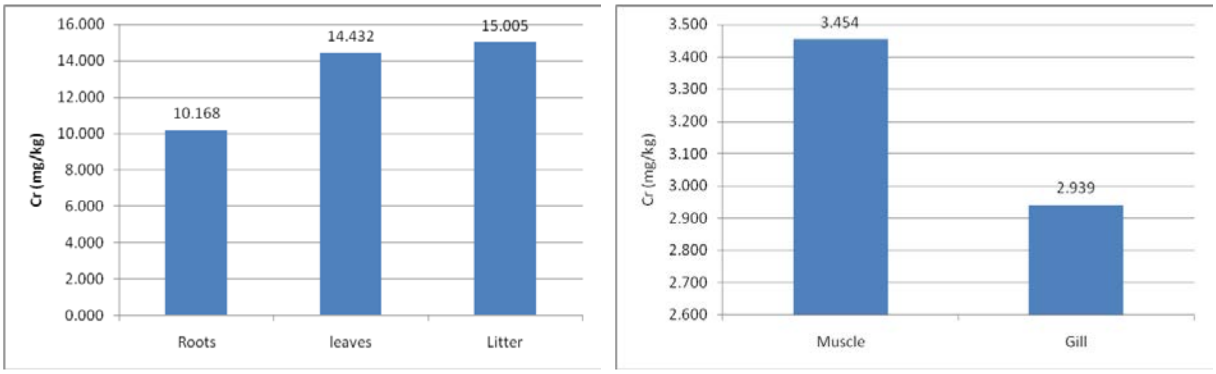

Figure 3. Cr content mangrove (left panel) and crab (right panel) body part.

According to Kartikasari et al (2002) the difference of Cr content on mangroves parts is related to the process of plant physiology. Similar result was also found in the measurement of Cadmium (Cd) in Gujarat-India where the highest concentration was found in leaves (Kumar et al 2011). Furthermore, according to Hamzah & Setiawan (2010) the high concentration of heavy metals in leaves compared to roots is suspected by the high heavy metal mobility rate. However, those results were in contrast with Einollahipeer et al (2013) in the Persian Gulf and Yim & Tam (1999) who find the highest concentration of heavy metals (Cu, Ni, Pb and Zn) in the roots. Continuous filtration and accumulation for long periods of time of heavy metals in sediment leads to the highest concentration in the roots (Abohassan 2013). The highest Cr content in the litter was suspected as one form of mangrove adaptation to expend heavy metals that enter into the body, just as the mechanism of excess salt that enters the mangrove body. Pinheiro et al (2012) also found the highest Cr concentration in *Rhizophora mangle* obtained on old leaves that almost fall. The heavy metal excretion entering the plant body passively through the accumulation in old leaves followed by leaf dropping (Wen-Jiao et al 1997). Overall, the results of the Cr content of the present study (Mati River Estuary) were higher than those obtained by Kartikasari (2002) in the Babon River, East Java Island at the upper roots, lower roots and leaves of 0.38, 0.80 and 5.96 mg kg^{-1} respectively.

Cr content in crab gills ranged from <0.001 to 9.12 mg kg^{-1}, whereas in the muscle ranged from <0.001 to 8.50 mg kg^{-1}. The average Cr content in muscle was higher than in gills (Figure 3 right panel). This was possibl due to the function of gills as water filter which cause high frequency of water-gill interaction and leads to a depuration process. The results of this study are inversely proportional to those obtained in *Scylla serrata* in Chennai Southeast Coast of India (Batvari et al 2012; Vasanthi et al 2014). Cr content in crabs at Mati River showed an average of 3.20 mg kg^{-1}, this content exceeds the standards required by Ministry of Health of the People's Republic of China GB 2762-2012 which only permits a maximum limit for Cr content of aquatic animals of 2 mg kg^{-1}.

Bioacumulation of Cr. Cr content of mangrove sediments at Mati River estuary was found to be 34.97 mg kg^{-1} (Dirgayusa et al 2017). Calculations of bioaccumulation through BCF show that BCF mangrove value was much higher than that of BCF crab (Figure 4a), this was supported by the high concentration of Cr in the mangroves. This can be explained by the fact that mangroves interact directly with the sediments that are the main source of Cr. BCF crabs were lower than mangroves suspected because of the ability of crab to excrete Cr that enters the body. Gundogdu et al (2011) and Vinodhini & Narayanan (2008) also explained that animals might be able to excrete accumulated metals through metabolic activity. Overall, the BCF value of mangroves in Mati River estuary is lower than that obtained by Hamzah & Setiawan (2010) on the leaves and roots of mangroves *Rhizophora mucronata*, *Sonneratia caseolaris* and *A. marina* for Zink (Zn) (0.72-1.53) and Pb (0.71-3.68). But it was smaller than values obtained by

MacFarlane et al (2007) for Pb in *A. marina*. The differences of material concentration and mangrove absorption ability are strongly suspected to be the main cause.

Translocation. The TF calculation results showed that the highest TF was obtained between roots and leaves (1.419) and the lowest TF between litter and gill (Figure 4 right panel). Baker & Brooks (1989) explained that TF>1 indicates that plants or animals are able to effectively translocate pollutants from one part of the body to another. The low TF between gill and litter is presumably due to the fact that gill function as a respirator, whereas litter is a natural food for crabs which resulting in many interactions in digestive and reproductive organs, as it was explained by Purwiyanto (2012) which found high correlation between Cu metal in *S. serrata* gonad with *Avicennia* sp old leaves in Tanjung Api-Api, South Sumatra.

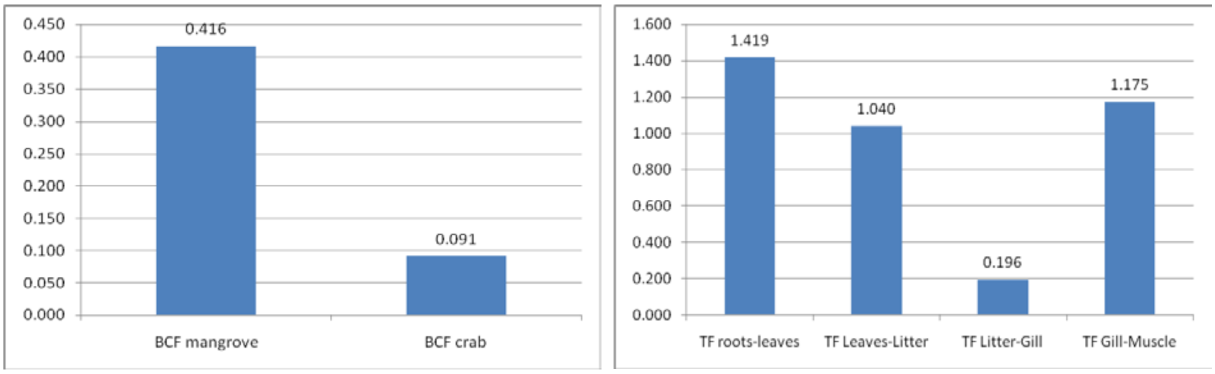

Figure 4. BCF (left panel) and TF (right Panel) organism in Mati River estuary.

Conclusions. This study has successfully showed that Cr content were higher in mangroves than crabs, with variation of Cr in mangroves body part (litter > leaf > root) and in the crabs (muscles > gills). The value of BCF on mangroves was higher than that of crabs and the TF of Cr on mangroves and crabs is very effective between the internal parts of the organism.

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