Mar. Res. Indonesia Vol. 39, No. 1, 2014: 31–37

BIOACCUMULATION OF CADMIUM (CD) BY WHITE SHRIMP *PENAEUS MERGUIENSIS* AT DIFFERENT SALINITY IN KEDUNGMALANG ESTUARY, JEPARA (CENTRAL JAVA)

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Received: April 2014 Accepted: May 2014

ABSTRACT

Estuarine of Kedungmalang has salinity variability and is assumed to bepolluted by cadmium (Cd) derived from human activities around Kedung region. In this study, bioaccumulation of Cd by white shrimp *Penaeus merguienis* in relation with salinity difference was determined. Sampling was conducted at four stations : estuary (15‰ and 25‰ of salinity) and husbandry area (15‰ and 25‰ of salinity). Data on *in situ* water quality parameters was obtained at each station. *Absorption Atomic Spectrometer* was used to measure Cd concentration. The water quality of parameters and the concentrations of Cd in the shrimp were compared with quality standards and weekly consumption limit of white shrimps is also suggested. The Cd concentrations on the white shrimp was found the highest concentration of 0.669 $\mu g.g^{-1}$. The limit comsumption of the white shrimp of Estuarine of Kedungmalang, suggested by the resut of this study, is about 523-1537 grams per week.

Keywords: *Cadmium (Cd), Kedungmalang estuary, salinity, Penaeus merguienis*

INTRODUCTION

The Kedungmalang Estuary water is derived from Serang River, along which there are industrial and residential areas. Anthropogenic activities along the river could be expected to contribute pollutants to the water, including Cadmium (Cd), which is one of the heavy metals with dangerous toxic effects even at at low doses (Yu, 2005).

Human activities that contribute to Cd pollution is the disposal waste from metal smelting industry, batteries, pigments, plastics, paints, fertilizers, petroleum refining (Hutagalung & Razak, 1982). The estuary is a place of final disposal of the waste of human activity and has become the most polluted waters (Hill, 2010)

Another specific trait of estuary is its salinity variability. At low salinity, level of the major salt ions decreases and it can lead to increase of free Cd cations (Cd^{2+}). The increase of free Cd^{2+} concentration in low-salinity waters can cause an increase in acute toxicity of Cd (McLusky & Elliot, 2004; Yu, 2010).

To estimate toxicological effects of some chemical pollutants in the environment, species representing the existing environment in the waters can be tested (Rainbow *et al.,* 2002). Advantages of using the white shrimp as a pollution bioindicator in the estuary are: 1) the white shrimp lives in the estuary with variabile salinity naturally; 2) it has high sensitivity to toxic materials and environmental changes that can detect pollutants in the environment even in small concentrations;

DOI : 10.14203/mri.v39i1.84

3) it can survive in polluted conditions without causing high mortality (Manullang, 2011).

In this study, bioaccumulation of cadmium (Cd) with different salinity in estuarine waters Kedungmalang, Jepara was determined.

MATERIALS AND METHODS

Research site

The study was conducted in April 2012 in Kedungmalang estuary,Two stations (Station 2 and Station 3) were located in the estuary and another two locations (Station 1 and Stations 4) were located in the shrimp husbandry. Figure 1 shows the sampling locations for this study.

Sampling

White shrimps *P. merguiensis* de Man were collected using nets at low tide. The mesh size of the nets was 0.5 cm. The shrimp were not differentiated by sex, in order to get a spreading picture of the actual of Cd concentration and were taken at random with the assumption that each experimental unit had the same opportunities (Latouche & Mix, 1982). Physical and chemical parameters of waters from four stations were measured by *in-situ* in bottom, middle and surface layer. The average of each stations is 1-2 meters. The salinity was measured by a refractometer, temperature using a thermometer, pH using a pH meter and measurement of oxygen levels with DO meter (UNEP, 2004).

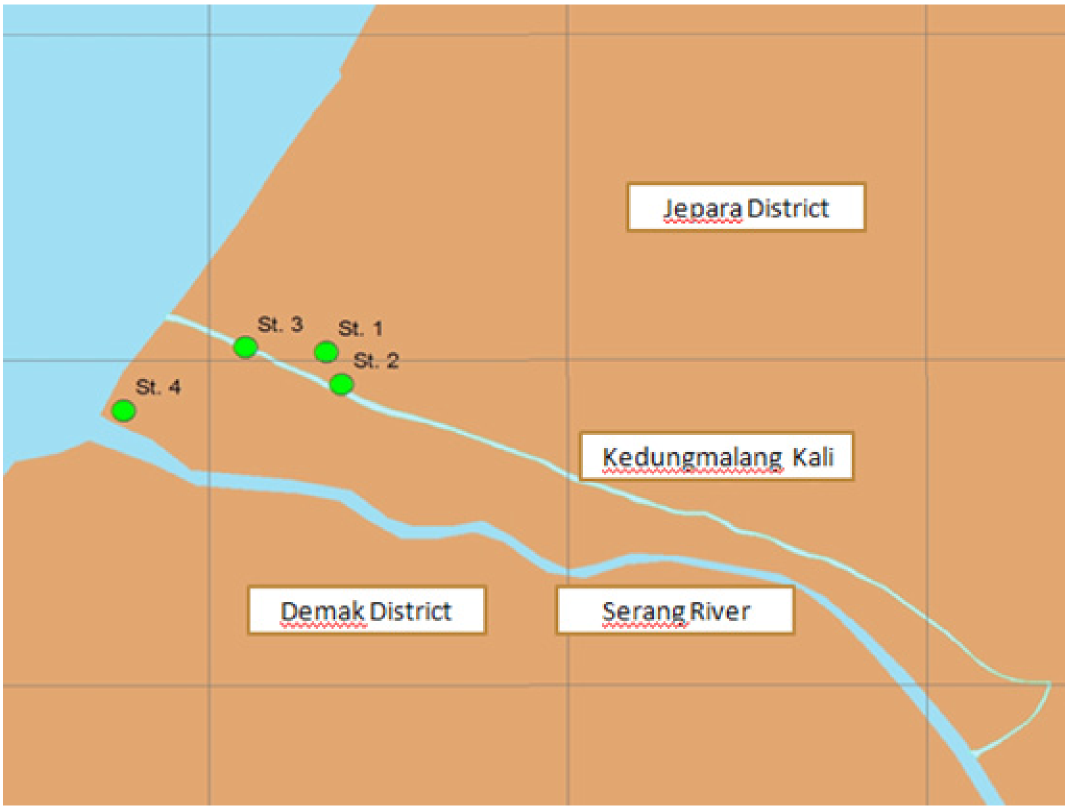

Figure 1. Site of sampling

Treatment in the laboratory

The samples were dried in an oven for ±3 days at 45^{0}C to obtain dry weight. The dried samples were then homogenized with a ceramic mortar. Then, the samples were mineralized to eliminate the biological material in the sample (Hédouin et al., 2009) by nitric acid (HNO_3) and sulphuric acid (H_2SO_4). Cd concentrations were measured by using Atomic Absorption Spectrometer (AAS) (PerkinElmer, 1996). The data were then analysed descriptively using Excel 2010 and were compared with quality standards.

RESULTS AND DISCUSSION

Physical and chemical parameters of waters

It is important to know the condition of physical and chemical parameters of waters because these parameters have an important role in the growth metabolism of shrimp and exert an influence on heavy metal solubility in water. McLusky and Elliott (2004) states that in addition to salinity, the solubility of heavy metals including Cd is also affected by several other chemical and physical parameters, such as temperature, pH and dissolved oxygen. Table 1 shows *in situ* physical and chemical parameters of waters at sampling stations.

The highest temperature was 31^{0}C and the lowest temperature was 29^{0}C. The highest level of dissolved oxygen in estuarine areas was at stations 2 (6.4 ppm), while the lowest was from station 1 (4.2 ppm). The highest pH value, 7.6, was detected at station 3 and the lowest, 5.2, was at station 1. According to Decree of Minister of Environment of Republic Indonesia No. 51 of 2004, the value of DO in both of husbandry area and estuary and the pH in station 2 had passed the quality standard.

Table 1. Physical and chemical parameters of waters

Station	Environmental Parameters	Resulf	Quality Standard
Station 1	Temperature (^{0}C)	29.0	natural [1(a)]
	Salinity (‰)	15	natural [1(b)]
	Dissolved oxygen (ppm)	**4.2**	>5
	pH	**5.2**	7 – 8.5[(c)]
Station 2	Temperature (^{0}C)	30.0	Natural[1(a)]
	Salinity (‰)	15	Natural[1(b)]
	Dissolved oxygen (ppm)	6.4	>5
	pH	7.0	7 - 8,5[(c)]
Station 3	Temperature (^{0}C)	30.5	Natural[1(a)]
	Salinity (‰)	25	Natural[1(b)]
	Dissolved oxygen (ppm)	6.2	>5
	pH	7.6	7 – 8.5[(c)]
Station 4	Temperature (^{0}C)	31.0	Natural[1(a)]
	Salinity (‰)	25	Natural[1(b)]
	Dissolved oxygen (ppm)	**4.9**	>5
	pH	7.3	7 – 8.5[(c)]

bold print: out of the normal limit of quality standard according to Decree of Minister of Environment of Republic Indonesia No. 51 of 2004.

Note :

1. Natural is the normal condition of the environment, vary over time (day, night, and, in season).

a. Allowed to change up to <2 ° C of the natural temperature

b. Allowed to change up to <5 ‰ salinity seasonal average

c. Allowed to change up to <0.2 pH units

The increase in temperature can increase the metabolism of aquatic biota and potentially increase the amount of heavy metal uptake into the body of aquatic organisms. On the basis of the results of heavy metal exposure of aquatic organisms with different temperatures, it has been reported that animal mortality increases with increasing temperature (McLusky and Elliott, 2004). Increased temperatures can also lower the body's resistance to toxins or foreign materials (Connell and Miller, 1995). In this study, water temperature was not so different among the sampling points. Waters of this temperature range is also still meet the normal limit for shrimp growth in the range 18 - 35^{0}C (Suyanto and Mujiman, 2003). White and Rainbow (1982) reported the laboratory studies of Cd exposure at different temperatures; the average rate of accumulation of Cd is 0.19 µg / day at a temperature of 10^{0}C and 0.52 µg/day at a temperature of 15^{0}C. This exposure was conducted using media of 50 µg.l^{-1}. In 1986, they continued the experiment with media of 100 µg.l^{-1}: The absorption rate was 0.30 µg/day at a temperature of 10^{0}C and 0.52 µg/day at temperature of 15^{0}C (White and Rainbow, 1986).

pH value of water has a close relationship with solubility of heavy metals. At low pH, their free ions are released into the water column. In addition, heavy metals availabilitas generally increases with decreasing pH value (Hill, 2010).

The pH values of Estuarine waters (Sts. 2 and 3) ranged: 7.0 to 7.6. pH value is quite high in the estuary possiblly due to the influence of water circulation withtidal movement. Station 1 (local shrimp) exhibited low pH values, namely 5.2, that is out of range of the normal standards under the Environment Decree No. 51 Year 2004. At station 4, which is also an area of shrimp farms, exhibited high pH values, namely 7.6.

In areas that lack oxygen or low DO conditions, the solubility of the metal will be lower and the metals tend to settle (Supriharyono, 2009). Aquatic organism respiration rate will increase due to the low availability of oxygen dissolved in water. This can lead to increased foreign substances or toxins that enter into the body of organisms (Connell and Miller, 1995).

DO measurement results from the four stations showed a pattern, in which the local pond has a lower oxygen content compared with the oxygen content in the estuary. DO values of the two stations that are in the pond was below the limitrecommended by standards under the Environment Decree No. 51 Year 2004. The low value of DO at stations 1 and 4 (pond area) is thought to occur because of the high density of the shrimp in the limited water supply (Wayan, 2010). In contrast, there are vegetation in the esturine area. Photosynthesis of the plants may supply oxygen to the water.

Concentrations of heavy metal Cd

Results of the analyses of Cd were shown in Table 2.

Tabel 2. Cd concentrations of heavy metals in the white shrimp *P.merguiensis* de Man and its comparison with the value of quality standards

Location	**Cd Concentration** (µg.g^{-1})
Station 1	0.669 ± 0,059*
Station 2	0.391 ± 0,022
Station 3	0.317 ± 0,018
Station 4	0.228 ± 0,242
Comparison of standards (µg.g^{-1})	
Food and Drug Monitoring Agency of Indonesia (=BPOM)	1
WHO	1
Hong Kong Environmental Protection Department (HKEPD, 1997)	2
Conseil supérieur d'hygiène publique de France (CSHPF) (Perancis) tahun 2006	1
Europe	**0.5**
CD 466/2001/EC (America)	**0.5**

*Exceeded the normal limit of quality standard indicated by bold numbers.

Tabel 3. The maximum intake of tolerance biota white shrimp *P. merguiensis* de Man every week.

Location	Station	Intake (gram)
Husbandry	1	523
Estuary	2	896
Estuary	3	1071
Husbandry	4	1537

The highest concentrations was found in station 1 (shrimp husbandry with salinity 15‰) = 0.669±0.059 $\mu g.g^{-1}$ whereas the lowest concentration was found at station 4 (shrimp husbandry with salinity 25‰) = 0.228±0.024 $\mu g.g^{-1}$. At station 2 and station 3 (estuarine area), the concentrations were 0.391±0.022 $\mu g.g^{-1}$ and 0.317±0.018 $\mu g.g^{-1}$.

The higher Cd concentrations is considered to be caused by the lower salinity due to the supply of fresh water from the river. Salinity is the sum of the salts including major mineral ions such as sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), chlorite (Cl), sulfate (SO4) and bicarbonate (HCO3) in water (UNEP, 2004). The gradient of salinity has an important role in the distribution of Cd in water (Modéran, 2010). Batty and Hallberg (2010) said that salinity is an environmental factor that plays an important role in the uptake of heavy metals in tissues of aquatic organisms. Decrease in salinity can cause an increase in the average number of absorbed heavy metals Cd (Yu, 2005).

Heavy metals dissolved in the water body naturally form free ions, ion-ion pair inorganic, organic and inorganic complexes. Cationic Cd dissolved in water will interact with the major ions of sea salt, namely: Cl^-, SO_4^{2-}, HCO^{3-} forming inorganic or organic compound that will reduce the presence of Cd ions in free form. At low salinity, where the levels of the major salt ions also decreased, free Cd cations increases, because small complex of salt ions is reduced. Free ion of Cd is a form of the metal most easily absorbed by aquatic organisms (Wright, 1995), the increased concentration of free Cd cations in water at low salinity may cause an increase in acute toxicity of heavy metal Cd (McLusky and Elliott, 2004; Yu, 2005).

Cd concentration which is found around the mouth of the Cisadane (Banten province) also showed a higher value in the mouth of the river and its concentration decreases towards the sea (Rochyatun et al, 2006). In addition, previous experimental research reported that a significant effect of salinity on the accumulation of heavy metals in the body of a white shrimp (Manullang, 2011).

Cd concentration in the white shrimp revealed in this study is still below the quality standard of BPOM (2009). However, Cd concentration of the shrimp from station 1 exceeded the threshold requirement of metal residue for export to the continent America and Europe. Excessive concentration can certainly hinder trade shrimp shrimp export to the country of destination.

Maximum Weekly Intake

The calculations were performed on a maximum intake of heavy metals Cd into the human body every week is 350 μg/week assuming a body weight of 50 kg. Based on the calculation of the maximum intake per week the maximum intake of tolerance unknown white shrimp *P. merguiensis* de Man for each of the station (Table 3).

Basically, people's understanding of the danger of heavy metal pollution on human health is not sufficient in this region. Although the concentrations of heavy metal Cd found in the body of the white shrimp *P. merguiensis* de Man still below the threshold set by Food and Drug Monitoring Agency of Indonesia (=BPOM) but consumption of shrimp with large amount Cd can be harmful to human health.

International food agencies (WHO and FAO) set a maximum limit consumption of heavy metal Cd to be 7 μg, which is smaller than most of other metal species. This proves that Cd is a metal that is quite harmful to human health. The results of Maximum weekly intake calculation (MTI) showed the value of which varies for each station depend on the concentration of heavy metals found in the shrimp body. The best MTI value was found in station 4, where the highest consumption limit is 1537 grams (1.5 kg) per week for a single person with an estimated weight of 50 kg. MTI lowest value was found at station 1, where the limit is the maximum consumption is 523 g (0.5 kg).

On the basis of this study, several recommendations can be given for Kedungmalang estuarine:

a) Mangroves replanting

Usefulness of mangroves as a sink and storage of heavy metals has long been known. Heriyanto (2011) reported that the mangrove species *Avicennia marina* and *Rhizophora apiculata* could potentially keep Cd as well.

b) Do not consume the shrimp heads and shell

Through interviews with local residents it was learned that people usually ate the whole shrimp, which means that they does not separate the head, carapace and muscle. Manullang (2011) reported that there are significant differences between heavy metal accumulation in the head, carapace and muscle. Measurement of heavy metal concentrations in the whole body of shrimp, carapace with muscle and muscle reported ratio = 1: 4: 8.

CONCLUSION

1. Some values of environmental parameters such as pH and DO in the shrimp farms were found to be out of the threshold value set by the Environment Decree No. 51 Year 2004.

2. Cd concentrations in the shrimp *P. merguiensis* are different according to the salinity of the habitat: 0.391 to 0.669 µg.g-1 for the specimens from the area of the salinity 15 ‰; 0.228 to 0.317 $\mu g.g^{-1}$for the specimens from the area of 25 ‰.

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