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ENRICHMENT FACTORS FOR CADMIUM AND LEAD IN SEDIMENT OF GEMBONG ESTUARY, BEKASI, INDONESIA

Stella Feska [1]✉, Muslim [2], Haeruddin [1]

[1] Graduate School of Coastal Resources Management, Faculty of Fisheries and Marine Science, Diponegoro University, 50275 Semarang, Central Java, Indonesia

[2] Department of Oceanography, Faculty of Fisheries and Marine Science, Diponegoro University, 50275 Semarang, Central Java, Indonesia

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ABSTRACT

The enrichment factors of Cd and Pb were determined in Gembong estuary as the biggest estuary in and polluted in Indonesia. Heavy metals over a period of time sooner or later will cause damage to aquatic ecosystems. Cd (cadmium) and Pb (lead) are non-essential metals. Various human activities both industrial and domestic around Gembong estuary waters have the potential to degrade the quality of the water. The purpose of this study is to analyze the content and enrichment factors of Cd and Pb in sediment. The study was conducted in October 2019 at the high tide and low tide. The method used was quantitative. Heavy metal analysis using the Atomic Absorption Spectrophotometer (AAS AA-7000). The result showed that the concentrations of heavy metals contained in the sediment at the high tide were Cd (0.345-1.261 µg/g) and Pb (13.200-47.600 µg/g) and at low tide were Cd (0.017-1.261 µg/g) Pb (15.600-45.240 µg/g). Based on IADC/CEDA quality standard criteria (1997). The standard quality criteria for Cd (0.8 µg/g) means that the concentration of Cd at high tide and low tide have exceeded the quality standard. Meanwhile, for Pb (85 µg/g), the concentration of Pb at high tide and low tide was still below the target level of quality standards. The enrichment factor values for Cd at the high tide and low tide fall into the moderate-very high enrichment category. The enrichment factor values for Pb at the high and low tide was in the moderate-high enrichment category.

1. INTRODUCTION

The presence of heavy metals cadmium and lead in aquatic environments constitutes a major risk and concern with fear, thus it needs for continuous monitoring (Usese et al., 2017). Gembong estuary is mouth of Citarum river that upper course from Wayang mountain. This estuarine is very dinamic because it is a confluence area between the Citarum river and the sea from the coast of Jakarta Bay (Aliyanta et al., 2018). Citarum river flows passing some regencies and the ending in Gembong estuary of Bekasi regency. This estuary considered as polluted area, because the water quality in this estuary is grossly polutted. Along the river there are many industrial buildings that use the river as a shipping channel and waste disposal without sufficient prior handling or pay less attention to environmental quality (Birry and Muetia, 2012). Based on a study conducted by the Regional Environmental Management Agency of West Java Province in 2007, there are 359 companies divided into 11 different industrial sectors located in four administrative areas along the upstream flow of the Citarum river. Meanwhile, the company directory issued by the Ministry of Industry's data and Information center (2012) showed an increase in industrial population in several sectors, such as agriculture, textile, leather tanning, food and electroplating industry. Among these industrial sectors, the textile industry is one of the most dominant sectors that produce a lot of heavy metals cadmium and lead wastes.

Heavy metals that enter to the waters continuously and continue to increase can cause toxic and persistence to most aquatic and human biota and a threat to aquatic ecosystems (EPA, 2004). Over time, heavy metals that enter the waters will settle and are contained in the sediment through the process of gravity (Permata et al., 2018) and can affect water quality (Dou et al., 2013). Estuarine and continental shelf are the important sink for settleable suspended solidsand biota in sediment associated with trace metal contaminants(Yeats & Bewers, 1982) and (Lo & Fung, 1992).

Research on the concentration of Cd, Cr and Pb in the along Citarum river has been carried out and the results are that in the downstream areas are detected higher than in the upstream area (Habibi et al., 2014). All the waste arrived at the estuarine, it will settle to the bottom of the sediment, and eventually it will always increase with time.

Although many studies have been done on related to heavy metals in Gembong estuary (Arief *et al.*, 2012); (Ambinari et al., 2016) and (Tidjani et al., 2016), but no information is available on enrichment factors of some trace metals. With regard to the increased accumulation pollutants in sediments especially for Cd and Pb in time, it is necessary to do research on the enrichment factor. Enrichment Factor (EF) has been used as diagnostic tools for assessing the pollution status of some trace metals (Likuku et al., 2013) and (Nowrouzi & Pourkhabbaz, 2014).

In the present study was carried out in order to : (1) Determine the level concentration of trace metals Cd and Pb in sediment and the safety level in terms of quality standards. (2) The enrichment factors of Cd and Pb that is determined for measuring containing range of Cd and Pb in sediment.

This research could be useful to determine the condition of the waters of the Gembong estuary, which can then be used in determining the management of its handling.

2. MATERIAL AND METHOD

Field sampling and sample treatment: Sediments sampling was carried out at Gembong estuary waters on October 31, 2019. The fields stations as shown in Fig.1. The coordinates and depths of the sampling stations are presented in Table 1. Approximately 2 kg wet sediment were obtained using Van-Veen grab sampler during the water in high tide and low tide. Sediment samples were then placed in plastic bag and transported to laboratory.

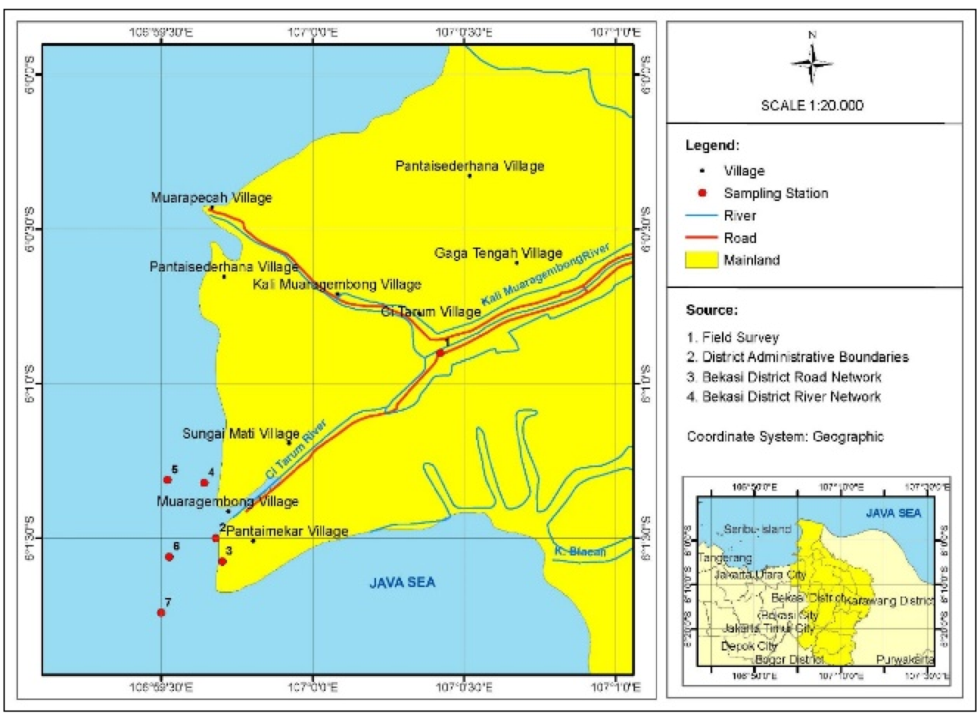

Figure 1: Sampling station sites, Bekasi, Indonesia.

Table 1: Station sites information

Station	Coordinate		Depth at high tide (m)	Depth at low tide (m)
	Longitude	Latitude		
1	107˚00’25.13”	06˚00’54.04”	1.28	0.60
2	106˚59’40.71”	06˚01’28.99”	1.18	0.22
3	106˚59’41.01”	06˚01’34.51”	0.69	0.20
4	106˚59’38.40”	06˚01’18.94”	1.00	0.50
5	106˚59’32.60”	06˚01’18.62”	1.24	0.38
6	106˚59’31.51”	06˚01’32.81”	1.12	0.44
7	106˚59’29.93”	06˚01’42.66”	1.34	0.54

2.1. SEDIMENTS SAMPLES ANALYSIS

Laboratory treatment and measurements heavy metals analysis: Sediments were air-dried for two to five days at room temperature. After drying, the samples were disaggregated and any visible remains of organisms and debris removed. Sediments were dried in an oven at 105 °C until dryness. Before analysis the sediments were then ground using a pestle and mortar and sieved trough a 63-70 microns nylon mesh sieved to normalize particle sizes for total Cd and Pb analysis (I. Muslim & Jones, 2003). The processed sediment samples were thereafter transported under strict quarantine procedure for further processing to the chemical laboratory located at the Jakarta National University. From the dried powdered sediment sample, approximately 5 g was weighed into an acid washed 100 mL Pyrex flask. 50 mL of aqua regia (HCl:HNO3 at a ratio of 3:1). This solution was shaken until homogenous, and left to stand for about 15 minutes in a fume cupboard at room temperature for an initial digestion phase. This solution was then refluxed for about 2 hours and 2 mL of HClO4 added. This solution was digested at 110 °C (±2 hours) on the hot plate until the aqua regia had evaporated. Then, it was digested at 180 °C to dryness. After digestion, sample solutions were cooled to room temperature and made up to 50 mL with double distilled water and filtered through a Whatman No 1 filter paper. The solution was subsequently measured heavy metals concentration using Atomic Absorption Spectrophotometer (AAS) AA-7000 on wave length 228.94 nm, 283.10 nm and 248.3 nm for Cd, Pb and Fe respectively. Precision and accuracy of trace metals analyses were checked against the standard BCSS-1, which was collected from the Baie des Chaleur by MacLaren Panesearch Ltd, Dartmouth, N.S

Methods for estimating Enrichment Factor (EF): Enrichment Factor (EF) is one of the methods for calculating method for quantifying the degree of metal enrichment in sediments (Abraham & Parker, 2008) and as a convenient measure of geochemical trend (Hasan et al., 2013) that is used to evaluate coastal contamination and can be used for making comparation between areas (Sinex & Helz, 1981). This method is suitable for some locations that get below contamination effect for long time period as effect of human activity such as industrial and agriculture activities. To measure the level EF we need comparation between polluted area in the present day trace metal level with their concentrations in standard earth materials such as with IADC/CEDA (1997) or with the recommended values of unpolluted sediments (Hasan et al., 2013) or with metal in Earth's crust(Abraham & Parker, 2008). According to Aprile and Bouvy (2008) the EF for metal concentration in sediment at all the stations were calculated by the formulation as below:

$$EF = \frac{X/Fe(Sediment)}{X/Fe(Earth'scrust)}$$

Where X is the metal in sediment that be studied (Cd, Pb) and X/Fe is the ratio of concentration of the trace metal that be studied and iron. According to Kamau (2002) that iron was chosen as the element of normalization, it due to the dominant input to sediment naturally (98%). The crustal abundance data of Krauskopf and Bird (1967)were used for all EF values.

Sutherland, (2000) had classified of EF into 5 levels
$EF < 2$ = Low EF
$2 \leq EF < 5$ = Moderate

5 ≤ EF < 20 = Significant
20 ≤ EF < 40 = Very high
EF ≥ 40 = Extremely high

3. RESULTS AND DISSCUSSIONS

The results of Cd concentration in sediment when water was in high tide and low tide were shown in Figure 2. In the high tide range 0.345 µg/g to 1.261 µg/g with average 0.737 µg/g. The lowest concentration occurred in station 3 and the highest concentration occurred in station 2. Meanwhile, at low tide concentration rage 0.017 µg/g to 1.261 µg/g with average 0.466 µg/g and the lowest concentration occurred in station 7 and the highest concentration occurred in station 2.

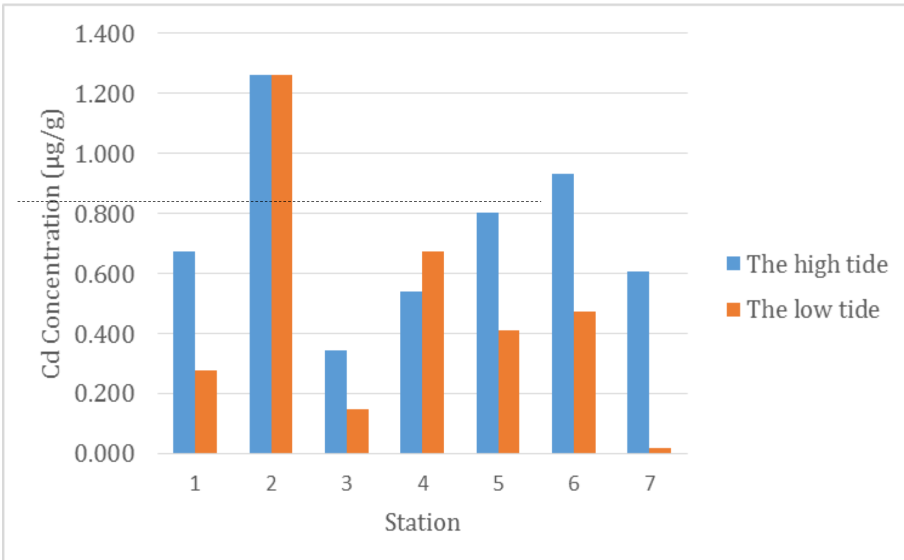

Figure 2: Cd concentration in sediment when water was in high tide and low tide, Gembong estuary, Bekasi, Indonesia.

Note:
.... = Quality Standard limits IADC/CEDA (0.8 µg/g)

The highest Cd concentration occurred in station 2 both in the high tide and low tide, it may due to the location of station 2 in the mouth of the river, where there is confluence between water from the sea and river occurred in this station, then deposition of Cd occurs together with suspended solid. It means that this station become a trap of Cd in sediment. Whereas in other stations the concentration fluctuates greatly, due to the influence of location condition which are influenced by dilution(M. Muslim & Wahyu Retno, 2017), resuspension (Muslim & Jones, 2003), Muslim et al., 2015), and deposition is caused by chemical binding (M. Muslim et al., 2015) & (Alviandini et al., 2019).

According to Rumahlatu (2011) state that industrial activities that produce a lot of Cd waste are paint dyes (such as painting coastal building and ship) and PVC plastic. While human activities that contribute to Cd are the use of pesticide. According to quality standard level IADC/CEDA (1997) that the concentration of Cd in station 2 and 6 have exceeded the allowable limit (> 0.8 µg/g). Meanwhile, according to the United States Environmental Protection Agency (EPA, 2004), all stations still meet the quality standards (< 0.6 µg/g).

Pb concentration at high tide and low tide are shown in Figure 3. The fluctuation of the Pb concentration looks very different from the fluctuation of Cd. This is due to the difference in sources of Pb and Cd, where Pb is dominated by fuel smoke in the atmosphere, while Cd comes from industrial waste which is directly discharge into the water.

Concentration of Pb range 13.20 µg/g to 47.60 µg/g with average 32.526 µg/g in the high tide. The highest Pb concentration occurred at station 1, where in this place there is a pier and a fish auction place, so that many ships unload and load goods and fish which produce a lot of Pb waste from the fuel smoke produce. The lowest Pb concentration occurred at station 5, this is because station 5 is located far from the river as a source of Pb. Whereas at low tide the Pb concentration ranges from 15.60 µg/g to 45.24 µg/g with an average 30.509 µg/g. The highest Pb concentration occurred at station 2 which is located in the mouth of river as a trap for sediments particles with several elements and the lowest concentration occurred at station 7 which is located far from the mouth of the river so that it has undergo dilution.

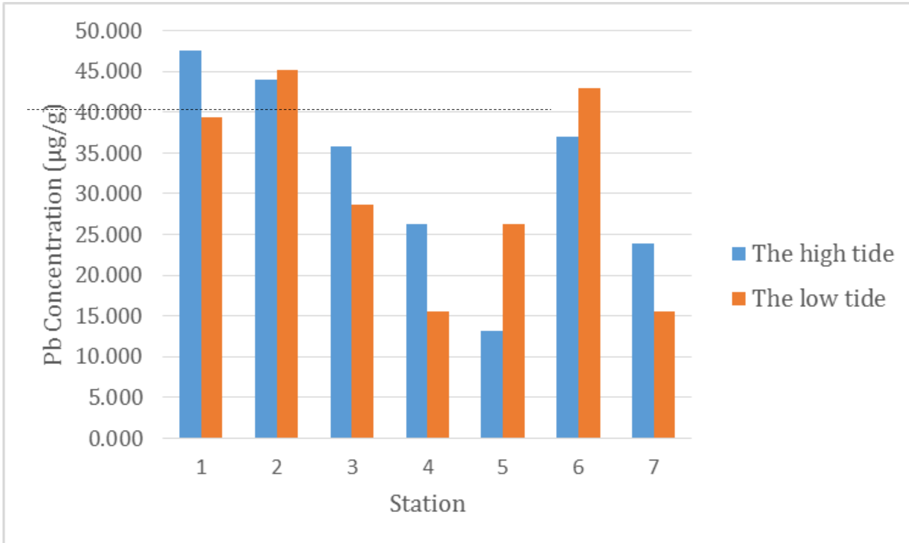

Figure 3: Pb concentration in sediment when water was in high tide and low tide, Gembong estuary, Bekasi, Indonesia.

Note:
.... = Quality standard limits = moderat polluted United States Environmental Protection Agency (40 µg/g)

Base on the quality standard according to IADC/CEDA (1997), the concentration is said be safe if the Pb concentration in the sediment is still below 85 µg/g, so that the waters of Gembong are still in the safe category. However, based on EPA (2004) which says it is safe if the concentration of Pb is still below 40 µg/g, so stations 1, 2 and 6 are no safe.

The high concentration of Pb at stations 1, 2 and 6 is because these stations are in direction of river water flow. and exceed the quality standard both at high tide and low tide occur at stations 1, 2 and 6, where these stations are in one direction with water river flow from upstream to downstream. Furthermore, at other stations the concentration decreases at the farther from the water river flow, this is due to the dilution process.

Enrichment Factors (EF): To evaluate the level of Cd and Pb contamination, it is necessary to measure Enrichment Factors (EF). The result of EF measurement at high tide can be seen in Figure 4. The EF value for Cd in the high tide ranged 11.444 to 41.804, it is in the category significant to extremely high, and the average was 24.349 which is in the category very high. While the EF value of Pb at high tides ranged 6.718 to 24.361 which in the EF category significant to very high, and the average was 16.536, which is in the category significant.

Table 2: Enrichment Factors for Cd and Pb in the high tide

Station	Enrichment Factor	
	Cd	Pb
1	22.357	24.361
2	41.804	22.462
3	11.444	18.248
4	17.805	13.307
5	26.566	6.719
6	30.698	18.667
7	19.775	11.988

The value of the EF for Cd and Pb at the lowest tide can be seen in Figure 5. The EF value for Cd ranged 0.549 to 41.178, which in the category Low EF to Extremely high, and the average value was 15.1387 which in the category

Significant. While, the EF value for Pb ranges 7.746 to 22.728 which in the category significant to very high and the average vale was 12.108 which in the category significant.

Table 3: Enrichment Factors for Cd and Pb in the low tide

Station	Enrichment Factor	
	Cd	Pb
1	9.180	19.904
2	41.178	22.728
3	4.798	14.284
4	21.726	7.759
5	13.176	12.993
6	15.364	21.338
7	0.549	7.746

This shows that the presence of Pb at high and low tide also Cd at low tide was influenced by natural and anthropogenic activities. Whereas the presence of Cd at high tide is strongly influenced by anthropogenic activities. Very high level of enrichment factors cause high concentrations of heavy metal and can affect organisms in a marine ecosystem. Heavy metals that suspended in the water eventually accumulate in the bottom sediments. Heavy metals in the bottom sediments can be accumulated by benthic organisms, where benthic organisms form the basis of the food chain and eventually become metal transfer agents from basic sediments to higher levels of tropics (Putra and Apriadi, 2018).

4. CONCLUSIONS

Based on this study, it can be concluded from quality standards of IADC/CEDA (1997) that the Cd concentration in waters of Gembong estuary has exceeded the quality standards, while for Pb concentration still on the quality standard. The enrichment factors of Cd and Pb at Gembong estuary is included in the minimal to very high enrichment category, which indicates that the source of heavy metals is mostly anthropogenic. The higher enrichment factor of heavy metal in a waters, it will have an impact on the aquatic ecosystem if it is not managed optimally.

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CONFLICT OF INTEREST

The author have declared that no competing interests exist.

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