# THE ASSESSMENT OF SEDIMENT CONTAMINATION LEVEL IN THE LAMPUNG BAY, INDONESIA: HEAVY METAL PERSPECTIVE

**Fitri Budiyanto[1] & Lestari[1]**

[1]Research Center for Oceanography, Indonesian Institute of Sciences

*ABSTRAK*

*Teluk Lampung memiliki nilai sosial-ekonomi dan ekologi yang tinggi berkaitan dengan potensi perairan dan penggunaannya oleh manusia. Di lain pihak, pemanfaatan Teluk Lampung mungkin mengubah kelimpahan bahan kimia berbahaya seperti logam berat. Tujuan dari penilitian ini untuk mengetahui konsentrasi logam berat Cd, Cu, Pb dan Zn dalam sedimen dan menilai kondisi periaran Teluk Lampung. Pengamatan konsentrasi logam berat dilakukan di 13 titik stasiun pada bulan maret 2008. Analisis logam berat dalam sedimen menggunakan tiga jenis asam: $HNO_3$, $HCl$, $H_2O_2$ kemudian sampel dianalisis menggunakan Spektrofotometer Serapan Atom. Hasil pengukuran menunjukkan variasi logam berat di setiap lokasi pengamatan dan konsentrasi tertinggi Cd, Cu, Pb dan Zn dalam sedimen secara berurutan adalah 0.08 mg/kg berat kering, 22.99 mg/kg berat kering, 24.75 mg/kg berat kering dan 118.48 mg/kg berat kering. Faktor yang dominan mempengaruhi variasi logam berat dalam sedimen dalam studi ini adalah jarak lokasi pengamatan dengan pusat kegiatan antropogenik dan fraksi sedimen. Indeks SQG-Q menunjukkan 7 titik stasiun memiliki nilai SQG-Q ≤ 0.1 sementara 6 titik stasiun lainnya memiliki nilai 0.1≤ SQG-Q <1. Hal ini berarti lebih dari setengah titik stasiun berada pada kondisi tidak tercemar.*

***Kata kunci: Teluk Lampung, konsentrasi logam berat, indeks SQG-Q***

**ABSTRACT**

The potency and utilization of Lampung Bay has been recognized for their socio-economical and ecological values. However, heavy use of this Bay may alter the abundance of hazardous chemical like heavy metals. The aims of this study were to determine the concentration of Cd, Cu, Pb and Zn in the sediment and to assess Lampung Bay water condition. The observation of heavy metal content in sediment of Lampung Bay was conducted at 13 stations in March 2008. Analysis of heavy metals in sediment was conducted using three kinds of acid: $HNO_3$, $HCl$ and $H_2O_2$ while measurement was carried out by Atomic Absorption Spectrophotometer. The result indicated a variation of heavy metal concentration in sediment and that concentrations of Cd, Cu, Pb and Zn in sediment were 0.08 mg/kg dry weight, 22.99 mg/kg dry weight, 24.75 mg/kg dry weight and 118.48 mg/kg dry weight, respectively. Factors influenced heavy metal concentration in sediment in this study including the distance between sampling location and anthropogenic activities and the sediment fraction  SQG-Q index indicated that 7 stations have SQG-Q ≤ 0.1 whereas other 6 stations have 0.1≤ SQG-Q <1, meaning that more than half sampling stations are in uncontaminated state.

**Keywords: Lampung Bay, heavy metals concentration, SQG-Q index**

## INTRODUCTION

Heavy metals enrich water body by several mechanisms (Lee & Morel, 1985) and their abundance in sediment can represent level of contamination of the environment (Lestari & Witasari, 2010). Riverine runoff becomes major source of metals in estuarine waters (Darmono, 1995) and depositional processes alter composition of metal in the sediment (Rompas, 2010). Changes of physicochemical properties (pH, salinity, temperature, eH) provoke the release of metals in sediment into upper water column (Hosono *et. al.,* 2010). Some of the released metals were redeposited in the sediment and this process will be repeated several times inflicting permanent release of metals into water column and/or permanent sink of metals into seabed sediment (Rejomon *et. al.,* 2010).

Lampung bay is located in the southernmost part of Sumatra that shows socio-economical and ecological value due to its marine resources and utilization (Fitriya, 2010; Thoha, 2010). Mangrove, coral reef, seagrass, sand and mud are part of ecosystem diversity in Lampung Bay (Cappenberg, 2010; Handayani, 2010). Coastal communities utilize those resources for aquaculture activities, such as: pearl farming, seaweed aquaculture and tourism (Kadi, 2010; Pramudji, 2010).

Local Government of Lampung (1999) explained that Lampung receives spill-over of economic growth of Jakarta causing rapid enhancement of anthropogenic activities like industry, urban area, agriculture and aquaculture. According to Susana *et. al.,* (2001), Lampung bay has been influenced by industrial activities like cement, coal, timber and oil production. These activities may alter metals concentration in aquatic ecosystem especially Cd, Cu, Pb and Zn which will be used and will be released in their production process (Darmono, 1995). The aims of this research were to determine Cd, Cu, Pb and Zn concentration in sediment and to assess its contamination level.

Korespondensi Penulis:
Jl. Pasir Putih I Ancol Timur, Jakarta Utara 14430.  Email: fitr019@lipi.go.id

## METHODOLOGY

### Sampling site

Sediment samples were collected in 13 observation stations in March 2008 in the geographical area of $105.22^0$ to $105.37^0$ East and $5.66^0$ to $5.46^0$ South (Figure 1). The stations were chosen representing local anthropogenic activities. Northern part of the Bay represents urban areas, and the western part is proximal to aquaculture area. The eastern part of the bay was selected for observation in the water near industrial area.

### The collection of sediment samples

In each station, sample was taken using stainless steel grab sampler then 0-10 cm of surface-layer sediment was collected using Polyethylene spoon. In the field, sediment sample was stored in ice box at ± $4^0C$ in temperature (Hutagalung *et. al.,* 1997).

### Analytical method

Acidic destruction and spectrophotometry measurement were used to analyze sediment samples according to USEPA 3050b procedure (USEPA, 1996). HNO3 (1+1) was added into a gram of dry sediment then the solution was heated for 15 minutes. After the heating, concentrated $HNO_3$, $H_2O_2$ 30% and concentrated HCl were added by dropper into solution and reheating of solution was performed. Aquadest was added into sample solution to 100 ml in volume. After the destruction processes finished, Cd, Cu, Pb and Zn in sediment were measured using Flame Atomic Absorption Spectrophotometer (FAAS) Varian SpectrAA 20 plus utilizing air-acetylene as ignition gas. Before used, all glasswares were soaked into HNO3 (1+1) for 24 hours and were rinsed by aquadest.

To understand Cd, Cu, Pb and Zn concentration in sediment, sediment fraction was measured then PCA analysis was conducted to discover the influence of sediment fraction to the metals concentration. Statistica version 6.0 was used to perform PCA Analysis and the sedimentary fraction data was taken from Helfinalis (2010) as a secondary data.

### Index Calculation

Ecosystem changes by anthropogenic activities in this research were evaluated using SQG-Q (mean sediment quality guideline quotient) index. SQG-Q was used to determine pollution level in the bed sediment by comparing with quality guideline. Caeiro *et. al.,* (2005) formulated SQG-Q index as:

$$SQG - Q = \frac{\sum_{i=1}^{n} PEL-Q_i}{n} \quad \text{.............................. 1)}$$

$$PEL - Qi = \frac{contaminant}{PEL} \quad \text{................................ 2)}$$

PEL-Qi : probable effect level quotient for each contaminant
PEL : probable effect level for each contaminant (Tabel 1)
Contaminant : metals concentration in sediment
n : number of parameter for calculation



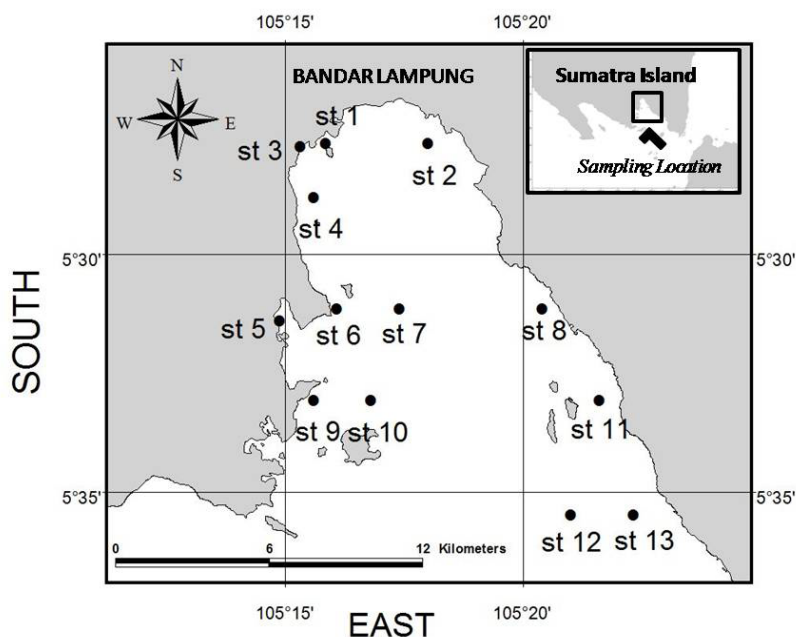Figure 1.    Sampling stations for sediment sample in the Lampung Bay.

Table 1.　　　　　The references for SQG-Q index

| Element | Cd | Cu | Pb | Zn |
|---|---|---|---|---|
| Probable effect level (PEL) value for each metal, mg/kg dry weight | 4,2 | 108 | 112 | 271 |

Source:Nobi *et. al.,* 2010

Table 2.　　　　　Interpretation of SQG-Q value

| SQG-Q value | Designation of sediment quality |
|---|---|
| SQG-Q ≤ 0,1 | Unimpacted: lowest potential for observing adverse biological effects |
| 0,1 < SQG-Q ≤ 1 | Moderate impact potential for observing adverse biological effects |
| SQG-Q ≥ 1 | Highly impacted potential for observing adverse biological effects |

In this calculation, PEL values were used to figure out the index value (Table 1). The others value could be used to substitute PEL like quality standard of metals in the sediment, even though, substituting this value possibly changes the calculated index.

The value obtained from those calculations varied from 0 up to 1. Caeiro *et. al.,* (2005) explained the meaning of the value of SQG-Q and the brief of that interpretation was summarized in Table 2.

**RESULT AND DISCUSSION**

Metals concentration varied among locations, and both anthropogenic activities and natural processes alter metals abundance. Cd became the lowest value and the tightest range of metals found in the bed sediment compared with Cu, Pb and Zn. On the opposite, Zn had the widest range of value among the others (Table 3). Cd shows the worst toxic effect and its presence in sediment probably affects benthic organism even in low concentration (Ellwood, 2004). Cd, Cu and Pb naturally exist in oil and coal then the utilizing of both oil and coal

as fuel may release the metals into aquatic ecosystems. Zn has been categorized as essential metal which is required and is used in metabolism, however, recent researches showed that excessive uptake of Zn into organism body gives toxic effect (Dean *et. al.,* 2007). Report of Zn hazards decribed that Zn deficiency have severe effects on all stages of growth, development, reproduction and survival, however, exceeding level of zinc causes negative effect.

Urban and aquaculture activities along Lampung Bay coast line influenced metals abundance. The high concentration of Cu, Pb and Zn were detected in the river mouth and urban area, and those metals tend to decrease by the distance. Cd evenly distributed in this Lampung Bay, for Cd naturally presents in a little amount in earth crust (Taylor, 1964), so little changes in enviroment have no significant effect to Cd concentration. Sanusi (2006) explained that river flow includes human waste such as metals contaminant. Other researchers reported that increasing metals content in the river mouth was affected by input volume/runoff of river containing metals (Rochyatun *et.*

Table 3.　　　　　Concentration of Cd, Cu, Pb and Zn in Sediment

| Station | Metal in sediment concentration mg/kg dry weight | | | |
|---|---|---|---|---|
| | Cd | Cu | Pb | Zn |
| st 1 | 0.05 | 20.58 | 21.61 | 111.00 |
| st 2 | 0.05 | 22.99 | 24.73 | 118.48 |
| st 3 | 0.08 | 18.27 | 6.05 | 99.06 |
| st 4 | 0.03 | 5.30 | 7.28 | 35.27 |
| st 5 | 0.04 | 16.88 | 12.20 | 71.65 |
| st 6 | 0.04 | 12.84 | 11.94 | 61.67 |
| st 7 | 0.01 | 11.01 | 10.01 | 63.79 |
| st 8 | 0.02 | 8.39 | 9.23 | 33.14 |
| st 9 | 0.03 | 8.82 | 9.22 | 57.52 |
| st 10 | 0.03 | 9.06 | 9.29 | 63.11 |
| st 11 | 0.04 | 8.33 | 9.49 | 58.62 |
| st 12 | 0.02 | 7.12 | 9.88 | 52.99 |
| st 13 | 0.02 | 8.35 | 9.99 | 54.01 |

*al.,* 2005; Ciutat *et. al.,* 2007). Rochyatun *et. al.,* (2006) observed the impact of riverine runoff in the Cisadane river as long as the fluctuation of metals content on bed sediment by flooding phenomenon. Their research discovered that Cd and Zn increased in two fold of concentration after the flooding, however, Pb and Cu showed no differences between pra and post of the flooding. Urban activities contribute in metals input mostly by fuel combustion, paint weathering, metal furniture corrosion and urban waste disposal (Ciutat *et. al.,* 2007). Aquaculture area contributes in Cu and Zn input into aquatic ecosystem. Dean *et. al.,* (2007) reported the highest Cu and Zn concentration found in fish farming area which feed and faecal of fish contain of Cu and Zn. In addition, Cu is used as antifouling in boat paint (Olsgard, 1999).

Sediment fraction also affected Cd, Cu, Pb and Zn concentration in bed sediment where clay fraction strongly bound Cd, Cu, Pb and Zn (Figure 2). Clay and silt concentrated in the urban and aquaculture area (Table 5) where Cd, Cu, Pb and Zn found in relatively high concentration. Considering the industrial area in the eastern part of the Bay have coarser sediment than the urban area metals concentration is in low concentration. Finer particles provide larger surface area, and these kinds of particle bind more metals onto particle. Moreover, finer particles form dense bed sediment inhibiting the realease of trapped-metals into water column (Donazzolo *et. al.,* 1984; Martinctic *et. al.,* 1990). River mouth and urban area of Lampung Bay tend to contain more clay and resulted in high concentration of metals detected in those areas (Figure 2).

Metals concentration in bed sediment of Lampung Bay is considered as natural concentration of metals in sediment. Cd, Cu, Pb and Zn concentration in sediment

Table 4.      Concentration of Cd, Cu, Pb and Zn in sediment in the other locations

| Location | Metals concentration in sediment, mg/kg dry weight | | | | Reference |
| | Cd | Cu | Pb | Zn | |
| --- | --- | --- | --- | --- | --- |
| East Kalimantan, Indonesia | <0.001-0.1 | 2.02-14.5 | 4.4-15.2 | 15.8-121.2 | Rochyatun, et. al., 2003 |
| Pari Islands, Indonesia | 0.03-0.06 | 13.24-15.93 | 0.84-6.01 | 0.73-17.83 | Rochyatun, 2003 |
| Semarang, Indonesia | 0.06-0.13 | 18.3-36.6 | 10.9-17.3 | 13.6-16.3 | Lestari, 2011 |
| Brest Harbour, France | - | 700 | 500 | 1160 | Cabon, et. al., 2010 |
| Masan Bay, Korea | 1.24 | 43.40 | 43.97 | - | Hyun, et. al., 2007 |
| Mexican Caribbean | - | 1.3 | 1 | - | Whelan III, et. al., 2011 |
| Andaman Islands, India (sandy ecosystem) | 0.69-1.96 | 6.64-7.04 | - | 10.4-27.72 | Nobi, et. al., 2010 |
| Andaman Islands, India (dead coral ecosystem) | 1.24-1.75 | 5.48-10.58 | - | 25.54-38.77 | Nobi, et. al., 2010 |
| Andaman Islands, India (seagrass ecosystem) | 1.04-3.88 | 44.36-86.76 | 3.08-6.64 | 21.64-48.72 | Nobi, et. al., 2010 |
| Andaman Islands, India (mangrove ecosystem) | 0.8-1.52 | 80.86-87.93 | 3.9-5.4 | 12.21-23.02 | Nobi, et. al., 2010 |
| Abundance in the continent crust | 0.2 | 55 | 12.5 | 70 | Taylor, 1964 |
| Lampung bay, Indonesia | 0.01-0.08 | 5.30-22.99 | 6.05-24.73 | 33.14-118.48 | This study |

Table 5.      Grain Size classification of the sediment in each station of The Lampung Bay

| Station | Sediment Classification (%)[a] | | | | | Remark |
| | Pebbles | Granules | Sand | Silt | Clay | |
| --- | --- | --- | --- | --- | --- | --- |
| st 1 | 0 | 0 | 4,32 | 52,64 | 43,04 | Urban area |
| st 2 | 0 | 1,83 | 5,74 | 27,5 | 64,93 | Urban area |
| st 3 | 0 | 0 | 14,22 | 42,2 | 43,57 | River Mouth |
| st 4 | 0 | 4 | 35,45 | 22,04 | 38,51 | - |
| st 5 | 0 | 0 | 1,66 | 48,87 | 50,46 | Aquaculture area |
| st 6 | 0 | 0 | 6,02 | 53,41 | 40,57 | Aquaculture area |
| st 7 | 9,14 | 8,52 | 11,78 | 28,55 | 42,02 | Aquaculture area |
| st 8 | 13,73 | 11,67 | 12,96 | 23,48 | 38,16 | Industrial area |
| st 9 | 0 | 0,38 | 13,55 | 56,6 | 29,47 | Aquaculture area |
| st 10 | 0 | 7,16 | 18,68 | 33,78 | 40,39 | Aquaculture area |
| st 11 | 0 | 0,73 | 3,55 | 32,34 | 63,37 | Industrial area |
| st 12 | 0 | 0,74 | 4,36 | 54,63 | 40,27 | Industrial area |
| st 13 | 0 | 0 | 3,92 | 47,05 | 49,03 | - |
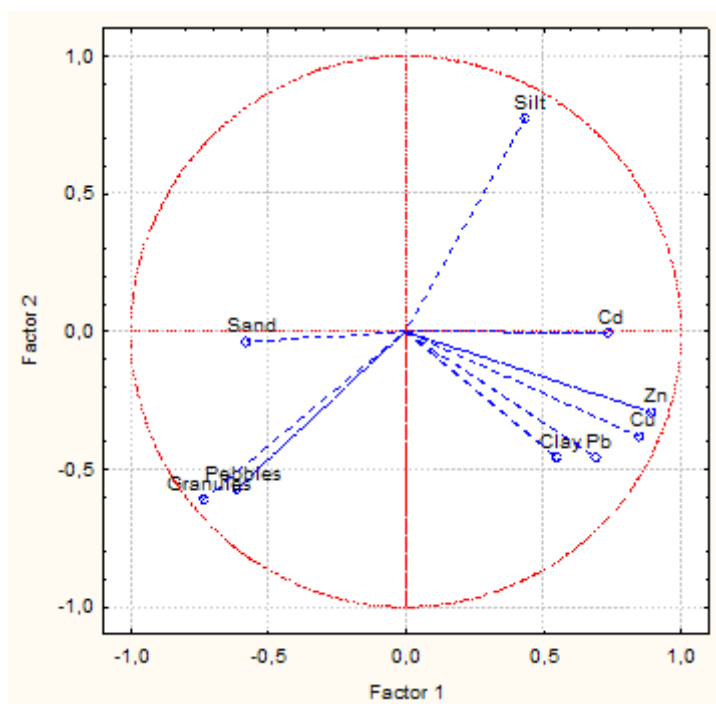
Figure 2. Principal Components Analysis for sediment fraction and concentration of metals in sediment.

Table 6. SQG-Q index for each station

| Station | PEL-Qi | | | | SQG-Q |
| --- | --- | --- | --- | --- | --- |
| | Pb | Cd | Cu | Zn | |
| st.1 | 0,193 | 0,0114 | 0,191 | 0,410 | 0,20 |
| st.2 | 0,221 | 0,0124 | 0,213 | 0,437 | 0,22 |
| st.3 | 0,054 | 0,0188 | 0,169 | 0,366 | 0,15 |
| st.4 | 0,065 | 0,0074 | 0,049 | 0,130 | 0,06 |
| st.5 | 0,109 | 0,0100 | 0,156 | 0,264 | 0,13 |
| st.6 | 0,107 | 0,0100 | 0,119 | 0,228 | 0,12 |
| st.7 | 0,089 | 0,0026 | 0,102 | 0,235 | 0,11 |
| st.8 | 0,082 | 0,0038 | 0,078 | 0,122 | 0,07 |
| st.9 | 0,082 | 0,0062 | 0,082 | 0,212 | 0,10 |
| st.10 | 0,083 | 0,0076 | 0,084 | 0,233 | 0,10 |
| st.11 | 0,085 | 0,0088 | 0,077 | 0,216 | 0,10 |
| st.12 | 0,088 | 0,0050 | 0,066 | 0,196 | 0,09 |
| st.13 | 0,089 | 0,0050 | 0,077 | 0,199 | 0,09 |

of Lampung Bay showed no extreme differences with the average abundance within continental crust in preindustrial period. Metal concentration in sediment in the Lampung Bay was lower than other areas like harbor and other urban waters (Table 4). This study supported the report in metal's bioaccumulation in Lampung Bay (Tugiyono, 2007) that discovered that Hg and Pb concentration in Lampung Bay was not dangerous for marine organisms. The concentration of Hg and Pb in green mussel (Perna viridis) increased, yet those concentrations surpassed none of existing regulation.

**SQG-Q index**

SQG-Q index value varied among station as the metals concentration differed among locations. Zn contributed the most in the calculation of SQG-Q index than other metals due to the high concentration of Zn compared with PEL value. Interpreting the SQG-Q index, 7 stations (more than a half of total stations) were unimpacted area and moderate impact was found in the rest of the stations (Table 6). The presence of metals in sediment will expose metals accumulation in benthic organism in various mechanisms. The effect of metals accumulation in organism differs in each metal, depending on: intake rate, exposure route, internal

factor of organisms (ages, sex) and physiochemical properties of environment (Luoma & Rainbow, 2008). Cd and Pb categorized as non-essential element having toxic effect even in low concentration. In contrast, Cu and Zn were essential elements used in metabolisms, however, exceeding concentration has toxic potential. In recent research, Cd was found to substitute Zn and its function in carbonic anhydrase enzyme of diatomae when the seawater lacked Zn. In this state, diatomae could maintain its growth rate, however, this phenomenon still is not be observed in higher trophic level organisms (Lane *et. al.,* 2005).

SQG-Q index calculates the sum of measured concentration and quality guideline (in this study, PEL was used), and it predicts toxicity of metals in sediment. The achieved score predicted the influence of metal's abundance in benthic organism, however, real adverse effect of metals to organism could not be determined by these scores only. The effect of metals bioaccumulation to marine organism is complex (Luoma & Raibow, 2008). The changes of water properties may affect the toxicity of sediment. The presence of other chemical components like sulphide or organic material influence metals bioavailabity. In metal-sulphide compound, metals were strongly bound and in this state metals mobility considered low, resulted in low toxicity effect of sediment to marine organism. Furthermore, the existence of other metals caused different impact on toxicity, particularly interaction of metal with one another. In most cases, the poisoning effect of Cd can be prevented by Zn consumption and the consumption of Cd decreases Cu concentration in the liver (Darmono, 1995).

## CONCLUSION

Anthropogenic activities along Lampung Bay coastal area altered Cd, Cu, Pb and Zn concentration in bottom sediment. Cu, Pb and Zn concentrated in urban and aquaculture area which represent human activity. However, Cd distributed evenly in the Bay due to low concentration of Cd in the natural sediment indicating another factor, such as sediment fraction also contributed in its concentration. Urban and aquaculture area are covered by finer sediment than other areas in the Lampung Bay resulted in high metals concentration. Comparison with previous study areas, Cd, Cu, Pb and Zn in the Lampung Bay were relatively low. Calculation of SQG-Q index showed that more than half of the total observation stations were claimed to unimpacted area and the others were in moderate impact state.

## ACKOWLEDGEMENTS

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