Analysis of lead (Pb) pollution in the river estuaries of Jakarta Bay

M. Rumanta
Universitas Terbuka, Indonesia

Abstract

The purpose of this study is to obtain information about the level of Pb in the sediment of the estuaries surrounding Jakarta Bay and to compare them. Samples were taken from 9 estuaries by using a grab sampler at three different location points – the left, right and the middle sides of the river. Then, samples were collected in one bottle sample and received drops of concentrated HNO_3. The taking of samples was repeated three times. In addition, an in situ measurement of pH and temperature of samples was taken as proponent data. The Pb concentration of the river sediment was measured using an AAS flame in the laboratory of Balai Penelitian Tanah Bogor. Data was analyzed statistically (one way ANOVA and t-test student) by using SPSS-11.5 software. The results show that Pb concentration in the sediment of the estuaries surrounding Jakarta was quite high (20–336 μg/g). The sediment of Ciliwung River in the rainy season was the highest (336 μg/g). Pb concentration of sediment in the dry season was higher than that in the rainy season, except in Ciliwung River. It was concluded that all rivers flowing into Jakarta Bay make a significant contribution to the Pb pollution in Jakarta Bay, and the one with the largest contribution was Ciliwung River.
Keywords: Pb, sediment, estuaries, dry season, rainy season, AAS flame.

1 Introduction

Jakarta Bay (89 km of length) is formed as a result of the extension of Karawang Cape in the eastern region and Kait Cape in the western region into the Java Sea (Rositasari [1]). The region has long been under pressure from organic and inorganic pollutants, both from domestic and industrial waste in the vicinity. This is due to the recent rapid development of industries and residential areas in

WIT Transactions on Ecology and The Environment, Vol 191, © 2014 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/SC141322

Jakarta and vicinity. The increasing number of industries and residential areas will always be followed by an increase in the amount of waste, in the form of solids, liquids and gases. The waste contains toxic chemicals which are hazardous (B3) and enter the Gulf of Jakarta through 13 rivers that empty into these waters. Among these rivers there are several major rivers, namely Cisadane in the west, Ciliwung River in the centre, also Citarum River and Bekasi River in the eastern part (Lestari [2]).

According to Rochyatun and Rojak [3], the concentration of lead (Pb) in June, in the western, central and eastern part of Jakarta Bay is around 8.49–31.22 ppm, 6.74–50.93 ppm, and 4.42–29.33 ppm, respectively. Here we can see that the highest levels of Pb in the sediments were found in the central part of Jakarta Bay. Lead (Pb) is a heavy metal that pollutes the main Jakarta Bay (Nurjanah Widiastuti [4], Rumanta [5], and Rumanta *et al*. [6]). Pb pollution has affected the aquatic ecosystem in the Gulf of Jakarta. It even has caused the captured makrozoobentos by fishermen in the Gulf of Jakarta to contain a high amount of Pb and has surpassed the threshold set by the CCFAC [7]. In addition, there is a tendency for the Pb content of the fishery products obtained from this ocean to affect the health of the consumers (Rumanta [5, 8]).

The high content of Pb in Jakarta Bay is quite alarming because, despite efforts to prevent contamination of the bay through various programs such as the blue sky and PROKASIH, until now the lead concentrations in the waters of Jakarta Bay still remain high. This happens because, in addition to the ineffective control of domestic and industrial waste disposal around Jabodetabek, heavy metals, especially Pb in waters are very stable and cannot be broken down by organisms.

Nowadays, there has been a lack of studies which reveal the Pb levels in waters surrounding Jakarta Bay. Most of the studies are focused on organic waste that is much more visible. Therefore, we conducted a bioremediation of Pb pollution in Jakarta Bay, with the first step being to know in advance the conditions of the river estuary waters that make a major contribution to Pb pollution in Jakarta Bay to get the attention of the government of Jakarta.

This study aims to: (1) determine the concentration of lead (Pb) in sediments from the rivers that empty into the Bay of Jakarta (Citarum, Bekasi, Cilincing, Marunda, Ciliwung, Sunter, Cideng, Angke, and Cisadane); (2) compare lead concentrations of sediment between the mouth of the rivers; (3) compare the sediment lead concentrations in each of the estuaries in the dry and rainy season.

2 Material and method

The main material used in this study is sediments derived from estuaries around Jakarta Bay. This study also required chemicals, which is necessary for sediment sampling namely HNO_3 (65%), for HNO_3 dilution to reach a concentration of 10%, to soak and wash the sample bottle before use. The chemicals needed for the analysis of Pb in the laboratory using AAS, among others were: HNO_3 (65%), $HClO_4$, aquabides, Whatman filter paper size 42, and a standard solution of Pb.

The equipment used in this study was bottles for sediment samples, tools for sediment sampling (grab sampler), gauges for the degree of acidity and temperature (pH meter and thermometer). The equipment needed for the analysis of Pb in the laboratory using AAS, were, among others: an analytical weighing scale, an oven, volumetric pipette, pumpkin takat, Erlenmeyer glass, watch glass, hotplate, and flame AAS.

2.1 Sampling procedure

Sediment sampling was performed in 9 estuaries (Citarum, Bekasi, Cilincing, Marunda, Ciliwung, Sunter, Cideng, Angke, and Cisadane). At each location sediments were taken in 3 points, which is on the edge of the left and right, and in the middle of the river. Furthermore, the results of the sampling were stirred until evenly mixed (composite). Once evenly mixed, the sample was inserted into the bottle of sediment samples and then washed with 10% HNO_3, given 5–10 drops of concentrated HNO_3 and covered with a lid. These samples were taken in three replicates (triplo) and taken to the laboratory for testing its Pb content using flame AAS. Sediment sampling was conducted in two periods, namely the period of the rainy season and the dry season.

2.2 Pb analysis of sediment samples

Sediment samples were put into a clean porcelain dish, dried in a 60°C oven for 2 days, then the dry weight was calculated. Samples were cooled, HNO_3 was added, then heated on a hot plate with a temperature that gradually increased until it reached 100°C or more. Once dry, the sediment was dissolved in 10% HNO_3, filtered with Whatman 42 paper, then put in a 50ml erlenmeyer and filled with distilled water until the volume reached 50ml.

The reading of Pb levels was done using AAS with light as an energy source and using the 228.8 nm wavelength. The Pb standards used were 0, 0.5, 1.0, and 2.0 µg Pb / ml. Standard Pb was prepared by diluting the working solution (10 µg Pb/ml) with 1 N HCl according to the desired concentration. Lead concentrations (µg/g) measurement results were calculated by the following eqn.

$$\text{Pb level } (\mu g/g) = \frac{(\text{The result of the sample concentration} - \text{blanc}) \times \text{dilution factor}}{\text{Wet weight of sample}}$$

Research data was analyzed using descriptive statistics and a difference test by using one way Anova or Student's t-test to determine differences in the Pb content of any sediment in the dry and rainy seasons. The software used was SPSS version 11.5.

3 Results and discussion

3.1 Pb sediments concentration of river estuaries in the rainy season

The results of the analysis using AAS of sediment samples from nine river mouth locations (Citarum, Bekasi, Cilincing, Marunda, Ciliwung, Sunter, Cideng, Angke, and Cisadane) during the rainy season is shown in Figure 1 below.

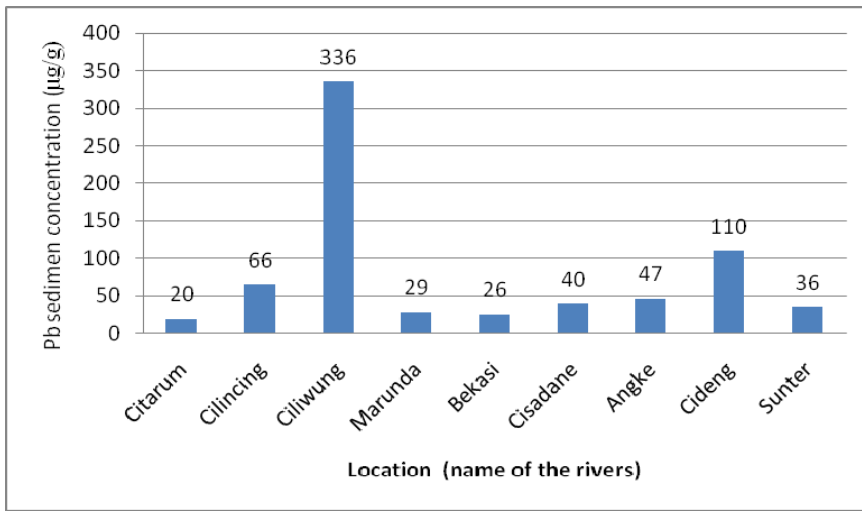

Figure 1: Pb sediment concentration of river estuaries in the rainy season.

In Figure 1 it appears that the Pb content in the rainy season sediment is generally less than 100 µg/g, except in Cideng and Ciliwung River which is 110 µg/g and 336 µg/g, respectively. Pb content of the rainy season tends to be much higher than in the dry season. This can occur because in the rainy season, the water discharge flow increases so the deposition of Pb at the mouth of the river is not as much as in the dry season where the water flow and river velocity is lower. Similarly with the content of Pb in water (data not presented in the paper, but contained in the full report of this study), sediment Pb levels in the rainy season also tend to be higher than in the dry season. This supports the assumption of the presence of a particular industry that utilizes high river discharge to dispose of their waste. Thus the DKI government should continue to monitor the industries along the river to see if they are already treating waste properly and not carelessly discarding their waste into the river around the time of the rainy season.

3.2 Pb concentration of sediment at the mouth of the river in the dry season

The results of the analysis of sediment samples using AAS flame, from nine locations of estuaries (Sunter, Cideng, Marunda, Bekasi, Cisadane, Ciliwung, Cilincing, Citarum, and Angke) in the dry season is illustrated in Figure 2.

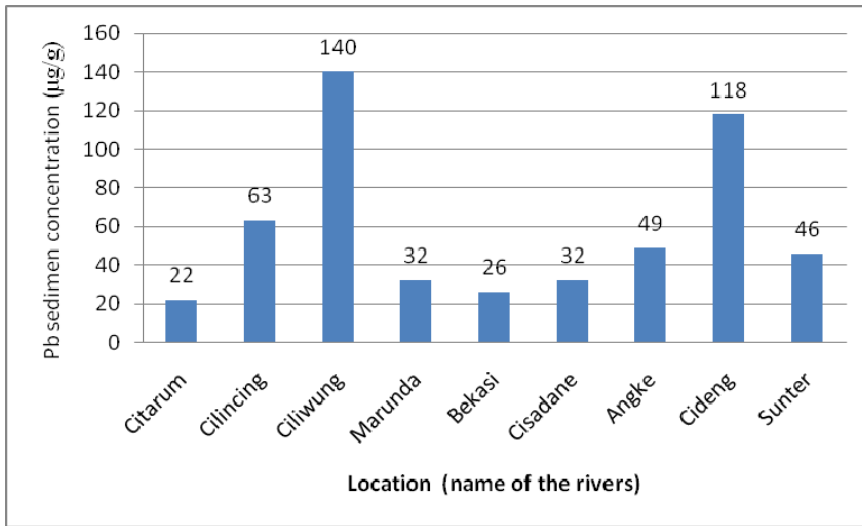

Figure 2: Pb sediment concentration of river estuaries in the dry season.

In Figure 2 it appears that, similar to during the rainy season, the results of the data analysis of sediment samples in the dry season shows Ciliwung River to be a major contributor of Pb pollutant in Jakarta Bay. This is reflected by Pb concentrations in the sediment contained relatively much higher (140 µg/g) compared to other river sediment Pb contents (22–118 µg/g). This shows that the Ciliwung River receives a heavy pollutant load of waste, especially inorganic Pb. This situation is very likely to happen because, in addition to the many industries that dispose hazardous waste in the surrounding watershed, domestic waste also contributes to the high levels of B3 waste, such as waste of batteries, lamps, oil cans, etc. (Sutondo [9]).

Sediment lead concentrations of Cideng estuaries is the second highest rank (118 µg/g) after the Ciliwung, whereas the concentration of Pb in Cideng estuaries is relatively low (0.03 µg/ml) compared to other rivers (data not presented in this paper). This can occur if the condition is sufficiently alkaline, so much Pb is deposited on the sediment surface. In contrast to the mouth of the Cisadane River, the Pb content in the sediment (32 µg/g) is relatively low; in the water it is quite high (0.06 µg/ml) compared to the levels of Pb estuaries Cideng (data not presented in this paper). This can occur if the pH of the water is relatively low (acidic) so that the solubility of Pb increases. Mobilization of Pb from the sediment into the water column usually occurs at low pH, as suggested by Herman [10] in that Pb is relatively insoluble in water at pH <5. This was

supported by Rumanta [8], where the content of Pb in coastal sediments and in the Angke River estuarine in the rainy season is also lower than in the dry season.

An anomaly that occurred at the mouth of the Ciliwung River is that the sediment lead concentrations in the rainy season are higher than in the dry season. This situation may occur if the communities and industries along the river dispose of their waste when the water level of the river rises. It often happens to industrialists who are unaware of the importance of the environment, due to the convenience of throwing waste in the river when the water discharge is high. It seems that the industry and settlements along the thirteen watershed rivers, especially the Ciliwung River need to be evaluated so that there is no more disposal of waste, because although the water discharge at the river having the highest discharge appears safe, the waste will accumulate in the Bay of Jakarta, including heavy metals such as Pb. Accumulation of heavy metals in the water can harm the aquatic ecosystem, including humans in the surrounding area.

If you look at the activities that have been carried out by the Jakarta local government, efforts appear to have been made to improve and manage B3 waste from industries which have been implemented well and socialized to the public and industrialists. The less optimum utilization of B3 waste treatment facilities exist, due to the lack of awareness of most of the players in the industry that have potential as B3 waste producers to manage waste. This can be seen from the results of the evaluation of waste documents (manifest) received by BPLHDs Jakarta Provincial which was either sent by PT, PPLI and/or B3 waste producers in 2004; only about 20 percent of the number derived from existing industries (BPLHD [11]). This shows the weakness of awareness of the industrialists on the importance of the environment. Therefore it is no surprise if the pollution of heavy metals, especially Pb at each mouth of the river from year to year does not show a decline but is more likely to increase. This has led to the increasing pollution of Pb in Jakarta Bay waters, as stated by Arifin and Fadhlina [12] in that over the last 30 years, the concentration of heavy metals in sediments in the waters of Jakarta Bay has increased sharply. This has led to a variety of heavy metal pollution of the marine fishery waters of Jakarta Bay such as fish, shrimp, and shellfish (Inswiari *et al*. [13] and Rumanta [8]). In addition, pelagic fish obtained from outside the Jakarta Bay area which is used as a fishing ground by fishermen, such as in Damar Island and in Angel Island, turned out to be contaminated with heavy metals such as Pb and Hg (Mustaruddin [14]).

3.3 The comparison of Pb sediment levels between river estuaries

The results of the statistical test using one way ANOVA towards the Pb content of sediment among river estuaries in the rainy and dry season can be seen in Table 1.

In Table 1 it is clear that the Pb sediment levels in the rainy season in general showed no significant differences between the river estuaries, except for the Ciliwung River estuary (336.43±166.57μg/g) where the concentration of Pb was significantly much higher than in other estuaries.

Table 1: The comparison of Pb level (μg/g) in sediments among river estuaries in Jakarta Bay during rainy and dry season.

No	Name of river	Level of Pb sediments during rainy season (X ± SD)	Level of Pb sediments during dry season (X ± SD)
1	Citarum	20.00 ± 1.00 A	21.77 ± 1,08A
2	Cilincing	66.00 ± 2.00 A	63.40 ± 1.42B
3	Ciliwung	336.43 ± 166.57 B	139.90 ± 39.49C
4	Marunda	29.00 ± 2.65 A	32.43 ± 1.45A
5	Bekasi	26.33 ± 0.58 A	26.37 ± 0.60A
6	Cisadane	40.00 ± 6.25 A	32.27 ± 0.84A
7	Angke	46.67 ± 9.87 A	48.87 ± 0.75B
8	Cideng	109.67 ± 26.63 A	118.00 ± 3.37C
9	Sunter	36.33 ± 16.26 A	45.70 ± 23.97AB

One way anova: the different letters in the same column indicate significant differences.

Slightly different from the conditions in the rainy season, the concentration of Pb in the sediment of the estuary river in the dry season tends to be more varied. The highest Pb content was found in sediments of the Ciliwung and Cideng river estuary where both were high and there was statistically insignificant Pb content between the two rivers. This occurs because Cideng River receives water from the Ciliwung River. Therefore it is not a surprise if the Pb sediment content of both rivers tended to be high in rainy and dry season. The second group with the highest content of Pb sediment were Cilincing, Angke, and Sunter Rivers. While the third group with the lowest Pb sediment content was the Citarum, Marunda, Bekasi, and Cisadane Rivers. Here it appears that Ciliwung River was the highest contributor of Pb sediment pollutant in Jakarta Bay, especially in the rainy season. The latter group is generally the group of rivers that do not pass through dense housing in the city, such as Bekasi and Citarum River in the east and in west Cisadane. While Marunda is a place for boat repair in Jakarta Bay.

3.4 Comparison of Pb content in water and sediment of river estuaries between seasons

Based on the statistical test using Student's t-test on the Pb content of water and sediment between the rainy and dry seasons can be seen in Table 2 below.

In Table 2 it is clear that the concentration of Pb in sediments in nine sampled estuaries were relatively stable and not significantly different ($p < 0.05$) between the rainy and dry seasons. This can happen because the content of Pb in the sediment is quite large and Pb mobilization from sediments into the water is relatively small and occur on the surface of the sediment. Therefore, although there are fluctuations in the concentration of Pb in the sediment, the fluctuation is generally relatively small, so if statistical tests were done, there were no significant differences. However, there is a tendency for the Pb content of

sediment in the dry season to be higher than in the wet season, except for the Ciliwung River where Pb sediment concentrations of the river estuary in the rainy season tend to be much higher than in the dry season.

Table 2: Comparison of Pb concentration in sediment of river estuaries between seasons.

River estuaries	Pb sediment levels ($\bar{X}$ ± SD), season:	
	Rainy	Dry
Ciratum	20.00 ± 1.00	21.77 ± 1.08ns
Cilincing	66.00 ± 2.00	63.40 ± 1.42ns
Ciliwung	336.43 ± 166.57	139.90 ± 39.49ns
Marunda	29.00 ± 2.65	32.43 ± 1.45ns
K. Bekasi	26.33 ± 0.58	26.37 ± 0.60ns
Cisadane	40.00 ± 6.25	32.27 ± 0.84ns
K. Angke	46.67 ± 9.86	48.87 ± 0.75ns
Cideng	109.67 ± 26.63	118.00 ± 3.37ns
K. Sunter	36.33 ± 16.26	45.70 ± 23.97ns

Student's t-test: ns = no significance difference between the Pb content of the rainy season and the dry season.

4 Conclusion

- Pb concentration of sediment in estuaries are around the Bay of Jakarta is quite high (20–336 μg/g), indicating serious treatment.
- Ciliwung River ranks as the highest contributor of Pb pollutant in Jakarta Bay, followed by Cideng River, while the contribution of other rivers to the Pb pollution in Jakarta Bay were relatively the same.
- The concentration of Pb sediment in estuaries in the dry season is generally higher than in the rainy season. This can happen because the water discharge of the river during the dry season is lower than during the rainy season. However there is a trend for Pb concentrations in Ciliwung River during rainy season to be higher than in the dry season.

5 Recommendation

- Jakarta province needs to improve the supervision and regulation of the industries and settlements in Jakarta, especially those around the watershed of rivers that empty into Jakarta Bay. It is appropriate that industrial waste, office, workshops, large shopping malls, hospitals and domestic premises process properly and do not directly discharge into the waters of the river in the vicinity. It is time for the government of Jakarta

to improve law enforcement efforts to the breaking of rules, so that the aspired-to environmental improvements are realized as planned.

- Along with the PROKASIH program that has already been implemented for quite some time, the management of industrial and residential zones should be done optimally, increasing the EIA for industrial and residential development and obliging the presence of adequate industrial and domestic wastewater treatment and increasing the monitoring of the industrialists and the possibility of mischievous housing development, because the EIA unattended is just rhetoric.
- In this study it appears that all the rivers that flow into Jakarta Bay have been polluted by Pb which has exceeded the threshold and the highest contribution to Pb pollution is the Ciliwung River. Despite the fact that the Ciliwung River has been the object of the PROKASIH program by the Jakarta local provincial since 1989 and used as a raw water source for the city taps. It is necessary for re-structuring and supervision of waste disposal of industrial, office, and domestic around Ciliwung River to take place.

References

[1] Rositasari R. 2011. The Characteristic of the Foraminifera Community in the Jakarta Bay. *Jurnal Ilmu danTeknlogi Kelautan Tropis*. 3(2): 100–111.

[2] Lestari Edward 2004. The impact of heavy metal pollution on water quality and marine fisheries resources (case studies of mass death of fish in the bay of Jakarta). Makara, Science. 8 (2): 52–58.

[3] Rochyatun E. & Rojak A. 2007. Monitoring of Heavy Metals in the Sediments of the Jakarta Bay. *Makara, Sains*. 11(1): 28–36.

[4] Nurjanah Widiastuti R. 1997. Again polluted by heavy metals. In warta Konsumen. Nopember 1997.

[5] Rumanta M. 2005a. *The Pb levels of makrozobentos (Mollusca dan Crustacea) and its effect on consumer health (case study in fishermen village in Muara Angke, Jakarta)*. Disertation. Post Graduate Progam IPB. Bogor.

[6] Rumanta M., Saeni S., Budiarti D. & Djokosetiyanto D. 2005. Pb concentration of waters and fish caught by traditional fishermen in Muara Angke Jakarta Bay. *Jurnal Geografi GEA*. 5 (9): 19–26.

[7] CCFAC. 1999. Maximum level for lead. Joint FAO/WHO food standards programe codex committee on food additives on contaminants. The Hague – The Netherlands. http://www.who.int/fsf/chemicalcontaminants/lead99_19e.pdf. [23 April 2003].

[8] Rumanta M. 2005b. Pb concentration of Custacea caught by Fishermen from Muara Angke Jakarta Bay. *J. Sains dan Tek.* 6(2): 5–13.

[9] Sutondo A. 2012. Ciliwung River is Contaminated by Hazardous Waste. http://green.kompasiana.com/polusi/2012/03/16/sungai-ciliwung-tercemar-limbah-b3-446845.html. [April 2012].

[10] Herman D. Z., 2006, *Review of the Tailings which Consist Arsenic (As), Mercury (Hg), Lead (Pb), and Cadmium (Pb) Contaminants from the Wastes of Metal Processing.* Center of Geologic Resources. Bandung.
[11] BPLHD DKI Jakarta. 2012. Pressure towards the Environment. Book I. http://bplhd.jakarta.go.id/slhd2012/Docs/Lap_SLHD/Lap_3J.htm [1 January 2014].
[12] Arifin Z. & Fadhlina D. 2009. Fraccination of heavy metals Pb, Cd, Cu, and Zn in Sediments and its Bioavailability towards the Biota of the Jakarta Bay Waters. J. Ilmu Kelautan. 14(1): 27–32.
[13] Inswiari A., Tugaswati T., & Lubis A. 1997. Metal levels Cu, Pb, Cd, dan Cr in Fresh Fish and Shellfish from the Jakarta Bay. *Bul. Penelit. Kesehat*. 25(1):19–26.
[14] Mustaruddin. 2013. The Pattern of Hg and Pb Pollution on the Fishing Ground and Caught Fishes by Fishermen: Case Study in Jakarta Bay. *J. Bumi Lestari*. 13(2): 214–224.