

The comparison of heavy metals (Pb and Cd) in the water and sediment during spring and neap tide tidal periods in Popoh Bay, Indonesia

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Abstract. This study attempted to investigate different concentration of lead (Pb) dan cadmium (Cd) in the water and sediment during spring and neap tidal periods in the Popoh Bay, Indonesia. Water and sediment samples were taken during spring and neap tides from eight sampling stations in the study area. The result shows higher concentration of Pb than the concentration of Cd in both spring and neap tides due to higher input of Pb from the oil pollution by boat and fisheries activities. Pb concentrations were doubled during neap tide in both water and sediments with the value of 0.51 and 0.28 ml/L in the water during neap and spring tide, respectively; and 0.27 ppm and 0.16 mg/kg in the sediment during neap and spring tide, respectively. On the other hand, Cd concentrations in the water were found in almost similar values between spring and neap tide (0.159 and 0.165 ml/L in spring tide and neap tide, respectively), but in the sediment, the concentration was a little higher during spring tide (0.09 and 0.05 mg/kg during spring and neap tide, respectively). This study shows that water movement during spring and neap tides has significant effect on the distribution of heavy metals.

1. Introduction

Heavy metals can be considered as pollutants to the environment due to its characteristics that are stable, persistent, non-biodegradable and toxic at certain levels. It enters the aquatic environment mostly through anthropogenic activities, either from domestic or industrial waste waters [1, 2, 3, 4]. Once in the water column, it can be transferred to sediments by the processes of adsorption onto suspended matter and sedimentation [5, 6]. The availability of metals in the water column that can be absorbed by soil depends on environmental conditions, such as pH [7, 8], redox potential [9] and organic content [10].

Water movement has been known to have roles in the circulation process of the aqueous environment such as influencing the distribution of nutrients, carbon and trace metals. Water movement, such as tidal exchange is important in controlling heavy metal distribution, especially in the estuaries and coastal areas. Spring-neap variations in tidal flow dominate in narrow, shallow estuaries [6, 11, 12] could drive the mechanism of heavy metal transports by suppressing the stratification of water column. Moreover, tidal regimes could result in the variations of the redox potential in the



sediment that can lead to the differences in metal concentration, as [9] found that metal concentrations in the pore water were generally lower in sites with higher inundation frequency due to tidal effects.

Popoh Bay is a semi-enclosed waters connected to the Indian Ocean. It receives metal input derived from multiple sources. The western side of the bay is dedicated to aquaculture activities that might discharge heavy metals from the culture system and feed. The eastern side of Popoh Bay is highly influenced by fishery activities from the fishing port. Moreover, this area is also subject to contribute metal pollution from tourism activities from several beaches surrounding the bay that are popular among the local people. Water movement from tidal periods (spring-neap tides) may have a significant impact on the distribution of the metal concentrations in this semi-enclosed waters that is connected to the open ocean. Therefore, the aim of this study was to determine the concentrations of Pb and Cd in the seawater and sediments during the spring and neap tidal periods; and to compare the distribution patterns of Pb and Cd in the seawater and sediments between the spring and neap tidal periods.

2. Methodology

The study was conducted in Popoh Bay, Tulungagung, which is located in the southern part of Java Island (Latitude $8^{\circ}26'84.85''\text{S}$ - $8^{\circ}25'91.70''\text{S}$ and Longitude $111^{\circ}77'36.18''\text{E}$ - $111^{\circ}80'16.10''\text{E}$). Samples were taken in May 2016 from eight sampling stations (figure 1) that could represent water quality parameters in the bay. Sampling was conducted in two periods, the first one was on May 11th (spring tide) and the second sampling was conducted one week after on May 18th (neap tide).

Heavy metal samples in the seawater were collected from the surface and placed in 250 ml bottles that were pre-washed with HNO_3 polyethylene. Seawater samples were then acidified by adding 10 ml HNO_3 . Heavy metal samples in the sediment were collected using a grab sampler at 0-10 cm depth. About 1 kg of sediments were obtained and stored in tightly sealed plastic bags. The grab sampler was washed with seawater before subsequent sampling to avoid contamination from the previous sample. Both the seawater and sediment samples were preserved in iceboxes before further analysis in the laboratory. Water quality parameters measured were for temperature, salinity, pH, DO and current.

In the laboratory, the seawater samples were filtered through $0.45 \mu\text{m}$ filter paper and Pb and Cd concentrations were measured using flame atomic absorption spectrometry. Sediment samples were air dried at 105°C for about 3 hours and ground using a mortar and pestle. About 1 g of sediment was placed in the erlenmeyer and then added with HNO_3 and H_2SO_4 and left to destruct for about 3 hours at 120°C . The samples were filtered and the concentrations of Pb and Cd were measured using flame atomic absorption spectrometry.

The Pearson's correlation test was conducted to test the relationship between water quality parameters and heavy metal concentrations in both spring and neap tide tidal periods. Independence students' t-tests were analysed to compare heavy metal concentrations between spring and neap tidal periods in both seawater and sediments samples. Prior to conducting the test, the normality and homogeneity of data were checked using the Shapiro-Wilk test. All statistical analyses were calculated using SPSS 16.0.

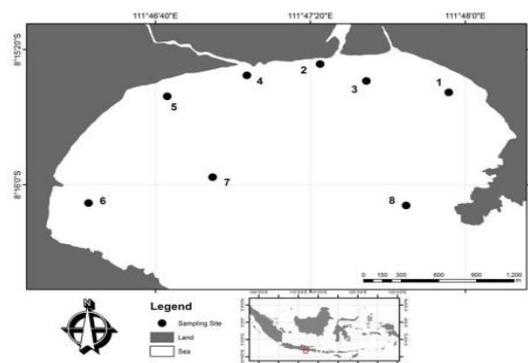


Figure 1. Study area and sampling sites in Popoh Bay, Tulungagung, Indonesia.

3. Result and discussion

The distribution of Pb concentrations in the seawater and sediments in Popoh Bay, Tulungagung are shown in fig. 2. The concentrations in the seawater were in the range of 0.40 – 0.57 ml/L and 0.16 – 0.43 ml/L during neap tide and spring tide, respectively. In the sediments, Pb concentration was in the range of 0.16 – 0.44 mg/kg during neap tide and in the range of 0.05 – 0.30 mg/kg during spring tide. Pb concentrations were found higher during neap tide for both the seawater and the sediments. This result is similar to the result of the study conducted by Teuchies et al. [9] that found lower metal concentrations in the site with higher inundation frequency compared to the one in the lower inundation frequency due to the mobility of metal which is lower under flooded conditions.

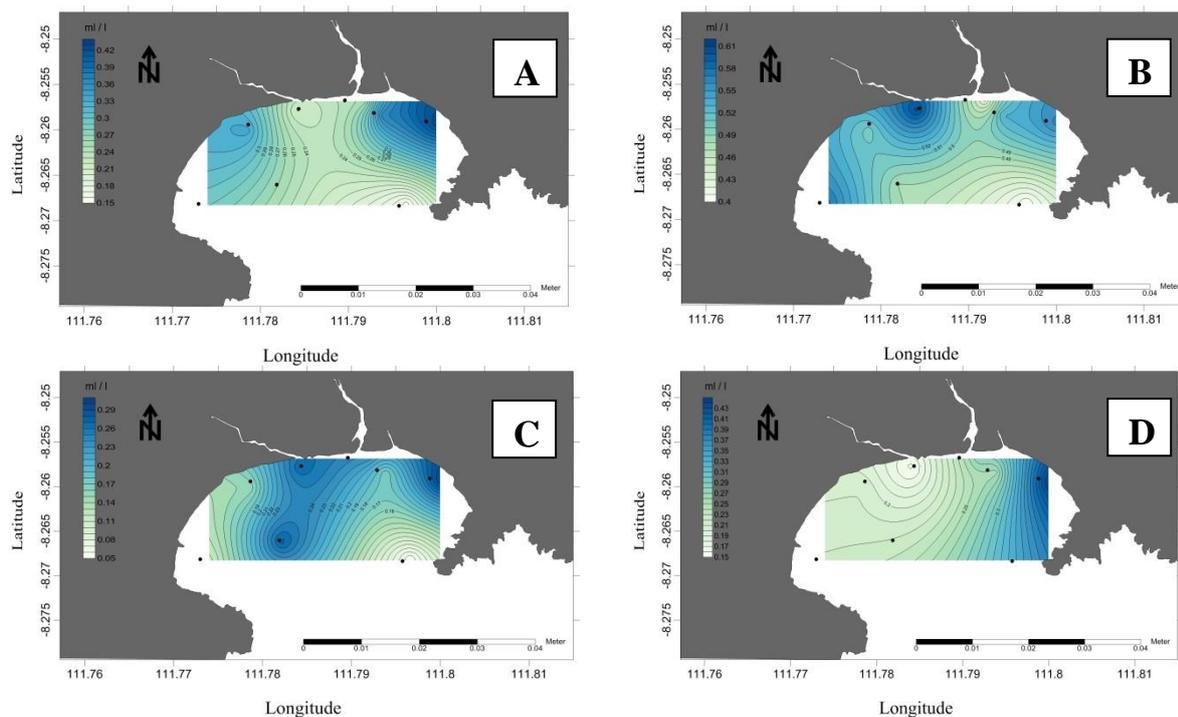


Figure 2. Distribution of Pb in the seawater during spring tide (A) and neap tide (B) and in the sediments during spring tide (C) and neap tide (D) in the Popoh Bay, Tulungagung.

Cd distribution patterns were found to be different between the spring and neap tidal periods for the seawater and sediments (fig. 3), but the concentrations were very much higher in the seawater than in the sediments. Cd concentrations in the seawater were found in the similar range between spring and neap tide (0.08 – 0.23 ml/L and 0.12 – 0.21 ml/L, respectively). However, higher concentrations were found in the sediments during spring tide (0.07 – 0.12 mg/kg) compared to during neap tide (0.02 – 0.08 mg/kg). Metals tend to accumulate in the sediment due to the lower mobility of metals under flooded conditions [9].

Spatial distribution of the metal concentrations were varied across the sampling areas between both tidal periods (fig. 2 and fig. 3). Higher Pb concentrations were observed in the seawater in the western and eastern sides of Popoh Bay during the spring and neap tidal periods. On the other hand, the Pb concentration in the sediments shows higher concentration only in the eastern side of Popoh Bay during neap tide. The spatial distribution patterns of Cd were observed and were rather similar to the spatial distribution of Pb. Higher concentrations were found in the western and eastern sides of the

study areas. The significant contribution of heavy metals in these sites were mainly due to the heavy activities from aquaculture (western side) and fisheries (eastern side).

Results of the t-test showed that there were significant differences of Pb concentrations in the seawater and Cd concentrations in the sediments ($p < 0.05$) between spring tide and neap tide tidal periods (table 1). On the other hand, Pb concentrations in the sediments and Cd concentrations in the seawater did not show significant differences between both tidal periods. These differences might be the result of the variability in the water capacity [13] during the tidal periods that influences the concentration of heavy metals to the environment. This variability of water capacity may be related to the tidal current, and the result was supported with the correlation between the current and heavy metal concentrations especially Pb. According to table 2, a strong negative correlation can be observed between the Pb concentration in the seawater during spring tide with the current ($r = -0.790$, $p < 0.05$) and also between Pb concentrations in the sediments during neap tide with the temperature ($r = -0.916$, $p < 0.05$) and current ($r = -0.927$, $p < 0.05$).

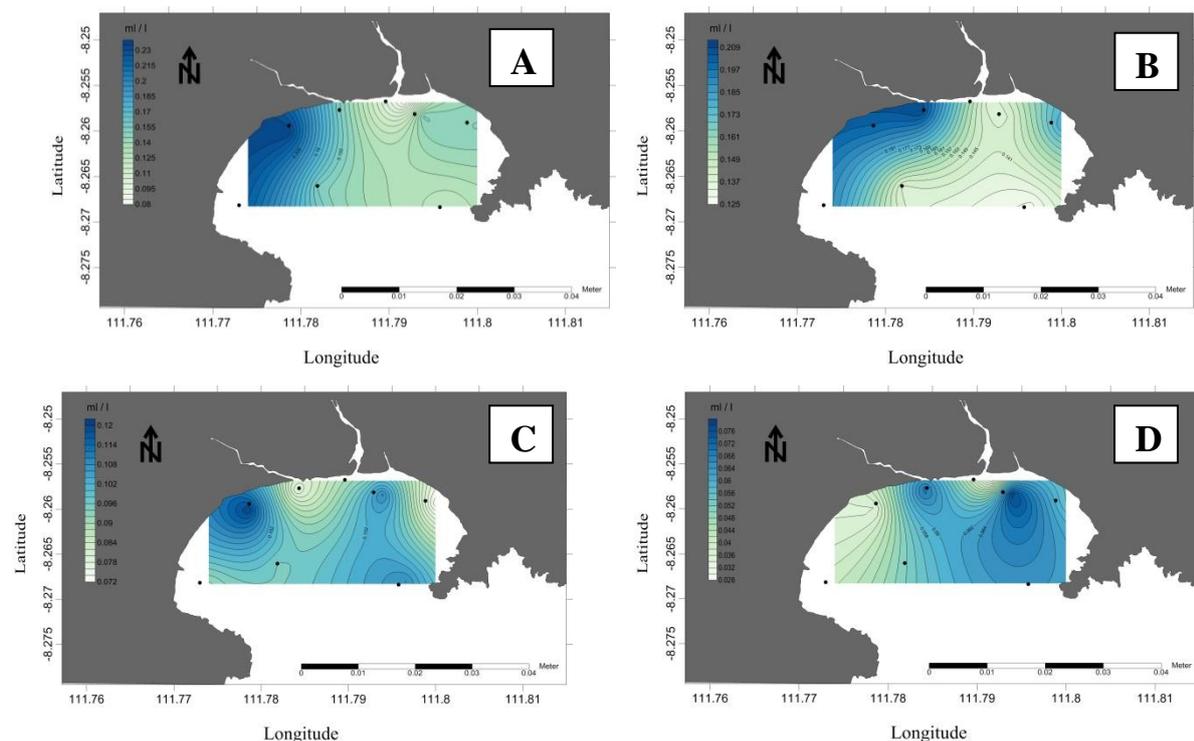


Figure 3. Distribution of Cd in the seawater during spring tide (A) and neap tide (B) and in the sediments during spring tide (C) and neap tide (D) in the Popoh Bay, Tulungagung.

Table 1. Results of t-test for tidal variability of heavy metal concentrations in the seawater and sediments

	t value	P value
Pb in seawater	-5.741	0.000
Pb in sediments	-1.329	0.211
Cd in seawater	-0.286	0.779
Cd in sediments	4.114	0.002

Changes in the water flow during tidal periods have been understood to play a significant role in controlling the transport of materials into the estuary and coastal regions [11, 12, 14, 15]. Shaha et al.

[12] in their study revealed that spring tide can cause the well-mixed conditions and rapid exchange of materials due to larger tidal amplitude, while neap tide causes stratification of the water column due to the reduction in vertical mixing. Moreover, this phenomenon might also affect soil conditions and pore water, causing the release of metals to the overlying waters [9, 16]. The results of this study found a variability of heavy metal concentration in the seawater and sediment during the spring and neap tidal periods. Tidal periods caused significant differences in the distribution of Pb in the seawater and Cd in the sediments (table 1).

Table 2. Correlation between heavy metal concentrations and environmental factors during spring and neap tidal periods.

	Temperature	Salinity	DO	pH	Current
Spring tide (n = 8)					
Pb in seawater	-0.590	-0.695	-0.373	-0.147	-0.790*
Pb in sediments	-0.637	-0.670	-0.685	-0.518	-0.298
Cd in seawater	0.318	0.364	0.122	0.079	0.023
Cd in sediments	0.460	0.579	0.382	0.795*	0.395
Neap tide (n = 8)					
Pb in seawater	0.399	-0.428	-0.285	-0.470	0.041
Pb in sediments	-0.916*	0.131	-0.457	0.447	-0.927*
Cd in seawater	0.350	-0.495	-0.246	-0.586	-0.017
Cd in sediments	0.290	-0.458	-0.467	-0.297	0.364

* correlation is significant at the 0.05 level (2-tailed).

4. Conclusion

This study shows that the concentrations of Pb and Cd in the seawater and sediments were varied between spring and neap tides with generally lower values of metals during spring tide. The variability was significantly due to the water movement which occurred during the tidal period, where the current and temperature have a rather significant effect especially on Pb concentration. Higher concentrations for both metals were observed in the western and eastern sides of the study area that were related to heavy activities of aquaculture and fisheries.

5. References

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