Heavy metals (Pb and Cd) contents in the seawater and sediment in Panjang and Pamujaan Besar Islands, Banten Bay, Indonesia

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Abstract. The industrial activities in the coastal area of Banten Bay harmed water quality and tourism aesthetics. This study aims to determine the accumulation of heavy metals Pb and Cd in the water and sediment, which was conducted for 3 months from May until July in 2019 in Pulau Panjang and Pamujaan Besar. Data were collected by using the purposive sampling method. The water samples were studied using Van Dorn Water Sampler, while sediment samples were undertaken using Peterson Grab. The concentration of Pb and Cd in water and sediment were analyzed at the Environmental Laboratory of the Department of Aquaculture. Those Concentrations in waters and sediments were the highest in June than in other months. In general, the water quality was still classified as normal because it was under the quality standards of the Decree of Ministry of Environment No. 51 of 2004. Heavy metal in Banten Bay fluctuated while Pb exceeded the quality standard in June and decreased in May and July. While Cd metal in May and June exceeded the quality standard and then declined in July. Those concentrations were still below the standard limits of the Canadian Council of Ministers of the Environment 2001.

1. Introduction

Heavy metals refer to a metallic element with a density value of more than 5 gr.m⁻³, which is classified as pollutants. Those metals can accumulate in the water, sediment, and aquatic organisms such as mangrove crabs [1, 2, 3, 4]. This dangerous element comes from the waste of human activities on the land that is carried out by the river to the sea [5, 6, 7, 8]. This condition is important to identify because the coastal area is commonplace where humans live around 70% of the world's population live there, leading to massive waste contaminating the water [9].

As one of the coastal in Indonesia, Banten Bay is the entrance to the waste from Serang Regency [10]. Due to many activities including industry, port, tourism in the surrounding area, the waste directly impacts the quality of the water and fishery resources [11]. One type of waste that is considered dangerous is heavy metals. That particular element accumulated in sediment can transfer toxic chemicals to the aquatic organism. When they are consumed by humans, it can lead to being serious health issues [12]. High concentrations of heavy metals such as Pb and Cd can cause acute poisoning that shows
symptoms such as hypertension, liver and kidney disease, low level of calcium in bones [13, 14, 15, 16, 17, 18].

Monitoring heavy metal pollution both in water and sediment in Banten Bay waters needs to be studied that aims to determine the heavy metal content of Pb and Cd in both media. The results can be references for evaluating and determining regulations for environmental management of Banten Bay coastal waters.

2. Material and Methods

2.1. Time and Location
This research was conducted from May to July 2019 in Panjang and Pamujaan Besar Islands in Banten Bay, Serang Regency of Banten Province. The samples were taken from some different stations namely St1, St2, and St3 in Panjang Island and St 4, St 5, and St 6 in Pamujaan Besar Island (Figure 1).

![Figure 1. Map of seawater and sediment sampling stations in Banten Bay](image)

2.2. Preparation and Protocols of Sampling
This study was conducted by using purposive sampling due to the possibility of heavy metals impact. It includes the observation to the water based on Physico-chemical parameters. Some water quality parameters were also measured in-situ, such as temperature, transparency, pH, dissolved oxygen (DO), and salinity. Meanwhile, the rest was done ex-situ for total suspended solids (TSS), biochemical oxygen demand (BOD), total ammonia nitrogen (TAN), and heavy metals of Pb and Cd.

Seawater samples were taken using a Van Dorn Water Sampler which able to reach the bottom surface. Then the water sample was collected in a 500 ml polyethylene bottle and preserved with nitric acid (HNO₃) until the pH of the sample reaches ± 2. The bottles containing the water samples were labeled and stored in a cool box containing ice. Sampling was taken three times at each station. On the other hand, the sediment was collected using the Peterson Grab that can be lowered to the bottom of the surface layer (0-20 cm). It was also taken three times in each station. The substrate sample was put into polyethylene plastic, labeled, and stored in a cool box filled with ice.

Ex-situ analysis of water using Physico-chemical parameters referred to the method [20] conducted in Aquatic Resources Laboratory, Bogor Agricultural University. Atomic Absorption Spectrophotometric (AAS) method were used to analyze heavy metals specifically Pb and Cd at waves 217.0 and 228.72 nm.
2.3. Data Analysis

The result of Pb and Cd measurement in the seawater was set based on State Minister of Environmental Decree No 51 of Indonesia about seawater quality [21]. The concentration of heavy metals in sediments and attention to marine life [22 and 23] use the SQG-Q (Sediment Quality Guidelines) guidelines [24]. The guidelines are presented in Table 1.

\[
P E L - Q_i = \frac{\text{Contaminant}}{P E L} \quad (1) \quad SQG - Q = \frac{\sum_{i=1}^{n} P E L - Q_i}{n} \quad (2)
\]

Description:
\(PEL-Q_i\) = Contaminant concentration are measured by the PEL value

\(SQG-Q\) = Several contaminant parameters were added and then divided by the total amount of evaluated contaminant

### Table 1. SQG-Q Category

| Class       | Categories                              |
|-------------|-----------------------------------------|
| SQG-Q < 1   | Unaffected, the lowest potential for observing adverse biological effects |
| 0.1 < SQG-Q < 1 | Moderate potential to observe adverse biological effects |
| SQG-Q ≥ 1   | The most potential to observe adverse biological effects |

Source: [23]

3. Result and Discussion

3.1. According to the Result of Research

According to the study, most parameters in Banten Bay waters evaluation were still below the standard limit. Those good parameters are salinity, pH, DO, BOD, and TAN (Table 2). This is in line with the previous studies conducted in the same area [24, 25, 26]. However, temperature and transparency parameters exceed the standard. Temperature is considered to be influenced by the weather at the time of conducting. Meanwhile, for the transparency, it is correlated with several rivers such as Cibanten, Cibeureum, Cengkok, Cikadeun, and Ciruas [27], that flow to Banten Bay. Those rivers, especially in the wet season, contribute suspension and other organic particles in the water, leading to a low light level. When the penetrated light is low, photosynthesis in the water cannot occur.

### Table 2. Water quality measurement result in Banten Bay

| Months  | Temperature (°C) | Transparency (M) | Salinity (Psu) | pH | DO (Mg.l.-1) | BOD (Mg.l.-1) | TAN (Mg.l.-1) |
|---------|-----------------|------------------|---------------|----|-------------|---------------|--------------|
| May     | 30.00-32.70     | 3.50-3.70        | 30.00-32.70   | 7.20-7.70 | 6.90-9.70   | 1.80-3.50     | 0.04-0.06    |
|         | (31.50±1.37)   | (3.63±0.12)      | (31.50±1.37)  | (7.33±0.15) | (8.17±1.42) | (2.40±0.95)   | (0.05±1.01)  |
| June    | 31.60-32.60     | 3.40-3.70        | 31.60-32.60   | 7.40-7.60 | 5.50-8.80   | 30.10-3.80    | 0.00-0.05    |
|         | (32.13±0.50)   | (3.62±0.26)      | (32.13±0.50)  | (7.50±0.10) | (7.40±1.66) | (3.33±0.40)   | (0.03±0.03)  |
| July    | 31.00-31.40     | 3.05-3.40        | 31.00-31.40   | 7.20-7.50 | 6.60-8.00   | 4.90-5.00     | 0.02-0.05    |
|         | (31.21±0.20)   | (3.27±0.19)      | (31.21±0.20)  | (7.30±0.17) | (7.40±0.06) | (4.97±0.06)   | (0.04±0.02)  |
| Seawater Standard Quality | 28-30 | >5 | 33-34 | 7-8.5 | >5 | 20 | 0.3 |

### Table 2. Water quality measurement result in Banten Bay

| Months  | Temperature (°C) | Transparency | Salinity (Psu) | pH | DO (Mg.l.-1) | BOD (Mg.l.-1) | TAN (Mg.l.-1) |
|---------|-----------------|--------------|---------------|----|-------------|---------------|--------------|
| Parameters in Pamujan Besar Island |
| Temperature | Transparency | Salinity (Psu) | pH | DO (Mg.l.-1) | BOD (Mg.l.-1) | TAN (Mg.l.-1) |
| Months  | °C   | M       | Psu   | -  | Mg.l.-1 | Mg.l.-1 | Mg.l.-1 |
| May     | 30.00-32.70     | 3.50-3.70   | 30.00-32.70 | 7.20-7.70 | 6.90-9.70 | 1.80-3.50 | 0.04-0.06 |
| June    | 31.60-32.60     | 3.40-3.70   | 31.60-32.60 | 7.40-7.60 | 5.50-8.80 | 30.10-3.80 | 0.00-0.05 |
| July    | 31.00-31.40     | 3.05-3.40   | 31.00-31.40 | 7.20-7.50 | 6.60-8.00 | 4.90-5.00 | 0.02-0.05 |

Seawater Standard Quality 28-30 >5 33-34 7-8.5 >5 20 0.3
3.2. **Heavy Metal Concentrations in Seawater**

Pb concentrations in Banten Bay waters were around <0.002-0.125 mg.l-1. It fluctuated from May (0.006 mg.l-1), June (0.027 mg.l-1) to July (0.004 mg.l-1). It is seen that Pb concentration surpassed the standard value which is 0.008 mg.l-1 only in June. This result is in line with [28] research in Mauk and Kronjo mouth river. On the other hand, Cd concentrations in Banten Bay waters were around <0.002-0.013 mg.l-1. It fluctuated from May (0.005 mg.l-1), June (0.009 mg.l-1), and July (<0.002 mg.l-1) (Tabel 3). It is seen that Cd concentration surpassed the standard value which is 0.001 mg.l-1 both in May and June. This result is similar to [28] research in Mauk dan Kronjo mouth river.

| Month | Station | Pb Water (mg.l-1) | Pb Sediment (mg.kg-1) | Cd Water (mg.l-1) | Cd Sediment (mg.kg-1) |
|-------|---------|------------------|----------------------|------------------|----------------------|
| May   | St1     | <0.002           | 0.27                 | <0.002           | <0.002               |
|       | St2     | <0.002           | 0.173                | <0.002           | <0.002               |
|       | St3     | 0.006            | <0.002               | <0.002           | 0.170                |
|       | St4     | 0.003            | <0.002               | 0.004            | 0.272                |
|       | St5     | 0.009            | <0.002               | 0.005            | <0.002               |
|       | St6     | <0.002           | <0.002               | 0.006            | <0.002               |
|       |         | **Average and SD** | **0.006±0.003** | **0.222±0.069** | **0.005±0.001** | **0.221±0.072** |
| June  | St1     | 0.004            | 2.868                | 0.007            | 0.046                |
|       | St2     | 0.005            | 13.666               | 0.011            | 0.442                |
|       | St3     | 0.007            | 2.519                | 0.013            | 0.299                |
|       | St4     | 0.012            | 18.447               | 0.009            | 0.361                |
|       | St5     | 0.009            | 3.016                | 0.007            | 2.196                |
|       | St6     | 0.126            | 17.289               | <0.002           | 2.343                |
|       |         | **Average and SD** | **0.027±0.049** | **9.634±7.651** | **0.009±0.003** | **0.948±1.033** |

Table 3. The results of water and sediment measurement for heavy metals in Banten Bay.
The concentration of heavy metals is influenced by the surrounding environment. According to [29] the water condition itself can be a huge factor. Certain pH levels can lead heavy metals to ionize to the water, increasing the amount of concentration [30]. The stream water also adds impact on heavy metal concentration. According to [8] it is stated that current can transfer heavy metals to Pamujaan Besar Island. This particular island is near Karangatu port and several mouth rivers such as Cibanten, Cibeureun, Cengkok, Cikadeun, and Ciruas [27]. Heavy metals such as Cd and Pb resulted from human activities [11] can easily be transferred from port and those mouth rivers’ streams to the sea. Besides that, rainwater streams from land contribute to high concentration of heavy metals [31].

3.3. Heavy metal concentration in sediment

Pb concentrations in Banten Bay's sediment way around (<0.002-18.447 mg.kg⁻¹). The detail shows the average in May (0.006 mg.kg⁻¹), June (0.634 mg.kg⁻¹), and July (0.709 mg.kg⁻¹). It is seen that the average concentration still below the standard quality. This is mainly happened due to the mangrove forest’s existence around Cibanten, Cengkok, and Ciujuung mouth river in coastal of Banten Bay. This forest is the one that maintains the water quality. This is in line with the [32 and 33] that states mangroves as a natural seawater filter. This biofilter feature allows mangroves to reduce the levels of toxic material in the form of household waste and excess sediment [33]. On the other hand, Cd concentrations in Banten Bay's sediment were around <0.002-2.343 mg.kg⁻¹. Cd's average concentration in May (0.221 mg.kg⁻¹), June (0.948 mg.kg⁻¹), and July (<0.002 mg.kg⁻¹), that not surpassing the limit standard in all of the stations.

In comparison, Pb and Cd concentration in the sediment is higher than in the water. This result is similar to the previous research [34, 35, 8, 4]. Sediment is said to be the last place that contains heavy metals [4]. After being carried by small particles on the water, they fall and accumulate. They are also bonded together causing them to be more solid than another ion [37]. In the case of Ciujuung Lama River, dust and clay contribute high concentration of heavy metals as well [27, 38]. These reasons promote a higher concentration of heavy metal on sediment than the water. This is dangerous because it can lead to aquatic ecosystem contamination [39].

Heavy metals occur from natural or human activities [40]. For manmade heavy metals, the huge contributors are industry, farming, and household [41]. The usual waste form of heavy metals are batteries, electronic waste, and paint tin [42]. In the Banten Bay area, there are paint industry, chemical industry, metal coating, manufacturing industry, pesticide industry, and thermal power plant which produce heavy metal waste especially Cd. Near the place of this research, there is a shipyard that builds repairs, and also redos ships. The process of painting and coating the ship adds heavy metal concentration specifically Pb [43]. From farming, phosphate fertilizer contains such a high level of Cd [44]. According [45], motor vessels also contribute heavy metals to the water of Banten Bay. It can be seen that the more industrial activities occur in the water area, the more heavy metal waste can accumulate [46]. Industry can negatively impact the quality of water [11].

Based on ANZECC/ARMCANZ (2000) [21], Pb and Cd concentration in sediment is still below ISQG low and ISQG high. This is in line with what was done the metal content of Pb and Hg in the waters of Cengkok Beach, Banten Bay, ranged from 0.005 to 0.108 ppm [47]. Moreover, based on CCME (2001) [22], the average concentration of Pb and Cd is still below PEL and ISQG values. Both of them show that the Pb and Cd's containment on sediment has not been negatively affecting the aquatic ecosystem, as seen in Table 4 and Figure 2.
Table 4. Comparison of Banten Bay’s sediment quality with the standard guidelines

| Locations                  | Pb     | Cd     |
|----------------------------|--------|--------|
| Banten Bay waters          |        |        |
| Minimum                    | 0.001  | 0.001  |
| Maximum                    | 18.447 | 2.343  |
| Rata-rata                  | 3.499  | 0.341  |
| ANZECC / ARMCANZ Guidelines|        |        |
| Low                        | 50     | 1.5    |
| High                       | 220    | 10     |
| CCME                       |        |        |
| ISQG*                      | 30.2   | 0.7    |
| PEL**                      | 112    | 4.2    |

(*) ISQG, interim sediment quality guidelines
(/**) Probable effect levels

Figure 2. PEL-Qi and SQG-Q values of heavy metals in sediment’s Banten Bay

4. Conclusions

Water quality in Banten Bay still met the standard value. Based on State Minister of Environmental Decree No 51/2004 of Indonesia, most parameters showed good results under the standard limit. Only temperature and transparency levels exceed the standard due to the weather and season when conducting. Heavy metal concentration in Banten Bay, throughout May to July 2019, it was seen that the average amount of Pb in the water surpassed the standard value in June. While Cd’s average amount in the water surpassed the standard in May and June. It indicated fluctuation for Pb and Cd concentration in seawater throughout the study. Meanwhile, the result showed the average concentrations of Pb and Cd in sediment are still below the standard limit of CCME 2001.

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