Analysis of mercury and its distribution patterns in water and sediment samples from Krueng Sabee, Panga and Teunom rivers in Aceh Jaya

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Abstract. Analysis of mercury (Hg) in water and sediment samples from Krueng Sabee (KS), Panga (P) and Teunom (T) rivers have been carried out. Water and sediment samples were collected at three different sampling points. Concentration of mercury was determined by using Atomic Absorption Spectrophotometer (AAS). Measurement of temperature, pH and salinity of the water samples was carried out in situ method. The results of in situ measurements showed a temperature ranges of 24 to 32 °C, pH of 6 - 8 and salinity of 0.1 - 0.3. Based on the analysis of samples, the concentration of mercury in water and sediment samples during March 2019 (sunny condition) were 0.3328 and 6.2330 µg/L, respectively and April 2019 (rainy condition) were 0.0560 and 0.2778 µg/L, respectively. Evaluation of the pattern of Hg distribution in water and sediment samples was conducted by the Principal Component Analysis (PCA) method. The result of PCA analysis in sediment samples showed a strong correlation between Hg concentration at the KS1 and KS2 sampling points. Meanwhile, the concentration of Hg in water samples showed a strong correlation at sampling points of T2 and T3.

1. Introduction

Industry, energy exploitation, and mining activity often caused environmental problems such as polluted waters, decline of natural resources potential and quality, critical land, health problems, disasters, and sedimentation in the river downstream [1]. This works often use or produce a metal in the process [2] that is easy to expose to water resources such as river and lake. The metal, especially the heavy metal, gives negative impact to human [3] and [4] or living organism that utilized the water [5]. The precipitated mercury can form a further accumulation with other heavy metals, which leads to a higher sedimentation surface compared to the water body itself [6]. Heavy metal condition in the bottom of the water may vary depending on the flow pattern and the events history of the river [7,8].

The water of Krueng Sabee, Panga and Teunom rivers is sourced from Gunong Ujeun mountain. In this mountain, it takes place local gold mine. The traditional gold plants that use mercury as gold separator agent were built along the river flow starting from foothills to the village. This condition makes the river very likely to be exposed by the mercury waste. The use of mercury to extract gold even in small scale gold mining has shown harmful indication and became an environmental disaster [9,10]. The mercury waste often contained the surface water and accumulated in the riverbed [11]. For

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health and environmental purposes, the tracking of transport pattern and mapping of mercury in environment around gold mine area, especially in water resources, is critically needed. Therefore, the objective of this present works was to evaluate the concentration of mercury and its distribution pattern in water and sediment samples from Krueng Sabee, Panga and Teunom rivers.

2. Material and methods

2.1. Site sampling and in situ measurement

Water and sediment samples of Krueng Sabee (KS), Panga (P) and Teunom (T) rivers were collected twice in March 2019 (sunny condition) and April 2019 (rainy condition). The map of sampling location was depicted in Figure 1. The sampling points were determined by purposive sampling method with three sampling point in each river (upstream (1), median (2) and downstream (3). Samples taken are random between morning and afternoon. Sediment samples are collected by using Ekman Grab on specific depth. In situ measurement were carried out which included pH, temperature and salinity of the water samples.

![Figure 1. Location map of the region and sampling sites.](image)

2.2. Samples preparation and mercury measurement

Water sample was prepared by introducing 50 mL of the sample into erlenmeyer and dried until it left 15 mL using water bath. 5 mL of HNO₃ was added into the sample and then heated for 15 min. Acid added and heated were repeated twice. Sediment sample was prepared by introducing 5 g of sediment into a cup and dried it in oven at 105°C for 12 h. Then, the sample is mashed up until it is homogenous. 5 mL HNO₃ was added into the sample and heated for 15 min. Acid added and heated were repeated twice. Next, the sample was filtered into an Erlenmeyer and added by 25 mL of distilled water. Mercury concentration was measured by using Atomic Adsorption Spectroscopy (AAS). The distribution spread pattern of mercury in water and sediment samples was analysed using Principal Component Analysis (PCA) method [12]. Mercury concentration data sets were applied to XLSTAT software. The results were displayed into Biplot between active variables and observations [13,14].

3. Result and discussion

3.1. In situ measurement

The result of in situ measurements was displayed in Table 1. According to Table 1, the pH value of water surface in Krueng Sabee, Panga, and Teunom rivers in March and April 2019 are in average of 7.62 - 7.70 and 6.67 - 6.83; 7.10 - 7.88 and 6.70 - 7.07; 7.10 - 7.88 and 6.70 - 7.07, respectively.
Distribution of pH value was suitable with the quality standard set by the Government. The pH value in water has significant influence on organisms that it is often used as indication of polluted water. Meanwhile, temperature of the aquatic environment has an impact on solubility of heavy metals in water. The formation of heavy metal ions increases at a higher temperature. So that it will increase the metal deposition through metal adsorption by the sediments. The water temperature of Krueng Sabee, Panga, and Teunom rivers in March and April (sunny and rainy condition, respectively) are in range of 26.93 - 28.17 and 27.10 - 27.63; 29.90 - 32.37 and 25.50 - 27.13; and 26.67 - 27.93°C, respectively. A high value of salinity increases a chloride ion formation, which is associated with a decrease of heavy metal ions in the waters. According to Suryono [15], the metal accumulation increases at low water salinity. The salinity of surface water of Krueng Sabee, Panga, and Teunom rivers in March and April are in range of 0.23 - 0.43 and 0.13 - 0.27; 0.13 - 0.33 and 0.13 - 0.23; and 0.13 - 0.37 and 0.27 - 0.33 ‰, respectively. Figure 2 showed trends of pH, temperature and salinity from water samples of Krueng Sabee, Panga and Teunom rivers which show a relatively no different from one point to others. Base on in situ water quality measurement, the pH, temperature and salinity of all river water is appropriate to quality standard of Government No. 82 Year 2001.

| Table 1. pH, temperature, and salinity parameters of Krueng Sabe, Panga and Teunom rivers. |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| No | Sampling points | pH | Temperature | Salinity % |
|----|-----------------|----|-------------|------------|
|    | March | April | March | April | March | April |
| 1  | KS 1  | 7.70 ± 0.01 | 6.83 ± 0.15 | 26.93 ± 0.06 | 27.23 ± 0.38 | 0.27 ± 0.06 | 0.13 ± 0.06 |
| 2  | KS 2  | 7.62 ± 0.01 | 6.67 ± 0.06 | 27.67 ± 0.06 | 27.10 ± 0.78 | 0.23 ± 0.16 | 0.23 ± 0.06 |
| 3  | KS 3  | 7.64 ± 0.02 | 6.70 ± 0.10 | 28.17 ± 0.15 | 27.63 ± 0.06 | 0.43 ± 0.06 | 0.27 ± 0.06 |
| 4  | P 1   | 7.88 ± 0.12 | 6.80 ± 0.10 | 30.10 ± 0.10 | 27.13 ± 0.06 | 0.13 ± 0.06 | 0.13 ± 0.06 |
| 5  | P 2   | 7.73 ± 0.07 | 7.07 ± 0.06 | 29.90 ± 0.10 | 25.50 ± 0.61 | 0.13 ± 0.06 | 0.13 ± 0.06 |
| 6  | P 3   | 7.10 ± 0.07 | 6.61 ± 0.17 | 32.37 ± 0.06 | 26.80 ± 0.61 | 0.33 ± 0.06 | 0.23 ± 0.06 |
| 7  | T 1   | 6.59 ± 0.04 | 7.31 ± 0.34 | 26.67 ± 0.06 | 24.67 ± 0.38 | 0.13 ± 0.06 | 0.27 ± 0.06 |
| 8  | T 2   | 8.26 ± 0.10 | 7.57 ± 0.06 | 27.10 ± 0.10 | 25.30 ± 0.17 | 0.17 ± 0.06 | 0.30 ± 0.06 |
| 9  | T 3   | 8.07 ± 0.03 | 7.53 ± 0.01 | 27.93 ± 0.15 | 25.30 ± 0.10 | 0.37 ± 0.06 | 0.33 ± 0.06 |

Figure 2. Trend of pH, temperature, and salinity of the rivers: (a) March 2019 (sunny condition) and (b) April 2019 (rainy condition).

3.2. Mercury analysis in water and sediment samples from Krueng Sabee, Panga dan Teunom rivers

3.2.1. Mercury concentration

Hg concentration of the water and sediments samples of Krueng Sabee, Panga and Teunom rivers was shown in Table 2. The result showed that Hg concentration in water of Krueng Sabee river in March and April are in range of 0.0799 - 0.3328 µg/L and 0 - 0.0100 µg/L, respectively. Hg concentration in water of Krueng Panga river in March and April are in range 0.0176 - 0.2149 µg/L and 0.0450 - 0.0530 µg/L, respectively. Meanwhile, Hg concentration in water sample of Teunom river are in range of 0.0979 - 0.2189 µg/L and 0.0390 - 0.0560 µg/L, respectively during March and April. Furthermore, concentration of Hg in sediments of Krueng Sabee river in March and April are in range of 0.2488 - 6.2230 µg/L and 0.0720 - 0.1599 µg/L, respectively. Hg concentration in sediments of Panga river in
March and April are in range of 0.1409 - 0.5227 µg/L and 0.02700 - 0.2778 µg/L, respectively. Hg concentration in sediments sample from Teunom River in March and April are in range of 0.1749 - 0.3898 µg/L. Furthermore, a higher mercury concentration was found during March compared to April. Research by Kassegne et al. [16] found out that Hg levels in sediments and biota are higher at rainy condition than at sunny condition. George [17], McComb et al. [18] found out that there is seasonal pattern in which highest concentration of heavy metal occurred on rainy seasons and lowest concentration occurred on premonsoon season. This is because water and sediments are transported through surface runoff during rainy seasons [19].

Tabel 2. Concentration of Hg in water and sediment samples collected on March and April from Krueng Sabee, Panga and Teunom rivers.

| No | Sampling points | March Water | Sediments | April Water | Sediments |
|----|----------------|-------------|------------|-------------|------------|
| 1  | KS1            | 0.0799      | 6.2230     | ND          | 0.1599     |
| 2  | KS2            | 0.0949      | 0.3758     | 0.0070      | 0.0770     |
| 3  | KS3            | 0.3328      | 0.2488     | 0.0100      | 0.0720     |
| 4  | P1             | 0.2149      | 0.5227     | 0.0530      | ND         |
| 5  | P2             | 0.1679      | 0.2838     | 0.0420      | 0.2778     |
| 6  | P3             | 0.0176      | 0.1409     | 0.0450      | 0.0200     |
| 7  | T1             | 0.2189      | 0.1749     | 0.0450      | ND         |
| 8  | T2             | 0.1269      | 0.2039     | 0.0390      | ND         |
| 9  | T3             | 0.0979      | 0.3898     | 0.0560      | ND         |

ND: Not Detected

Figure 3. Distribution patterns of Hg in waters (A), sediments (B) waters and sediments (C).
3.2.2. Distribution pattern of mercury

The interpretation of spread pattern of Hg spatially at three different rivers was evaluate by PCA method. Data analysis is referring to Bengen [20] by using XLSTAT software. Information that could be obtained from PCA are relative similarity between observation objects in which if two objects have similar characteristics, it will be portrayed as two dots adjacent to each other. The relation between variables is if the correlation value of two variables (Hg in water and sediments) approaches 1, then the correlation is positive.

The result of PCA analysis showed that Hg spread pattern in waters and sediment samples of Krueng Sabee, Panga and Teunom rivers on March and April have relation between variables tested. The closer variable position to principal component, have positive correlation of the value. Meanwhile, the different of position and coordinate (quadrant) describe direction of positive and negative correlation. PCA analysis result also shows that Hg levels in waters (Figure 3A), KP1 and KT1 have different correlation, but there are have similar variables. Then, Hg levels in sediments (Figure 3B) shows that in Krueng Sabee upstream (KS1) and Panga median (P2) rivers have different correlation because different sampling points and river.

The concentration of mercury in water and sediment samples (Figure 3C) shows a strong correlation between Krueng Sabee upstream (KS1) and midstream (KS2) river. Based on Figure 3, Teunom median (T2) and downstream (T3) river have strong positive correlation of Hg concentration in water samples. It means that if there is an increase of Hg levels on the downstream (T3), the Hg levels in the midstream (T2) will also increase (same quadrant). On sediments, Hg levels found in Krueng Sabee upstream (KS1) and midstream (KS2) have same high concentration and strong correlation, where the quadrants are the same. Sediment from KS1 and T3 has rainy condition concentration of Hg, which are indicated by the similar variables.

4. Conclusion

The result of in situ measurement (pH, temperature, salinity) showed that quality of surface water of Krueng Sabee, Panga and Teunom rivers was suitable with the water quality standard by Government. The results of mercury analysis showed that mercury content was detected in all water and sediment samples from all rivers. The Hg concentration in the water and sediment sample incline in sunny condition (March) whereas concentration of Hg in the water and sediment samples decline in sampling time of April (rainy condition). From the result of PCA analysis, there is a strong correlation between high mercury content in sediment in upstream and median of Krueng Sabee river and in water in median of Teunom and downstream of Teunom river.

References

[1] Suparjo M N 2009 Saintek Perikanan Jurnal 4 38–45
[2] Idroes R, Yusuf M, Alatas M, Subhan L, Muslem A, Suhendra R, Idroes G M, Suhendrayatna, Marwan and Riza M 2019 Geochemistry of Warm Springs in the Ie Brouk Hydrothermal areas at Aceh Besar District, IOP Conference Series Materials Science and Engineering, vol 523
[3] Suhartono E, Thalib I, Aflanie I, Noor Z and Idroes R 2018 Study of Interaction between Cadmium and Bovine Serum Albumin with UV-Vis Spectroscopy Approach IOP Conference Series: Materials Science and Engineering 350 12008 (IOP Publishing)
[4] Suhartono E, Noor Z, Edyson, Budianto W Y and Idroes R 2019 Effect of chronic lead exposure on bone using ATR-FTIR spectroscopy AIP Conference Proceedings
[5] Mohiuddin K M, Ogawa Y, Zakir H M O K and S N 2011 Int. J. Environ. Sci. Technol. 8 723–36
[6] A N W 2009 Mar. J. 2 158–64
[7] Domagalski J 2001 Appl. Geochemistry J. 16 1677–1691
[8] Randall P M 2006 Management of mercury pollution in sediments: research, observations, and lessons learned.
[9] Aspinall C 2001 Mining, Minerals and Sustainable Development Journal 14–24
[10] Donkor A K, Bonzongo J C, Narrey V K and Adotey D K 2006 Sci. Total Environ. J. 368 164–176
[11] EPA US 1999 Water Monitoring Report, Sediment Quality Monitoring of the Port Rivers Estuary
[12] Smith L I 2002 *A tutorial on Principal Components Analysis*

[13] Idroes R, Japnur A F, Suhendra R and Rusyana A 2018 Kovats Retention Index Analysis of Flavor and Fragrance Compound using Biplot Statistical Method in Gas Chromatography Systems *IOP Conf. Ser. Mater. Sci. Eng.* 1–6

[14] Rajashree Dash, Debahuti Mishra, Amiya Kumar Rath M A 2010 *Int. J. Eng. Sci. Technol.* 2 pp 59-66

[15] Suryono C A 2006 *Ocean Sci.* 9 1–9

[16] Kassegne A B, Jonathan O, Okonkwo, Tarekegn B E, Kabeled N M and Tshia M S L A 2018 *J Emerg. Contam.* 4 37–9

[17] George M D 1993 *Indian J. Mar. Sci.* 22 216–20

[18] McComb J, Alexander T C F X H and P B T 2014 *J. Bioremediation Biodegrad.* 5 1–3

[19] Mitra A 1998 *Indian J. Ocean Study* 5 135–8

[20] Bengen D G 2002 Synopsis of Coastal Natural Ecosystems and Resources. Center for Coastal and Ocean Resources Studies *Pus. Kaji. Sumberd. Pesisir dan Lautan IPB Bogor* 63

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