Water quality index and the sediment criteria due to anthropogenic activity in West Aceh District, Indonesia

Rahmatillah¹, H Meilina², I Ramli¹,³,⁴*  
¹Department of Environmental Master’s Program, Universitas Syiah Kuala, Indonesia  
²Chemical Engineering Department Universitas Syiah Kuala, Banda Aceh, Indonesia.  
³Agricultural Engineering Department, Universitas Syiah Kuala, Jalan Tgk. Hasan Krueng Kalee 3, Darussalam-Banda Aceh 23111, Indonesia  
⁴Research Center for Environmental and Natural Resources, Universitas Syiah Kuala  

*Email: ichwana.ramli@unsyiah.ac.id

Abstract. The existence of river environmental components or sediment and river pollutions are influenced by domestic, industrial, and agricultural waste, it will reduce water quality. The purpose of this study was to determine the index of water quality and sedimentation due to anthropogenic activities. Pollution Index (PI) method for water quality and Sediment Quality Guidelines (SQGs) method for sedimentation. The Krueng Woyla and Krueng Meureuebo watersheds include have the highest intensity of anthropogenic activity at West Aceh District. Surrounding the Krueng Woyla watershed has illegal mining such as class C minerals like sand and stone and gold mining. In the Krueng Meureuebo watershed, there are mining activities to dispose of company waste flowing through the Meureuebo tributary accompanied by sand mining activities. These activities result in the pollution index (PI) calculation. It shows that there has been a decrease in the water quality of the Meuruebo and Woyla rivers with 1.0 <PI< 5.0 classified as lightly polluted river water quality conditions. The highest pollution index value is in the Krueng Meruebo downstream watershed which is 2.41 classified as “Slightly Polluted”. Based on the Sediment Quality Guidelines (SQGs) and equations for a mercury concentration of 0.915, it is found that sediment has medium a negative effect index of heavy metals on river biota.

1. Introduction
Water is an important requirement of human and industrial development as one of the most sensitive parts of the environment [1]. Along with developments progress, population growth, increase in the number of industries and other activities will increase the production of waste in watersheds so that the quality of river waters decreases.

Human activities affect the chemical distribution, quantity, and quality of water resources [2]. The rapid industrial development, use of metals in production processes has led to increased release of heavy metals carried by runoff water [3,4]. Evaluation of river and sediment quality is very important as an indicator of water quality because of its capacity to accumulate pollutants [6,7]. Water quality identification using the water pollution index (PI) can determine the quality of polluted water. Sediment Quality Guidelines (SQGs) showing chemical concentrations of biological effects on aquatic biota [8]. The accumulation of metal contaminants through the deposition of suspended particles supports the
accumulation of pollutants in the riverbed [9,10] can cause serious environmental problems [11]. River water quality is influenced by the quality of water supply originating from the catchment area, while the quality of water supply from the catchment area is related to human activities surrounding it [12]. The Kreung Meureuebo watershed and the Krueng Woyla watershed are rivers located in West Aceh District where the residents carry out illegal class C (sand and stone) mining activities and gold mining using heavy equipment.

Currently, many indices have been used to estimate the quality of water and river sediments due to human activities. Determining the water quality index using the National Sanitation Foundation-Water Quality Index (NSF-WQI) based on major water quality parameters [13]. Geoaccumulation Index (Igeo) [14], Enrichment Factor (EF) [15]. Potential Ecological Risk Index (PERI) [16]. Pollution Load Index (PLI) [17]. However, this is not based on matching chemical and biological data. On the other hand, Sediment Quality Guidelines (SQGs) such as Effects Range Low and Median (ERL/ERM) [18]. Predicted and Threshold Effects Level (PEL/TEL) [19] and Ecological Risk Factor (ERF)[16]. However, they are purely additive and It will not consider the possibility of synergism or antagonism originating from the combined effects of several pollutants. This study determines the value of the water quality and sediment quality index due to human activities by using the Pollution Index (PI) method for the water quality and Sediment Quality Guidelines (SQGs) for the sedimentation method.

2. Materials and methods

Water and sediment quality data analysis was carried in 2 (two) watersheds in West Aceh District. According to Department of Environment and Forestry (DLHK) data of West Aceh District, namely Krueng Meurebo upstream watershed located on the Keude Aron Bridge, Kaway XVI Sub-District with a position of 04°.13’.26,77” and 96°.10’.24,24“. Krueng Meurebo downstream watershed is located at Besi Bridge, Johan Pahlawan Sub-District with positions 04°.13’.15,72“ and 96°.08’.24,754“. Krueng Woyla upstream watershed is located on the Woyla Talent Bridge with positions 04°.31’.79,67“ and 96°.07’.22,71“. While the Krueng Woyla downstream watershed is located on the Pribu Bridge, Arongan Lambalek Sub-District with positions 04°.23’.19,64“ and 96°.02’.43,89“ (figure 1).

![Figure 1. Research location](image-url)
Descriptive data analysis was carried out to measure the results of several parameters. Comparative analysis of the results of the water sample compares with the quality standard according to Government Decree Number 82 of 2001 [21] (table 1). Meanwhile, the mercury content in the sediment was compared with the quality standard for heavy metal concentrations based on the Canadian Council of Ministers of Environment CCME (2001). This study uses secondary data obtained from the Environmental Service of West Aceh Regency including parameters Potential of Hydrogen (pH), Total Dissolved Solids (TDS), Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), and Biochemical Oxygen Demand (BOD). Water quality data were analyzed using the Pollutant Index (PI) method and heavy metal sediment quality data were analyzed using the Sediment Quality Guidelines (SQGs) method.

| Table 1. Water Quality Parameters by Class |
|-------------------------------------------|
| Parameters | Unit | Class I | Class II | Class III | Class IV |
|---------------|-------|----------|----------|-----------|----------|
| Ph | mg/L | 6 - 9 | 6 – 9 | 6 - 9 | 5 – 9 |
| Dissolved Residue | mg/L | 1.000 | 1.000 | 1.000 | 2.000 |
| Suspended Residue | mg/L | 50 | 25 | 50 | 100 |
| COD | mg/L | 10 | 4 | 3 | 0 |
| DO | mg/L | 6 | 0,001 | 0,001 | 0,001 | 0,005 |
| BOD | mg/L | 2 | 3 | 6 | 12 |

Source: Government Regulation Number 82 of 2001

Based on the Decree of the State Minister of the Environment No. 115 of 2003 for the Pollution Index (PI) method, the PIj price can be determined in the following way ([22]

\[ PI_j = \sqrt{\left(\frac{C_i}{L_{ij}}\right)^2_M + \left(\frac{C_i}{L_{ij}}\right)^2_R} \]

Description :
- \( PI_j \) = Pollution index
- \( C_i \) = Concentration of water quality parameters obtained from the laboratory
- \( L_{ij} \) = Concentration of water quality parameters listed in the water quality standard
- \( M \) = Maximum value of \( (C_i/L_{ij}) \)
- \( R \) = Average value of \( (C_i/L_{ij}) \)

After obtaining the \( PI_j \) value, it is then compared with the water quality criteria for the Pollution Index (PI) category as shown in table 2.

| Table 2. Pollution Index (PI) Criteria |
|--------------------------------------|
| No | Kriteria Pollution Index (PI) | Keterangan |
| 1 | 0 \( \leq PI \leq 1 \) | Meet Quality Standard (Good) |
| 2 | 1,0 \( \leq PI \leq 5 \) | Slightly Polluted |
| 3 | 5,0 \( \leq PI \leq 10 \) | Fairly Polluted |
| 4 | \( PI \geq 10 \) | Heavily Polluted |

Source: Decree of the State Minister of Environment No. 115, 2003

The Sediment Quality Guidelines (SQGs) method for the price of SQGs can be determined by selecting parameters, calculating the PEL-Qi price (Canada Council of Minister of Environment CCME, 2001) for each parameter and the price of SDGs [23].
\[ PEL - Q_i = \frac{\text{contaminant}}{PEL} \]  
\[ SQG - Q = \frac{\sum_{i=1}^{n} (PEL - Q_i)}{n} \]

Remarks:
- Contaminant = Pollutant parameter
- PEL = Quality standard set by CCME
- N = Number of parameters
- PEL-Qi = Calculated result of contaminant concentration measured by its PEL value
- SQG-Q = Sediment pollution

After obtaining the SQG-Q value, it is then compared with the sediment quality criteria of the Sediment Quality Guidelines (SQGs) criteria as listed in table 3.

| No | Criteria | Pollution Index (PI) | Remark |
|----|----------|----------------------|--------|
| 1  | SQG-Q<0,1|                      | Negative effects of heavy metals on low biota |
| 2  | 0,1< SQG-Q<1 |              | Negative effects of heavy metals on medium biota |
| 3  | SQG-Q≥1 |                      | Negative effects of heavy metals on tall biota |

3. Result and Discussion

3.1 Water Quality

Water quality test data in 2018 and 2019 included parameters of pH, TDS, TSS, COD, DO, and BOD and in 2020 includes parameters of pH, TDS, and TSS (table 4 and 5). Those existing data were analyzed using the Pollution Index (PI) method to know the status of water quality. Furthermore, it compared with the class II surface water quality standard according to government regulation Number 82 of 2001 concerning Indonesian water quality standards.

| Parameter | Krueng Meureubo Upstream | Krueng Meureubo Downstream |
|-----------|--------------------------|---------------------------|
| pH        | 7.44 7.81 7.81 6.88 7.79 7.79 |                           |
| TDS       | 58 30 7.76 62 19 8.22 |                           |
| TSS       | 24 25 30 50 37 19 |                           |
| COD       | 17 31.54* - 17 20.57 - |                           |
| DO        | 8.01* 7.76* - 7.68* 8.22* - |                           |
| BOD       | 2.81 3.18* - 2 2.28 - |                           |

Source: West Aceh District Environmental Service
Remarks: * Exceeds the Surface Water Quality Standard Group II, PP No. 82 of 2001.

Based on the test results of river water samples; river water quality standards for Class II. In 2019, the parameters that exceed the quality standards at Krueng Meureubo upstream are DO, COD, and BOD with increased concentrations in the COD, DO and BOD parameters, in downstream the DO is parameters that exceed the quality standard. In 2018 the upstream and downstream Krueng Woyla
watersheds of TSS and DO exceeded the quality standard and in 2019 the concentration of COD, DO and BOD exceeded the quality standard.

**Table 5.** Results of the Krueng Woyla Watershed Water Quality Test Based on the DLHK Report of West Aceh District

| Parameters | Krueng Woyla upstream | Krueng Woyla downstream |
|------------|-----------------------|-------------------------|
|            | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| pH         | 7,18 | 7,54 | 7,03 | 7,93 | 7,03 | 7,93 | 7,03 | 6,93 |
| TDS        | 128  | 25   | 111  | 22   | 111  | 22   | 111  | 22   |
| TSS        | 51*  | 18   | 53,5*| 27   | 53,5*| 27   | 53,5*| 27   |
| COD        | 16   | 37,45*| 17 | 45,89*| 17 | 45,89*| 17 | 45,89*|
| DO         | 7,58*| 9,5* | 7,28*| 9,19*| 7,28*| 9,19*| 7,28*| 9,19*|
| BOD        | 2    | 2,87 | 2    | 3,1* | 2    | 3,1* | 2    | 3,1* |

Source: West Aceh District Environmental Service
Remarks: * Exceeds the Surface Water Quality Standard Group II, PP No. 82 of 2001,

Estimate pollution that occurs in water bodies in the Krueng Meureubo and Krueng Woyla watersheds can be further analyzed using the Pollutant Index (PI) to reveal the absolute size of the pollution that occurs. The pollution Index (PIj) graph is in figure 2.

**Figure 2.** Value of Pij Calculation Results (Pollution Index)

Overall water sample points conducted by the DLHK of West Aceh District in 2018, 2019, and 2020 in the Krueng Meureubo and Kreung Wolya watersheds are classified as lightly polluted (Figure 2). Started in 2018, the poor quality of river water in the Krueng Meuruebo downstream with the condition being slightly polluted. In 2019, the results of the pollution index value from upstream to downstream tend to decrease. However, in 2020 it’s increased again. There are several locations in the Krueng Meurebo watershed showing pollution in groundwater [24]. The Krueng Woyla watershed shows bad water quality only happens upstream and tends to experience an increase in water pollution in 2020 compared to 2019, even though in 2019 the condition water quality considers lightly polluted.
The river quality will change in accordance with the development of the surrounding river influenced by various activities of human life. Data analysis found that; TSS, COD, DO, and BOD in the study location exceed the required quality standards. This condition results in the amount of oxygen needed by microorganisms through chemical reactions tend to be very high. (Pollution Index can provide the information quality of water bodies and to take action to improve water quality.

3.2 Sediment Quality
Pollutants in the aquatic ecosystem tend to accumulate and attach to sediments. Therefore, sediments contain a lot of toxic pollutant compounds that can cause symptoms of toxicity for aquatic biota and endanger human health. The negative impact of toxicity can disrupt physiological processes and cause morphological defects. Furthermore, studies show that toxicity changes community structures by the decrease in biological integrity, namely the ability to support the balance of adaptive communities of organisms in the waters.

The location of sediment collection is determined based on the position or coordinates of the data from the Environmental Service of West Aceh District. The results of the laboratory analysis for the Hg (mercury) parameter can be seen in figure 3.

![Figure 3](image)

**Figure 3.** Concentration of Hg (mg/kg) in Krueng Meuruebo and Krueng Woyla Watersheds, West Aceh District.

The data of laboratory analysis found that the concentration of mercury in the sediments in the Krueng Meuruebo upstream was 0.1042 mg/Kg, in the Krueng Meuruebo downstream watershed 0.1058 mm/Kg, in the Krueng Woyla upstream 0.4892 mm/Kg and the Krueng Woyla watershed at 0.605 mg/Kg; If these results are compared with the sediment standard based on the CCME (2001) quality standard of 0.13 mg/Kg, it shows that the lowest Hg concentration value is found in the upstream and downstream Krueng Meuruebo watersheds. Meanwhile, Hg concentrations exceeding the sediment quality standards were found in the upstream and downstream Krueng Woyla watersheds. Contamination of mercury (Hg) in the sediment exceeds the sediment quality standard in both Krueng Woyla upstream and downstream. It’s because surrounding the watershed area there are anthropogenic activities in the form of gold mining and traditional gold processing (amalgamation) using raw materials containing mercury [8].
The results of the calculation of the sediment quality index on Hg contamination (figure 4); in the upstream Krueng Meureubo watershed found that the SQG-Q value of 0.1489 categorizes as the low metal negative effect. The Kreung Mereubo downstream watershed found that the SQG-Q with the value of 0.1511 categorizes as a medium metal negative effect, the SQG-Q Krueng Wolya Downstream is 0.6989 classified as a medium metal negative effect, and the SQG-Q Krueng Wolya downstream is 0.9150 classified as medium metal negative effect category. Based on these results, Hg contamination in sediments in the Krueng Wolya upstream and downstream watersheds has the potential to give harmful biological effects to living things in the vicinity. As a comparison, it can be seen from Government Regulation Number 18 of 1999 concerning Management of Hazardous and Toxic Waste, where the threshold value (NAV) for Hg metal is 0.01 mg/Kg or 0.01 ppm. The high of Hg contamination is suspected to have something to do with illegal gold mining. It has the potential of a negative impact on the environment around the Krueng Woyla upstream and downstream watersheds.

Mercury is one of the heavy metals types of pollutant substances often found in watersheds. Moreover, when these heavy metals accumulate in sediments, their concentration is always higher comparing to the concentration of metals in water. The sediment is easily suspended because the movement of the water will dissolve the metal back into the water. The sediment becomes a potential source of pollutants in a certain time scale. Type of activities that cause river pollution include domestic activities (the effluent that is usually discharged is usually in the form of organic pollutants, but can also be in the form of inorganic compounds, metals, salts such as detergents which are quite dangerous because they are pathogenic), industrial activities, agricultural activities (agricultural waste consists of solid organic former plant material, fertilizers and pest, and disease repellents (pesticides); fertilizer materials containing nitrogen, phosphorus, sulfur, minerals that are not easily decomposed even in small amounts, but are active at low concentrations). These activities increase the chemical content in the soil which in turn increases the chemical content in river water. It will affect the quality of river water.

Water quality identification on total dissolved solids (TDS and sulfate concentration can be known quickly through near-infrared spectroscopy with the (Fourier Transform near infrared spectroscopy FTIR) technique [25]. It can be used to assist water authorities, policymakers, and the community in detecting trends spatially and temporally quickly. It can identify pollutant sources, bad policies, and bad environmental programs. The recommendations for future improvements are needed [26,27]. Poor water
quality can cause disruption of natural ecosystems, affect food chains, and can reduce the population of aquatic biota and wildlife [28, 29]. Hence, it is very important to maintain the quality of the river.

4. Conclusions
Based on the data and discussion of the research, it can be concluded that the quality of river water in the Krueng Meuruebo and Krueng Wolya watersheds, West Aceh Regency in 2018, 2019, and 2020 using the Pollutant Index (PI) method is classified as lightly polluted. The sediment quality of heavy metal mercury (Hg) in the Krueng Meuruebo and Woyla watersheds using the Sediment Quality Guidelines (SQG-s) method shows the category as medium of negative effects of heavy metals on biota. The highest SDQ-s value of mercury levels in sediments is found in the Krueng Wolya watershed due to anthropogenic activities in the form of gold mining. It is very important to maintain the quality of the river for the environment. The water authorities, policymakers, and the communities require to work together to improve water quality in the river.

References
[1] Das, J., dan Acharya, B.C. 2003 Hydrology and assessment of lotic water quality in Cuttack city, India. Water, Air, Soil Pollut., 150, 163-175
[2] Berny, P., Sadoul, N., Dol, S., Videman, B., Kayser, Y., dan Hafner, H.2002 Impact of local agricultural and industrial practices on organic contamination of little egret (Egretta garzetta) eggs in the Rhone Delta, southern France. Environmental Toxicology and Chemistry, 21(3), 520–526
[3] Avenant-Oldewage, A., dan Marx, H.M. 2000 Bioaccumulation of chromium, copper and iron in the organs and tissues of Clarias gariepinus in the Olifants River, Kruger National Park. Water S/A, 26, (4), 569-582
[4] Zourarah, B., Maanan, M., Carruesco, C., Aajjane, A., Mehdi, K., dan Conceição Freitas, M. 2007 Fifty-year sedimentary record of heavy metal pollution in the lagoon of Oualidia (Moroccan Atlantic coast). Estuarine, Coastal and Shelf Science, 72: 359-369
[5] Devesa-Rey, R., Diaz-Fierros, F., dan Barral, M.T. 2012 Trace metals in river bed sediments: an assessment of their partitioning and bioavailability by using multivariate exploratory analysis. J. Environ. Manag., 91, 2471-2477
[6] Bartoli, G., Papa, S., Sagnella, E., dan Fioretto, A. 2012 Heavy metal content in sediments along the Calore river: relationships with physical–chemical characteristics. J. Environ. Manag., 91, S9–S14
[7] Ichwana Ramli, Syahrul, Mutia Rizka Lestari, 2020. Water And Sediment Quality Index Due to Gold Mining in The Krueng Kluet Hilir Watershed, Aceh Selatan Regency, International Conference on Technology, Innovation, and Society, Padang, ITP Press, 978-602-70570-4-
3. Innovation, and Society, Padang, ITP Press, 978-602-70570-4-3

[14] Nowrouzi, M., dan Pourkhabbaz. 2014 Application of geoaccumulation index and enrichment factor for assessing metal contamination in the sediments of Hara Biosphere Reserve, Iran. *Chem. Spec. Bioavailab.*, 26(2), 99-105

[15] Kausik, A., Kansal, A., Santosh., Meena., Kumari, S., dan Kaushik, C.P. 2009 Heavy metal contamination of river Yamuna, Haryana, India: Assessment by Metal Enrichment Factor of the Sediments. *J. Hazard. Mater.*, 164(1), 265-270

[16] Kabir, M.I., Lee, H., Kim, G., dan Jun, T. 2011 Correlation assessment and monitoring of the potential pollutants in the surface sediments of Pyeongchang River, Korea. *Int. J. Sediment Res.*, 26 (2), 152–162

[17] Banu, Z., Chowdhury, M.S.A., Delwar, M.H., dan Nakagami, K. 2013 Contamination and ecological risk assessment of heavy metal in the sediment of Turag River, Bangladesh: an index analysis approach. *J. Water Resour. Prot.*, 5, 239–248

[18] Tokatli. 2017 Bioecological and statistical risk assessment of toxic metals in sediments of a worldwide important wetland: Gala Lake National Park (Turkey). *Arch. Environ. Prot.*, 43(1), 34-47

[19] Zheng, Na., Wang, Q., Liang, Z., dan Zheng, D. 2011 Characterization of heavy metal concentrations in the sediments of three freshwater rivers in Huludao City, Northeast China. *Environ. Poll.*, 154(1), 135-142

[20] Birch, G.F. (2018). A review of chemical-based sediment quality assessment methodologies for the marine environment. *Mar. Pollut. Bull.*, 133, 218-232

[21] Government Regulation of the Republic of Indonesia decree number 82 in 2001 concerning *Water Quality Standards, Management, and Water Pollution Control*

[22] Nemerow, N.L., and Sumitomo, H., 1970. *Benefits of Water Quality Enhancement*, Syracuse University, New York

[23] Fairey, R., Long, E.R., Roberts, C.A., Anderson, B.S., Phillips, B.M., Hunt, J.W., Puckett, H.R., Wilson, C.J., 2001. An Evaluation of Methods for Calculating Mean Sediment quality Guideline Quotients as Indicators of Contamination and Acute Toxicity Tamphipods by Chemical Mixture. *Environmental Toxicology and Chemistry*, 20: 2276-2286

[24] Sayed Murtadha, Ismail Yusof, Rosmadi Fauzi, dan Ichwana, 2017 Analysis of Groundwater Quality for irrigation purposes in shallow aquifers: a Case Study from West Aceh, Indonesia, *Singapore Journal of Tropical Geography*, Vol. 3, 185 - 200, 2085 – 2614

[25] Ichwana I, Nasution Z and Arip Munawar A 2020 near-infrared spectroscopy as a rapid and simultaneous assessment of agricultural groundwater quality parameters INMATEH Agric. Eng. 233–40

[26] Finotti, A.R., Finkler, R., Susin, N., dan Schneider, V.E. 2015 Use of water quality index as a tool for urban water resources management. *Int. J. Sus. Dev. Plann.*, 10(6), 781-794

[27] Gitau, M., Chen, J., dan Ma, Z. (2016). Water Quality Indices as Tools for Decision Making and Management. *Water Resour. Manag.*, 30(8), 2591-2610

[28] Amneera, W. A., Najib, N. W., Yusof, S. R., dan Ragunathan, S. 2013 Water Quality Index of Perlis River, Malaysia. *International Journal of Civil & Environmental Engineering IJCEE-IJENS*, 13, 55-59

[29] Ramli I, Rusdiana S, Basri H, Munawar A A and Zelia V A 2019 Predicted Rainfall and discharge Using Vector Autoregressive Models in Water Resources Management in the High Hill Takengon *IOP Conference Series: Earth and Environmental Science* vol 273 (Institute of Physics Publishing)