River water quality modelling in Barito watershed

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Abstract. Barito River becomes one of the biggest river in Indonesia. It is located between Central Kalimantan Province and South Kalimantan Province, which is its length of 900 km and Barito watershed covers area approximately 46,500 km$^2$. Based on Presidential Decree No. 9 in 1999 about the identification of river crisis (IPA > 0.5 and Coefficient of Variation (CV) > 0.4), so Barito River can be classified into watershed crisis (priority - 2). Based on evaluation in 40 rivers during 1995-2000 with parameters biological oxygen demand (BOD), chemical oxygen demand (COD), and dissolve oxygen (DO) concentration, there is only one river which is not contaminated. That is Jeneberang River in Lebang Regency, South Sulawesi. Compared to this conditions, Barito River can be classified as a slightly contaminated river. Based on this experiment, the DO concentration was 4.74 mg.l$^{-1}$ – 5.36 mg.l$^{-1}$ less than the standard value 6 mg.l$^{-1}$, BOD was approximately 2.68 mg.l$^{-1}$ – 4.05 mg.l$^{-1}$ above threshold 2 mg.l$^{-1}$. In the other hand, COD above the standard 10 mg.l$^{-1}$ were approximately 20.5 mg.l$^{-1}$ – 30.1 mg.l$^{-1}$. Almost all of the metal concentration in the rivers had a high value above standard deviation. In other hand, some of this parameter also had a value above standard deviation. Those were the acidity degree (pH), suspendable substances (TSS), BOD$_5$ and Phosphat (PO$_4$).

Keywords: Barito river, coefficient of variation, water contaminant, water index use

1. Introduction
A river is a natural container or reservoir and channel of water flow with everything contained in it from the river drainage area to a lower place and ending in a lake or sea. The river is one of the water resources that are very important for human life. Various human activities take advantage of the existence of rivers, although on the other hand there is river behaviour that threatens and even endangers human survival. Sustainable river management is needed so that the river can be utilized optimally and can reduce the danger posed.

Most of the river utilization activities that have taken place are still carried out in a way that does not pay attention to sustainability and the public interest. This is indicated by the following conditions, namely, a decrease in the condition of water sources (quality and quantity) due to environmental damage and an imbalance between the availability of water and the need for water for various purposes both related to quantity, quality, desired time and a certain place.

Barito River is one of the major rivers in Indonesia. The river is located in Central Kalimantan Province and South Kalimantan Province, with a length of ± 900 km and a watershed area of 46,500

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km². In Presidential Decree No. 9 of 1999 concerning the identification of critical rivers (IPA > 0.5 and Coefficient of Variation (CV) > 0.4), it can be categorized that the Barito River is included in the critical watershed (priority - 2). Based on the levels of BOD, COD and DO, the classification of water pollution levels in 40 rivers in urban areas (1995-2000), there is only one river that is classified as non-polluted, namely the Jeneberang River in Lebang, South Sulawesi. While the Barito River is included in the classification of lightly polluted rivers.

The current decline in water quality does not only occur in the downstream area of the river but has penetrated into the upstream area of the river, which is caused by the habit of the community in using the river as a family toilet. This is reflected in the presence of very high Escherichia coli and coliform bacteria. In addition, agricultural activities and deforestation in the upstream area resulted in erosion resulting in an increase in the content of suspended solids (SS) and sedimentation in rivers.

The potential for critical land, floods, and landslides that occur in districts/cities in the Barito watershed is an indicator of damage and deterioration in soil quality, where the main cause of the potential impact is an error in land management in the upstream area. This study aims to develop modelling of river water quality in Barito watershed.

2. Methodology
Data collection in this study was conducted using secondary data collection methods obtained from various relevant agencies and also literature studies. The secondary data used for this study were as follows:

1. Water Quality Measurement
   Data on Barito River water quality was obtained from the Banjarmasin City Environmental Impact Management Agency, the results of measurements were monitored at several points of observation of the Barito River water. The harvesting points were taken from the Basirih, Mantuil, Pelambuan, Kuin Cerucuk, Kayutangi, Mulawarman, Banua Anyar, Bilu Rivers, Sungai Baru Estuary and Kelayan River Estuary.

2. Spatial Analysis Methods
   Spatial mapping and analysis were intended for data processing and also the presentation of data and information resulting from processing for the purpose of recommendations.

   Regression equations were used in this study to obtain the correlation form and the equation model. Regression equations were divided into three parts, namely linear regression, quadratic regression or parabolic regression and exponential regression or logarithm [1]. Linear regression is a regression whose independent variable (variable x) has the highest rank one. For simple linear regression, namely, linear regression which only involves two variables (variables x and y), the regression line equation can be written in two forms as in equation (1) [1].

   \[ y = a + bx \]  \hspace{1cm} (1)

Information:
- \( a, b \) = constants or parameters
- \( a \) = price \( y \) if \( x = 0 \) (constant price)
- \( b \) = number direction or regression coefficient, which shows the number of increase or decrease in the dependent variable based on the independent variable.
- \( x \) = an independent variable whose value can be used to predict
- \( y \) = dependent variable

3. Result and Discussion
   Barito River was one of the major rivers on the island of Borneo. This river had a watershed area (DAS) of 46,500 km² with a length of ± 900 km, upstream in Murung Raya Regency, Central Kalimantan and its downstream area were in the Regency of Barito Kuala, South Kalimantan. In
addition, the Barito River is the longest river in Central Kalimantan Province with an average depth of 8 meters and an average width of 650 meters. The maximum river discharge was 5,764.2 m³/sec⁻¹ and the minimum discharge was 973 m³/sec⁻¹.

The Barito River flowed in Central Kalimantan Province through 5 districts, namely: Murung Raya Regency, Barito Utara Regency, Barito Timur Regency, Barito Selatan Regency, and Kapuas Regency. Barito River flowed in South Kalimantan Province through 11 districts, namely: Tabalong Regency, Balangan Regency, Hulu Sungai Utara Regency, Hulu Sungai Selatan Regency, Tapin Regency, Batola Regency, Banjarmasin City, Banjar Baru City, Banjar Regency, Regency of Tanah Laut.

Type of climate in the working area of BPDAS (Indonesian Central Management of Regional River Flow) Barito which covered the entire Province of South Kalimantan and some districts in Central Kalimantan Province (4 districts) including type B to E which meant wet to rather dry. Climate type D (medium) covered the spread of most areas of South Kalimantan, namely all Tabalong District, Balangan, Hulu Sungai Utara, Hulu Sungai Tengah, Hulu Sungai Selatan, Barito Kuala, and parts of Tapin, Banjar, Tanah Laut, Tanah Bumbu districts and Kotabaru. Areas that belonged to the C type climate (rather wet) covered a portion of the Banjar and Tapin Regencies. Climate Type E (rather dry) covered part of the area of Tanah Laut Regency, Tanah Bumbu and Kotabaru. Whereas type B (wet) climate only covered a small part of the Tapin district. The South Kalimantan area consisted of 2 (two) seasons, namely: the rainy season and the dry season. The rainy season usually occurs from October to May, at that time the wind blew from the northeast direction, while the dry season (heat) occurs in June to August and between the two seasons there was a transition season. The same thing happened in 4 (four) districts in Central Kalimantan Province.

The air temperature in one place was determined by the high and low of the place on the sea surface and the distance from the beach. The air temperature data reported by the Meteorology and Geophysics Agency of the Meteorological Station Syamsuddin Noor, the maximum air temperature in the Kalimantan region, ranges from 33.1-35 °C, minimum air temperatures ranging from 22.6-23.8 °C. The average temperature ranged from 15.6-26.9 °C. The maximum air humidity in this area ranged from 96-98% and minimum humidity ranges from 35-58%, while the average monthly was 60-87%. Solar radiation in South Kalimantan with the highest intensity in April was 75% and the lowest intensity occurred in December, namely 33%, with an average irradiation intensity of 52.5%.

Rainfall in one place was influenced by conditions of climate, geography and rotation/meeting of air currents. The highest rainfall in this area occurred in March, which was 426 mm while the lowest rainfall occurs in September which was 75 mm. The South Kalimantan region received annual rainfall between 922 mm yr⁻¹ and 2,455 mm yr⁻¹. Wet months occurred from November to April, while the dry months on average started from May to October (according to Schmidt-Ferguson).

Based on the Land Use and Land Cover Map of the Barito Watershed, the majority of the Barito watershed area was dry land and dry forest-agriculture, which were 17.19% and 15.86% of the total Barito watershed area (figure 1). In addition, most of the other Barito watershed areas were also natural forest areas (12.87%) and swamp forests (10.22%). In more detail and clear, the closure and land use of the Barito watershed were presented in Table 1.

In determining segmentation, materials in the form of a basic map were needed, including river networks and watershed boundaries with a map scale adjusted to the needs, watershed area and river length (figure 3). The natural vegetation of an area was influenced by a combination of factors such as topography, sea level, geology, soil, climate and water supply, especially rainfall. Kalimantan was located on the equator whose region received heat throughout the year and was a humid area in Indonesia. These conditions along with geological and climate conditions encouraged the emergence of high classification and species diversity.
Figure 1. Land cover and land use map of Barito watershed

Table 1. Closure and Land Use of the Barito Watershed

| Nr | Land Cover            | Area (ha) | (%)  |
|----|-----------------------|-----------|------|
| 1  | Cloud                 | 693,739.50| 10.81|
| 2  | Cloud shadow          | 408,391.60| 6.37 |
| 3  | Lake                  | 3,196.97  | 0.05 |
| 4  | Dry land forest       | 1,017,592.29| 15.86|
| 5  | Nature forest         | 825,674.60| 12.87|
| 6  | Mangrove              | 158,405.72| 2.47 |
| 7  | Swamp                 | 655,624.36| 10.22|
| 8  | Plant                 | 502,157.82| 7.83 |
| 9  | Mixed plantation      | 165,190.99| 2.58 |
| 10 | Palm plantation       | 230,494.66| 3.59 |
| 11 | Other plantation      | 207,044.23| 3.23 |
| 12 | Settlement            | 135,427.42| 2.11 |
| 13 | Dry land agriculture  | 1,102,853.87| 17.19|
| 14 | Savanna               | 3,932.86  | 0.06 |
| 15 | Paddy fields          | 80,408.64 | 1.25 |
| 16 | Bushland              | 78,207.16 | 1.22 |
| 17 | Pond                  | 19,409.50 | 0.3  |
| 18 | Open land             | 85,086.19 | 1.33 |
| 19 | Water body            | 42,167.59 | 0.66 |
|    | **Total**             | **6,415,005.97** | **100** |

A land that was viewed geographically was as a certain area on the surface of the earth, especially covering all the constituent objects of the biosphere which were able to be considered to be sedentary or moveable above and below the area, including the atmosphere, soil, and host rock, topography, water, plants and animals, as well as the consequences of human activities in the past and present, all of which had a real effect on land use by humans, both now and in the future [2].
Figure 2. Relationship between administrative boundaries and sub-watersheds in the Barito river

Land use is all kinds of human intervention, either permanently or relocating to a group of natural resources and artificial resources, which as a whole are called land, with the aim of fulfilling both material and spiritual needs, or the needs of both [3]. Land use is generally used to refer to present land use because human activity is dynamic, so study attention is often directed at land-use changes (both qualitatively and quantitatively) or anything that affects the land. Land use in reality in the field shows a complexity. In the inventory, it is often done grouping and classification or classification so that it can be treated as uniform units for a specific purpose.

Segmentation of water bodies was based on several considerations, namely water use (current and future), regional topography, river morphology, potential water sources, pollutant potential and administrative boundaries. Segmentation of this water body was used to determine the boundary of water quality management area (KPKA) where this area showed a wide range of activities and processes affecting certain segments.

Parameters that exceeded water quality standards in certain river segments so that they were not in accordance with the expected water class, especially dissolved oxygen, BOD, COD, Coli, Fecal Coli and phosphate, which were indications of the entry of organic pollutants, both domestic and agricultural waste, livestock and industry, as well as physical parameters such as turbidity and TSS which were indicative of the entry of pollutants of organic and sedimentary waste sourced mainly from land erosion along the Barito watershed. These parameters were at the same time as the key parameters that must be prioritized handling. In other words, by handling these key parameters, other water quality parameters could be handled simultaneously. When compared with the expected level of water quality (Water Class), the current conformity of water quality to the expected water class from upstream to downstream was seen in table 2.

Based on the measurement results, the quality of water found in the Barito watershed ranged between class II-IV. According to [4], class II was water whose designation could be used for water recreation facilities/infrastructure, cultivation of freshwater fish, livestock, water for irrigating plantations, and/or other designations that require water quality that was the same as those uses. Then, class III was water whose designation could be used for the cultivation of freshwater fish, livestock, water to irrigate crops, and/or other designations that required water quality that was the same as that
of use [4]. Whereas, class IV was water whose designation could be used to irrigate plantations and/or other designations which require water quality that was the same as those used [4]. From the measurement results, the physical parameters of turbidity and suspended solids (TSS) on average met the expected class, but the maximum fluctuations in a year exceed or did not meet the class. The absence of water classifications with class I indicated that pollution along the Barito River had occurred.

**Table 2.** Compatibility of current water quality against water class from upstream to downstream

| Nr  | Location     | Sample Point | Class | pH   | BOD | PO₄  | TSS |
|-----|--------------|--------------|-------|------|-----|------|-----|
| 1   | Murung Raya  | 1            | II    | 6.42 | 5.1 | 0.38 | 62  |
| 2   | Barito Utara | 2            | II    | 6.64 | 4.9 | 0.08 | 16  |
| 3   | Barito Selatan | 3       | III   | 6.56 | 10.0| 0.071| 90  |
| 4   | Barito Timur | 4            | III   | 5.43 | 13.3| 0.104| 185 |
| 5   | Tabalong     | 5            | III   | 6.006| 6.8 | 0.061| 196 |
| 6   | Barito Kuala | 6            | III   | 6.22 | 8.8 | 0.129| 205 |
| 7   | Hulu Sungai Utara | 7       | III   | 7.48 | 5.0 | 0.310| 411 |
| 8   | Hulu Sungai Tengah | 8       | III   | 7.25 | 8.0 | 0.318| 397 |
| 9   | Hulu Sungai Selatan | 9      | III   | 6.42 | 10.3| 0.117| 52  |
| 10  | Tapin        | 10          | III   | 6.36 | 5.0 | 0.203| 259 |
| 11  | Tabalong     | 11          | III   | 5.4  | 7.7 | 0.083| 107 |
| 12  | Barito Kuala | 12          | IV    | 6.72 | 16.2| 0.179| 294 |
| 13  | Banjarmasin | 13          | IV    | 6.89 | 8.1 | 0.083| 306 |
| 14  | Banjar       | 14          | III   | 6.34 | 5.0 | 0.073| 269 |
| 15  | Banjar Baru | 15          | III   | 6.02 | 4.6 | 0.261| 229 |
| 16  | Banjar Baru | 16          | III   | 5.98 | 4.5 | 0.070| 481 |
| 17  | Tanah Laut  | 17          | III   | 6.77 | 5.0 | 0.125| 83  |

The degree of acidity (pH) indicated the balance between acid and base in water and the measure of the concentration of hydrogen ions in the solution. PH measurement was usually used to determine the pollution index by looking at the acidity or basicity of water with values ranging from a scale of 0 to 14. Value 7 stated a neutral condition, a value of less than 7 stated an acid condition, and a value greater than 7 stated the alkali condition in solution. Natural freshwater was in the range of 4 to 9 as controlled by the carbonate-carbonate system. Surface water generally tended to be alkaline, while water in the soil was more acidic [5].

The measured pH values in the Barito watershed ranged from 5.4-7.48. Based on the figure 3, pH parameters were below the quality standard. However, in the 7th segment, the pH exceeded the quality standard, namely in Tabalong Regency. This was because, in the district, there were many coal mining activities, so that the measured pH value tended to be high. A pH value of more than 7 indicated the condition of the alkali in solution [5]. Based on linear regression, the mathematical equation for pH modelling was \( y = -0.0017x + 6.4243 \).
Figure 3. Relationship of the degree of acidity (pH) from upstream to downstream

Figure 4. Relationship of suspended solids (TSS) from upstream to downstream

Figure 4 shows TSS parameters were above the quality standard with the required threshold value of 50 mg/l. This was because the area traversed by the Barito River from upstream to downstream mostly experienced mining activities. However, in the second segment, the TSS concentration value was below the quality standard located in Murung Jaya Regency. The measured value of TSS in the Barito watershed ranged from 16 mg/l to 481 mg/l found in Banjar Baru City. Based on linear regression, the mathematical equation for TSS modelling was \( y = 11.074x + 113.4 \).
Figure 5. Relationship of BOD$_5$ from upstream to downstream

The BOD$_5$ threshold value is 3 mg.l$^{-1}$ so that from the graph above, all BOD$_5$ parameters were above the quality standard with values ranging from 4.5 mg.l$^{-1}$ to 16.2 mg.l$^{-1}$. This could be because the area traversed by the Barito river from upstream to downstream was mostly located in settlement areas. Based on linear regression, the mathematical equation for BOD modelling was $y = -0.1169x + 8.5993$

Then, based on figure 6, all PO$_4$ parameter values were above the quality standard which ranged from 0.038 mg.l$^{-1}$ to 0.318 mg.l$^{-1}$ in the 8th segment located in Hulu Sungai Utara Regency. The magnitude of the phosphate threshold was 0.001 mg.l$^{-1}$. The magnitude of the measured PO$_4$ concentration value could be due to the Barito river area from upstream to downstream mostly located around the industrial area. Based on linear regression, the mathematical equation for PO$_4$ modelling was $y = 0.0031x + 0.1082$.

Figure 6. Relationship of phosphate (PO$_4$) from upstream to downstream

The decrease in environmental carrying capacity due to a large amount of waste thrown into the river was feared to disrupt the ecological balance of the Barito watershed. This situation indicated that
there were environmental changes in these waters and this indicates that the waters showed an increase in water fertility (eutrophication) so that it could affect the extraordinary growth of phytoplankton due to the excess availability of vitamins and nutrients, especially nitrogen and phosphorus [6]. This was very dangerous for the fish community on the Barito River because there was no adequate source of oxygen.

4. Conclusion
From the results of the study of the Model of River Water Quality Change in the Barito Watershed, it was found that:

1. The relationship of the degree of acidity from upstream to downstream of the Barito River tended to decrease. With mathematical equations \( y = -0.0017x + 6.4243 \)
2. The relationship of suspended solids (TSS) from upstream to downstream of the Barito River tended to increase. With a mathematical equation \( y = 11.074x + 113.4 \)
3. The relationship of BOD\(_5\) from upstream to downstream of Barito river tended to decrease. With a mathematical equation \( y = -0.1169x + 8.5993 \)
4. The relationship of phosphate (PO\(_4\)) from upstream to downstream of the Barito River tended to increase. With mathematical equations \( y = 0.0031x + 0.1082 \).

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