Spatial Variation of Electrical Conductivity, Total Suspended Solids, and Total Dissolved Solids in the Batang Arau River, West Sumatera, Indonesia.

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Abstract. This study aims to analyze the spatial variation of electrical conductivity (EC) values, total suspended solids (TSS), and total dissolved solids (TDS) concentrations along the Batang Arau River. Water samples were collected from eight stations along the river at biweekly intervals between March and May 2014. The results indicate an increasing trend in the value of three parameters from upstream to downstream, reflecting the effect of natural and anthropogenic activities along the river. The EC values were in the range of 173-5,097 μS/cm and had exceeded the water quality standard established by World Health Organisation (WHO) at the downstream. The TSS and TDS concentrations were in the range of 76-2,078 mg/L and 124-3,560 mg/L, respectively. The TSS concentrations at all stations had exceeded the river quality standard of class II established by Governor Regulation of West Sumatera, while the TDS concentrations had exceeded only at the downstream area. Significant spatial variation of the EC and TDS concentrations was observed between the upstream-midstream and the downstream but was not obtained along the river for the TSS concentrations. It indicates that the anthropogenic activities along the river affected the variability of EC and TDS, but not for TSS. Based on these results, reducing the number of sampling points into three stations could be performed for the EC and TDS, while TSS monitoring at only one station could be applied.

1. Introduction

In many parts of the world, the water quality control is a top-priority policy agenda [1], because if the water quality is contaminated, it can affect human health. The potential sources of water contamination are industrial, domestic, and agricultural activities as well as geological conditions, and water treatment plants. These contaminants are further categorized as physical, chemical, and microbial parameters [2].

Physical parameters such as electrical conductivity (EC) and total solids including total suspended solids (TSS) and total dissolved solids (TDS) are important parameters that must be analyzed in monitoring water quality. EC is a measure of water's capability to pass electrical flow that is directly related to the concentration of ions in the water. TSS is the measurement of solids that can be retained on a water filter and can settle out of the water column onto the stream bottom. They include silt, clay, organic wastes, inorganic precipitates, and plankton. TDS are those that pass through a water filter. They include some organic materials, as well as salts, inorganic nutrients, and toxins. The high concentration of solids in water can increase the turbidity and inhibit the penetration of sunlight into the water body which in turn will affect the photosynthetic process in the water. The sources of...
material in EC, TSS, and TDS can come from nature, i.e. geological condition, and seawater, and human activities, i.e. domestic and industrial waste, and agriculture [3-6]. Many standards govern EC and TDS in water. For health reasons, EC is no more than 1,500 μS/cm and the desirable limit for TDS is between 500 mg/L and 1,000 mg/L [1].

The Batang Arau River is one of the most important rivers in Padang, West Sumatra. There are various activities along the Batang Arau River, including villages, factories, industries, restaurants, pharmacies, agriculture, fisheries, and workshops, which can contribute to various types of pollutants that are carried by the current into the river [7,8]. From the monitoring result of the river in 2013, the TDS concentrations were 190 mg/L and 191 mg/L at the upstream point, 190 mg/L, and 185 mg/L at the midpoint, 171 mg/L and 164 mg L at the downstream point. Meanwhile, for the TSS, the concentrations of 16 mg/L and 26 mg/L at the upstream point, 44 mg/L and 63 mg/L at the midstream point, 97 mg/L and 109 mg/L at the downstream point were obtained [9]. These results indicate that the concentration of the parameters studied in general tends to increase from the upstream to the downstream area of the river.

Efforts to monitor water quality are very necessary to avoid more severe river water pollution. However, so far, monitoring of the water quality of the Batang Arau River has only been limited to presenting concentration and pollution load profile data, without analyzing the correlation between pollutant parameters and variations in sampling locations (spatial). This study aims to analyze spatial variation on physical parameters including EC, TSS, and TDS in the Batang Arau River due to the many activities around the Batang Arau watershed. Analysis of spatial variations will provide information on how significant the differences in sampling locations are, resulting in variations in the concentration of physical parameters. Besides, a spatial analysis should be performed to examine the effects of various anthropogenic activities and or land-use types on water quality and to design strategic sampling locations in the management of water resources for an effective monitoring program [10-12]. This research is expected to provide more comprehensive information on the quality of the Batang Arau River in terms of physical parameters and develop water management of the Batang Arau River basin.

2. Material and methods

2.1. Water sample collection

![Figure 1. The sampling locations and land use along Batang Arau River](image-url)
Water sampling was carried out biweekly from March to May 2014 at eight stations along the Batang Arau River. The stations were divided into one baseline station (S1) and seven impact stations (S2, S3, S4, S5, S6, S7, and S8). The baseline station is located upstream of the river referring to the natural and unpolluted state of the river. The impact stations are located next to the upstream where some anthropogenic activities exist i.e. domestic, agricultural, industrial, and commercial activities along the river. The locations of sampling are presented in figure 1 and a detailed description of sampling points is displayed in table 1. Some environmental parameters including temperature, pH, and dissolved oxygen were measured in the field. Water samples were collected in 1 L glass bottles and were placed in cooler boxes with ice at approximately 4°C before analysis.

| Stations | Latitude   | Longitude  | Elevation (m) | Distance (from S1) | Description                                                                 |
|----------|------------|------------|---------------|--------------------|-----------------------------------------------------------------------------|
| S1       | 0°56’49.9” | 100°30’31.5” | 229           | 0                  | As a reference point for the upstream of the river located in a forested area and no human activity around this location. |
| S2       | 0°57’30.4” | 100°27’08.0” | 124           | 4.2                | This point is 4.2 km from S1. The quality of the river changes marked by the brownish-yellow color of the water as the effect of the limestone crushing and agricultural activities around the location. |
| S3       | 0°57’39.7” | 100°25’29.7” | 72            | 10.1               | This location was representing the water quality of the midstream of the Batang Arau River where has received the domestic and commercial discharge. |
| S4       | 0°57’40.8” | 100°24’02.3” | 18            | 13.8               | Located in residential areas. This location has passed through agricultural and industrial areas. |
| S5       | 0°57’43.3” | 100°22’54.1” | 7             | 16.7               | At this location, the river has received wastewater from the rubber industry. |
| S6       | 0°57’26.8” | 100°22’41.1” | 6             | 17.6               | At this location, the stream joins the flow from a secondary drainage channel and has received wastewater from commercial and domestic activities. |
| S7       | 0°57’41.4” | 100°22’28.4” | 3             | 18.9               | This point has received domestic wastewater, restaurants, workshops, hospital, and hotel wastewater. |
| S8       | 0°57’44.8” | 100°21’51.5” | 1             | 19.9               | Downstream of the river. |

2.2. Analytical methods
The environmental parameters including, pH, temperature, and DO were measured at the field by using the corresponding portable meters (Hanna, USA) pH and temperature and DO-meter (Lutron, Taiwan) for DO. The EC was measured by the conductometric method based on Indonesia's standard method (SNI 06-6989.1-2004). The TSS and TDS were measured using the gravimetric method based
on the standard method (SNI 06-6989.3-2004 for TSS and SNI 06-6989.27-2005 for TDS). Each sample was measured in triplicate, and average readings were automatically determined.

2.3. Statistical analysis
Data are presented in tables and graphs after analyzing using MS Excel 365. Spatial analysis was analyzed using the one-way analysis of variance (ANOVA) with SPSS version 20.0 at 95% confidence level.

3. Results and discussion
Table 2 summarizes the overall means, standard deviations, and minimum and maximum values of environmental parameters including pH, temperature and DO as well as the physical parameters including EC, TSS and TDS concentration in the Batang Arau River at the eight stations. The decreasing of pH and DO concentration were observed at eight stations from upstream to downstream of the river, while the temperature increased. The presence of several effluents entering the river and the different conditions of land-use from upstream to downstream may result in this finding. However, the values of the environmental parameters had not exceeded the quality standard for river water class II based on the Governor Regulation of West Sumatera No. 5/2008.

Table 2. The means, standard deviations, minimum and maximum values of environmental parameters and concentrations of nitrogen at the eight sampling locations on the Batang Arau River (n = 5).

| Parameters       | S1   | S2   | S3   | S4   | S5   | S6   | S7   | S8   | Quality standard |
|------------------|------|------|------|------|------|------|------|------|------------------|
| pH               | mean | 8.3  | 8.7  | 8.7  | 7.9  | 7.7  | 7.6  | 7.6  | 7.5             | 6-9*              |
|                  | stdev| 0.35 | 0.35 | 0.87 | 0.43 | 0.55 | 0.42 | 0.39 | 0.58            |
|                  | min  | 8.0  | 8.1  | 7.8  | 7.4  | 7.1  | 7.2  | 7.2  | 6.9             |
|                  | max  | 8.9  | 9.1  | 9.6  | 8.5  | 8.2  | 8.1  | 8.2  | 8.1             |
| DO (mg/L)        | mean | 8.2  | 7.2  | 7.4  | 6.2  | 6.9  | 7.2  | 7.0  | 6.7             | min. 4*           |
|                  | stdev| 0.39 | 0.72 | 0.87 | 1.82 | 1.09 | 0.27 | 0.54 | 0.93            |
|                  | min  | 7.9  | 6.4  | 6.1  | 3.3  | 5.2  | 6.9  | 6.6  | 5.5             |
|                  | max  | 8.9  | 8.3  | 8.2  | 7.9  | 7.9  | 7.9  | 8.0  |                 |
| T (°C)           | mean | 24.9 | 28.6 | 30.7 | 30.6 | 30.5 | 30.5 | 30.4 | 30.4             | ± 3*              |
|                  | stdev| 0.78 | 1.82 | 2.48 | 1.67 | 1.83 | 1.73 | 1.07 | 1.13            |
|                  | min  | 24.2 | 26.4 | 28.1 | 29.3 | 29.2 | 29.6 | 29.7 | 29.5            |
|                  | max  | 26.2 | 31.2 | 34.7 | 33.4 | 33.7 | 33.6 | 32.3 | 32.4            |
| EC (µS/cm)       | mean | 193  | 216  | 216  | 249  | 262  | 316  | 1,362 | 4,051           | < 1,500**         |
|                  | stdev| 18   | 60   | 21   | 43   | 49   | 142  | 594   | 1,211           |
|                  | min  | 173  | 176  | 182  | 182  | 183  | 183  | 369   | 2,018           |
|                  | max  | 206  | 308  | 234  | 298  | 312  | 559  | 1,910 | 5,097           |
| TSS (mg/L)       | mean | 94   | 392  | 462  | 579  | 622  | 716  | 1,077 | 1,611           | 50*               |
|                  | stdev| 15   | 212  | 230  | 252  | 208  | 213  | 535   | 510             |
|                  | min  | 76   | 224  | 228  | 342  | 326  | 418  | 568   | 1,052           |
|                  | max  | 112  | 756  | 840  | 938  | 824  | 966  | 1,654 | 2,078           |
| TDS (mg/L)       | mean | 140  | 184  | 169  | 220  | 244  | 262  | 1,106 | 2,884           | 1,000*            |

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The spatial variation of EC values along the Batang Arau River is presented in figure 2. The EC values increased from upstream to downstream. The lowest conductivity value is at S1 station with an EC value of 173 μS/cm. The natural and rarely polluted by wastewater as well as no human activities around that location, as it is an upstream area, may cause this finding. Next to S1 station, the average EC values at S2 until S6 were in the range of 216-316 μS/cm, not much different from the EC value at S1. At S7 the average EC value increased to 1,362 μS/cm and the highest EC value was at S8 station with a value of 5,097 μS/cm. In this location, there are many pollutants or other compounds in the form of ions, that can increase the ability of water to conduct electricity. Besides, S8 station is very close to the sea, so that the possibility of seawater intrusion is quite high. Usually, the higher the conductivity in the water, the water will taste brackish to salty. This value has exceeded the limit of water quality standards by WHO, i.e. no more than 1,500 μS/cm. Figure 2 also shows the differences in data distribution, due to the differences in conditions at the sampling time such as weather conditions before and at the sampling time.

![Figure 2. Spatial variability of EC values in Batang Arau River.](image-url)
Figure 3 shows the spatial distribution of the TSS concentrations at the eight stations of the Batang Arau River. From Table 2, it is demonstrated, generally, the TSS concentration contained in the Batang Arau watershed exceeds the quality standard for river water class II based on the Governor Regulation of West Sumatera No. 5/2008 (50 mg/L). An increasing trend from upstream to downstream was also observed for TSS concentrations along the Batang Arau River. The lowest concentration is at S1 stations with a value of 76 mg/L and the highest concentration is at S8 with a concentration of 2,078 mg/L. The S1 is the upstream area, located in a forested area where no human activities existed there. In the upstream, the concentration of the pollutants in rivers is very low and mostly derived from the weathering of rock and soil [7, 8, 11, 12]. The various activities including domestic, industry, commercial, and agriculture along the river increased TSS concentration.

Figure 4 shows the spatial variability of TDS concentrations in Batang Arau River.

The TDS variability along the Batang Arau River is illustrated in figure 4. The concentration of TDS in the Batang Arau River for the upstream to middle areas is still below the quality standard, as shown in table 2. Meanwhile, in the downstream areas, the TDS concentration exceeded the quality...
standard. The main source for TDS in waters is runoff from agriculture, domestic and industrial waste.

Figure 4 shows that the TDS concentration has increased from upstream to downstream. The results of TDS concentrations ranged from 124-3,560 mg/L with the lowest value at S1 station (124 mg/L) and the highest at S8 with a value of 3,560 mg/L, that not meet the water quality standard for class II based on Governor’s West Sumatra Regulation No.5 of 2008 (1,000 mg/L). Figure 4 also demonstrates the distribution of TSS concentration as the result of the different human activities along the river.

For spatial analysis, a one-way analysis of variance (ANOVA) was performed to verify the significant variability in EC and solids concentrations along the Batang Arau River. Tables 3, 4, and 5 show the comparison of p values of EC, TSS, and TDS concentrations at eight stations. Table 3 indicates that the EC values at S1 until S6 had no significant difference, while with S7 and S8, the significant differences were obtained (p<0.05). As mentioned above, S1 is the upstream area and from S2 to S6 the river receives wastewater from industrial, agricultural, commercial, and domestic sources. However, these conditions did not lead to significant variability in the spatial distribution of EC values. While at S7 and S8 were located near to estuary and the coastal area, the accumulation of the wastewater from the various activities exist, result in the significant differences of the EC value with those at S1 until S6. The EC values between S7 and S8 also have significant differences, indicating the different effects of activities around those locations.

For TSS concentrations, there was no significant difference among the eight stations, as shown in Table 4. These results revealed that different anthropogenic activities upstream to downstream of the Batang Arau River did not cause a significant difference in the spatial distribution of TSS concentrations in the river. However, for TDS concentrations, the significant differences were found between S1-S6 and S7-S8 stations, similar to the spatial distribution of the EC values. The value of EC and TDS are correlated [13-15]. EC is the measure of liquid capacity to conduct an electric charge, which depends on temperature, ionic strength, and dissolved ion concentrations (TDS) [16,17]. Moreover, the significant differences were also observed between the S7 and S8 stations, as an effect of the different anthropogenic activities at those stations.

Table 3. p values of EC concentrations at eight stations.

| EC | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 |
|----|----|----|----|----|----|----|----|----|
| S1 |    |    |    |    |    |    |    |    |
| S2 | 1.000 |    |    |    |    |    |    |    |
| S3 | 1.000 | 1.000 |    |    |    |    |    |    |
| S4 | 1.000 | 1.000 | 1.000 |    |    |    |    |    |
| S5 | 1.000 | 1.000 | 1.000 | 1.000 |    |    |    |    |
| S6 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |    |    |    |
| S7 | 0.011* | 0.014* | 0.014* | 0.018* | 0.020* | 0.031* |    |    |
| S8 | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |    |

* The mean difference is significant at the 0.05 level.

Table 4. p values of TSS concentrations at eight stations.

| TSS | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 |
|-----|----|----|----|----|----|----|----|----|
| S1  |    |    |    |    |    |    |    |    |
| S2  | 1.000 |    |    |    |    |    |    |    |
| S3  | 1.000 | 1.000 |    |    |    |    |    |    |
| S4  | 1.000 | 1.000 | 1.000 |    |    |    |    |    |
| S5  | 1.000 | 1.000 | 1.000 | 1.000 |    |    |    |    |
| S6  | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |    |    |    |
| S7  | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |    |    |
| S8  | 0.994 | 1.000 | 1.000 | 1.000 | 0.997 | 1.000 | 1.000 |    |

* The mean difference is significant at the 0.05 level.
From the result of spatial analysis, an effective future spatial monitoring program can be designed for evaluation of the physical parameters including EC and solids along the Batang Arau River. For this, the determination of sampling points can be defined at the location where had a significant difference only from all monitored stations. For the EC values and TDS concentrations, from eight stations, it can be reduced to three stations only to monitor the concentrations, i.e., S1, S6, and S8. While for TSS concentrations, it can be selected one from eight stations for the sampling point, as there was no significant difference was observed from all monitored stations. Reducing the number of locations for sampling can reduce the time and money and, in turn, can be an effective monitoring program for the management of water resources[8,12].

4. Conclusions
The monitoring result of the EC, TSS, and TSS concentrations along the Batang Arau River for 3 months sampling indicates an increasing trend in concentration from upstream to downstream. It demonstrates that the EC values and solids concentration was affected by the natural and anthropogenic activities along the river. The EC values were in the range of 173-5,097 μS/cm. The TSS and TDS concentrations were in the range of 76-2,078 mg/L and 124-3,560 mg/L, respectively. The EC values at S1-S7 stations were still below the maximum permissible value of the water quality established by WHO. However, the TSS concentrations at all stations had exceeded the river quality standard of class II established by Governor Regulation of West Sumatera, while the TDS concentrations had exceeded only at the downstream area, S7 and S8 stations. Significant spatial variation of the EC values and TDS concentrations was observed between the upstream-midstream and the downstream of the Batang Arau River but was not obtained along the river for the TSS concentrations. It indicates that the anthropogenic activities along the river did not affect the variability of TSS concentrations. While for the EC and TDS, no significant difference was found in the upstream area as the natural condition of the river and in the midstream where received the wastewater from industrial, agricultural, commercial, and domestic activities. However, the activities near the downstream affected the variability of both parameters may be due to the accumulation of wastewater at the locations. For an effective monitoring program of the EC and TDS parameters, reducing the number of sampling points into three stations could be performed, while for TSS parameters, monitoring at only one station could be applied. These results can be a reference to water management in the Batang Arau River for local authorities.

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Table 5. p values of TDS concentrations at eight stations.

| TDS | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 |
|-----|----|----|----|----|----|----|----|----|
| S1  |    |    |    |    |    |    |    |    |
| S2  | 1.000 |    |    |    |    |    |    |    |
| S3  | 1.000 | 1.000 |    |    |    |    |    |    |
| S4  | 1.000 | 1.000 | 1.000 |    |    |    |    |    |
| S5  | 1.000 | 1.000 | 1.000 | 1.000 |    |    |    |    |
| S6  | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |    |    |    |
| S7  | 0.999 | 0.004* | 0.004* | 0.007* | 0.009* | 0.011* |    |    |
| S8  | 0.003* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |

* The mean difference is significant at the 0.05 level.
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