Spatial and temporal distribution of nitrate concentration in Ciliwung River, Bogor City

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Abstract. Water is very important as a source of life for human and other living organism. Bogor City has two main rivers, i.e. Cisadane River and Ciliwung River. Those rivers, particularly Ciliwung River has low in water quality, that has been affected by land use changes and human activities. Nitrate concentration is one of hazardous chemical observed in this research, due to Nitrate contamination is very dangerous for human health. Focus of this paper is how the spatial distribution of Nitrate concentration in Ciliwung River. There were 13 sites of water sampling in Ciliwung River. Water samples were collected in December 2016, January 2017, and February 2017. Inverted Distance Weighted method was used to identify spatial distribution of Nitrate concentration. According to the analysis results, Nitrate had different concentrations in December 2016, January 2017, and February 2017. The highest concentration of Nitrate in December 2016 has occurred in three sites, i.e. Kedung Halang, Cibuluh and Sukaresmi. Nitrate concentration had increased from 4.30 to 5.70 mg/L in January 2017, and the highest had occurred in Sukaresmi. Furthermore, Nitrate concentration had decreased become 4.80 mg/L in February 2017, where the highest concentration of Nitrate had occurred in Cibuluh, Sukaresmi, Bantar Jati, and Kebun Raya Bogor.

Keywords: Ciliwung River, nitrate concentration, spatial distribution, water quality

1. Introduction
Water pollution is big issue worldwide, especially in urban landscape. Hazardous chemicals are detected in rivers due to global rapid population growth and intensive domestic activities in urban landscape [1, 2, 3]. One of hazardous chemical in river is Nitrate concentration. Nitrate concentration is very soluble in water [4]. This condition affected contamination in river, because river flow lead Nitrate concentration spread along the river. Nitrate contamination is an environmental issue of considerable concern, because the potential health hazards to both human and animal populations [5, 6, 7, 8]. Limit concentration of Nitrate for drinking water is 10 mg/L [9].

Ciliwung River is one of aquatic environment in Bogor City. Population growth resulted in land use changes. Land use in riparian Ciliwung River dominated by settlement (38.69 ha) and housing (20.67 ha). In addition, human activity in riparian Ciliwung River affected water quality in the river. Nitrate concentration coming from human waste and agricultural waste. Composition of water pollution on
Ciliwung River is industrial 7.3%, detergent 40%, human waste 44%, and household waste 6.7% [10]. The purpose of this paper is to determine spatial and temporal variation of Nitrate concentration in Ciliwung River.

2. Site Description and Methodology

2.1. Site description

This study was conducted at Ciliwung River, which is located in Bogor City with elevation 157 – 367 m above sea level (asl). There were 13 sites in Ciliwung River, all sites in this river divided based on villages around the Ciliwung River (Table 1). Length of Ciliwung River, which flows in the part of Bogor City is 14.5 km (Figure 1).

| Site         | Longitude      | Latitude       |
|--------------|----------------|----------------|
| S1 Katulampa | 106°50'16.014" | 6°38'1.2210"   |
| S2 Tajur     | 106°49'22.824" | 6°37'27.856"   |
| S3 Sukasari  | 106°48'49.458" | 6°36'59.814"   |
| S4 Baranangsiang | 106°48'36.461" | 6°36'38.510"   |
| S5 Babakan Pasar | 106°48'21.552" | 6°36'26.205"   |
| S6 Kebun Raya Bogor | 106°47'57.837" | 6°35'27.875"   |
| S7 Sempur    | 106°47'51.792" | 6°35'4.1190"   |
| S8 Tanah Sereal | 106°48'17.830" | 6°34'25.884"   |
| S9 Bantar Jati | 106°48'28.089" | 6°34'13.179"   |
| S10 Kedung Badak | 106°48'31.575" | 6°33'42.262"   |
| S11 Kedung Halang | 106°48'13.020" | 6°33'3.2380"   |
| S12 Cibuluh  | 106°48'19.756" | 6°33'7.4350"   |
| S13 Sukaresmi | 106°48'5.0890" | 6°32'51.727"   |

2.2. Sampling and analysis

Water samples collected 50 ml from Ciliwung River in December 2016, January 2017, and February 2017. Water samples from each site analyzing with Ion Chromatography (LC-10A, Shimadzu, Japan). Ion chromatography used to determine the concentrations of Nitrate (NO$_3$). Before determine Nitrate concentration, water samples stored in refrigerator with temperature under 4°C.

2.3. Data analysis

This study used spatial interpolation. Spatial interpolation is used determined the distribution of Nitrate concentration in Ciliwung River furthermore, the basic principles of spatial interpolation is to create a surface that models the sampled phenomenon in the best possible way. There were 13 sampling point in this study, the point is determined by a random distance where each point represents a village based on the administrative boundaries of the village. This study uses one of spatial interpolation method that is inversed distance weighted.

Inverted distance weighted interpolation (IDW) is an interpolation method commonly used in spatial interpolation analysis [11]. In IDW method, it is assumed substantially that the rate of correlations and similarities between neighbours is proportional to the distance between them that can be defined as a distance reverse function of every point from neighbouring points [12]. Inverted distance weighted
method is used to predict the value of a point to be known by using values from known points [13]. Where, \(Z(x)\) is the value of the point to be known, \(n\) is the number of sample points, \(Z_i\) is the value of the known sample point. The distance between the known sample point and the sample point you want to know is \(d_i\), and \(u\) is the weight value based on the distance.

\[
Z(x) = \frac{\sum_{i=1}^{n} \frac{Z_i}{d_i^u}}{\sum_{i=1}^{n} \frac{1}{d_i^u}}
\]

(1)

3. Result

3.1. Spatial variation of Nitrate
River water flows from Katulampa (S1) to Sukaresmi (S13), this means the concentration of Nitrate flows from Katulampa (S1) to Sukaresmi (S13). Spatial variation of Nitrate influenced by land use. Land use of Ciliwung river riparian in the Bogor city is dominated by settlements 38.69 ha and housing 20.67 ha (Figure 2). Kedung Halang (S11), Cibuluh (S12), and Sukaresmi (S13) are villages dominated by settlements and housing. The highest Nitrate concentration was in all three villages and the lowest concentration was in Katulampa (S1). So, the concentration of Nitrate increases from Katulampa (S1) to Sukaresmi (S13).
3.2. Temporal variation of Nitrate

The average of Nitrate concentrations in December 2016 was 4.30 mg/L with a maximum concentration was 4.90 mg/L in Kedung Halang, Cibuluh and Sukaresmi. The minimum concentration was 2.79 mg/L in Katulampa (Figure 3). In January 2017, the average of Nitrate concentration had increased from 4.30 to 5.70 mg/L with maximum concentration was 6.80 mg/L in Sukaresmi and minimum concentration was 4.09 mg/L in Katulampa (Figure 4). But, the average of Nitrate concentrations in February 2017 had decreased from 5.70 mg/L to 4.80 mg/L where, the maximum concentration was 5.39 mg/L in Cibuluh, Sukaresmi, Bantar Jati, dan Kebun Raya Bogor, and the minimum concentration was 4.00 mg/L in Katulampa (Figure 5).
3.3. Variation of water temperature

Water temperature is a physical parameter that can encourage the occurrence changes in concentration on chemical parameters, this depends on height and low water temperature [14]; [15]; [16]. In December 2016, the average of water temperature in the Ciliwung River was 26.9 °C. In January 2017, the average of water temperature had decreased became 24.9°C. It’s identified that in February 2017 had decreased become the lowest, i.e. 22.3°C (Figure 6).

![Water temperature graph](image)

**Figure 6. Water temperature.**

4. Discussion

The decreasing and increasing of Nitrate concentration in Ciliwung River is influenced by several factors. In the term of temporal variation, seasonally water temperature has affected to decreasing and increasing of Nitrate concentration. When the water temperature decreases, it can decrease the concentration of Nitrate [17]. In this research, the average of water temperature was different for each month. It’s 26.9°C, 24.9°C, and 22.3°C in December 2016, January 2017 and February 2017, respectively.

Other factors that affect the decrease and increase of nitrate concentration are water discharge and rainfall. When, water discharge and rainfall were high, this condition can affect the decrease of Nitrate concentration, because the occurrence of dilution [18, 19].

In the term of spatial variation, land use may affect the decrease and increase of Nitrate concentration [20, 21]. Nitrate concentration was very high in Kedung Halang (S11), Cibuluh (S12), and Sukaresmi (S13), since the land use of these villages are settlements and housing predominantly. Household waste from settlements or housing can degrade water quality [22, 23, 24, 25].

The Nitrate concentration in Kedung Halang (S11), Cibuluh (S12), and Sukaresmi (S13) was different with Katulampa (S1). Nitrate concentration in Katulampa is the lowest one, due to the land use in this village is not dominated by settlements and housing.

5. Conclusion

It’s well known that spatial and temporal distribution of Nitrate concentration was different. Water temperature, rainfall, and water discharge were affected distribution of Nitrate concentration through temporal variation. This condition influenced nitrate concentration in December 2016, January 2017, and February 2017. Where, Nitrate concentration in January 2017 was higher than Nitrate concentration in December 2016 and February 2017. On the other hand, the type of land use affects the distribution of
Nitrate concentrations in spatial variation. Where, the highest concentration in Kedung Halang (S11), Cibuluh (S12), and Sukaresmi (S13) with the use of land dominated by settlements and housing.

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