The Pollutant Load In Downstream Segment Of Citarum River, Indonesia

Ayu Widya Utami, Pramiati Purwaningrum, Diana Irvindiaty Hendrawan

Abstract: The purpose of this study was to analyze the pollutant load of downstream segment of Citarum River. Citarum River is the longest river in West Java which is divided into several segments, namely the upstream, middle and downstream segments. Downstream segment of Citarum River crosses 18 sub-districts in Karawang and 12 sub-districts in Bekasi Regency whose land use is dominated by agriculture, settlements, fisheries, and industrial estate. The poor water quality of downstream segment of Citarum River is caused by the excessive inclusion of pollutant loads into the river bodies derived from anthropogenic activities around the watershed. This research was conducted during 3 observation periods, namely March, April, and June 2019 with 11 locations of water quality monitoring. The levels of pollutant analyzed were BOD, COD, nitrate and phosphate. BOD pollutant in downstream segment of Citarum River ranges from 10029.35 kg/day - 67496.73 kg/day; COD load was 52438.75 kg/day - 199866.92 kg/day; nitrate load was 617.21 kg/day - 5545.57 kg/day and phosphate load was 1653.60 kg/day - 13457.56 kg/day. The high pollutant load of BOD, COD, nitrate and phosphate in downstream segment of Citarum River is caused by the presence of excess waste and comes from domestic, farm, agricultural and industrial activities.

Index Terms: Anthropogenic Activities, Citarum River, Downstream Segment, Pollutant Load, Potential Pollutant Source, Water Quality, Water Pollution.

1 INTRODUCTION

The Citarum River downstream segment flows from Curug Dam, Karawang and ends in the Java Sea, Muara Gembong, Bekasi crossing 18 and 12 sub-districts in Karawang and Bekasi respectively. Furthermore, it is dominated by human activities such as industrial, domestic, agricultural, and fishery, which are the major causes of water pollution in the river. Water pollution occurs due to the entrance of other elements or substances, thereby decreasing its quality. The main sources of pollution in surface water, rivers, and underground water emerge from anthropogenic activities. These are primarily caused by the living habits of poor and unhygienic people and the environmentally-unfriendly activities from agriculture, factories, and industries, which results in poor and unprocessed disposal of waste [1]. When a large amount of waste enters the river, it causes water pollution. Domestic and industrial waste contains high levels of nitrate, phosphate, as well as BOD and COD. In addition, waste containing nitrate and phosphate also originates from agricultural activities. The Citarum River is "crowned" as one of the dirtiest rivers in the world [2]. This indicates that the Citarum river has poor water quality conditions. Some studies show a decline in water quality where 127 km or 47.1% of the Citarum River has been heavily polluted [3]. Polluted rivers can be caused by excess loads entering the river bodies. Pollutant sources that have the largest contribution in polluting the downstream segment of Citarum River are 1) originates from domestic activities, 2) originates from industrial activities and 3) originates from non point source pollutants from the farm and agriculture sectors [4]. Therefore, the purpose of this study is to analyze the pollutant load in downstream segment of Citarum River.

Pollutants are foreign to nature or materials naturally derived which enters into an ecosystem setting, thereby, disrupting its allocation. Due to the emerging technique into the environment, pollutants are divided into two groups, namely natural and anthropogenic [5]. Water pollution is the release of all liquids, solids, gases, pathogenic organisms, or other substances into the water thereby, disrupting and making it dangerous to the health, safety, or welfare of the community and environment. It generally comes from human activities such as manufacturing industries, agriculture, mining, and poor waste management [6]. Pollution originates from the remains of objects made, used, and disposed of by humans. Also, it is from the escape of some/remaining raw materials used in a production process. Pollution increases not only because of the land used by humans but also due to the yearly increase in demand [7]. The sources of river pollution are classified into point and nonpoint. Point sources refer to waste entering into the water bodies through pipes such as industrial, domestic, and, wastewater treatment plants. While non-point originates from spreads such as agricultural activities and runoff water [8]. Pollutant load is the amount of elements contained in water. It is also essentially the amount of pollutant mass in the water bodies for a certain period, expressed in a unit of total load per unit of time [9]. Furthermore, it is the concentration of pollutants (C) multiplied by water flow discharge (Q) [10].

2 RESEARCH METHODOLOGY

2.1 Location and Time of the Study

This study was conducted in six months from February up to July 2019 in the Citarum River downstream segment, from Curug Dam, Karawang to Muara Gembong, Bekasi.

2.2 Stages of the Study

The various stages carried out in this study are listed as follows.

1. The preparation stage, which determines the monitoring locations of the water quality and identifies the potential pollutant sources.
2. Determining the water quality parameters, namely BOD, COD, nitrate, and phosphate.
3. Calculating the river pollutant load.

The monitoring locations of the water quality were based...
on the conditions of the watershed, thereby analyzing the overall research area. The sampling was conducted during three observation periods, namely March, April, and June 2019 at ten main river monitoring locations and one point source, which is in the tributary using the grab sampling method. The sampling is done twice at each quality monitoring point. The monitoring locations of the water quality in downstream segment of Citarum River can be seen in Table 1.

### Table 1
The Monitoring Locations Of The Water Quality

<table>
<thead>
<tr>
<th>Point</th>
<th>Location of Monitoring</th>
<th>Coordinate Point EL &amp; SL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jl. Demang, Karawang</td>
<td>107°22'06.8&quot; &amp; 6°24'44.6&quot;</td>
</tr>
<tr>
<td>2</td>
<td>Jl. Rumambe I, Karawang</td>
<td>107°19'28.3&quot; &amp; 6°21'45.1&quot;</td>
</tr>
<tr>
<td>3</td>
<td>Teluk Jambe Bridge, Karawang</td>
<td>107°18'43.3&quot; &amp; 6°19'36.8&quot;</td>
</tr>
<tr>
<td>4</td>
<td>Tarumanagara Bridge, Karawang</td>
<td>107°17'16.4&quot; &amp; 6°17'54.7&quot;</td>
</tr>
<tr>
<td>5A</td>
<td>Labansari, Cikarang Timur, Bekasi (point source)</td>
<td>107°15'54.1&quot; &amp; 6°16'56.2&quot;</td>
</tr>
<tr>
<td>6</td>
<td>Jl. Raya Proklamasi, Karawang</td>
<td>107°16'34.7&quot; &amp; 6°14'57.0&quot;</td>
</tr>
<tr>
<td>7</td>
<td>Jl. Raya Pebayuran, Bekasi</td>
<td>107°16'21.4&quot; &amp; 6°13'10.9&quot;</td>
</tr>
<tr>
<td>8</td>
<td>Jl. Raya Tugu Proklamasi, Rengasdengklok, Karawang</td>
<td>107°17'14.1&quot; &amp; 6°09'24.9&quot;</td>
</tr>
<tr>
<td>9</td>
<td>Jl. Teluk Bango, Karawang</td>
<td>107°12'31.7&quot; &amp; 6°05'52.1&quot;</td>
</tr>
<tr>
<td>10</td>
<td>Jl. Raya Pakisjaya, Karawang</td>
<td>107°07'22.3&quot; &amp; 6°02'50.2&quot;</td>
</tr>
<tr>
<td>11</td>
<td>Muara Gembong, Bekasi</td>
<td>107°02'38.7&quot; &amp; 5°59'04.5&quot;</td>
</tr>
</tbody>
</table>

Also, the data analysis was conducted, which included water quality and pollutant load analysis. The pollutant load of the river is calculated using the following formula:

\[ RPL = Qs \times Cs \times f \]

**Information:**
- **RPL**: River pollution load (kg/day)
- **Qs**: River flow discharge (m³/second)
- **Cs**: Pollutant element concentration (mg/L)
- **f**: Conversion factor

### 3 RESULTS AND DISCUSSION

Pollutant load discharged to river waters comes from activities in the surrounding areas of the watershed. The table 2. lists the various activities around the monitoring locations of the water quality. The activity around the monitoring locations in downstream segment of Citarum River can be seen in Table 2.

### Table 2
Activities Around The Monitoring Locations

<table>
<thead>
<tr>
<th>Point</th>
<th>Pollutant Resource Potentials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The settlement, agriculture, fishing grounds, and stalls</td>
</tr>
<tr>
<td>2</td>
<td>Industry, settlement, stalls, and restaurants</td>
</tr>
<tr>
<td>3</td>
<td>Settlement, stalls, restaurants, and, shops</td>
</tr>
<tr>
<td>4</td>
<td>Settlement, hotels, stalls, restaurants, and, shops</td>
</tr>
<tr>
<td>5A</td>
<td>Settlement and stalls</td>
</tr>
<tr>
<td>6</td>
<td>Agriculture, settlement, stalls, and shops</td>
</tr>
<tr>
<td>7</td>
<td>Agriculture, settlement, and restaurants</td>
</tr>
<tr>
<td>8</td>
<td>Agriculture, farm, settlement, stalls, and restaurants</td>
</tr>
<tr>
<td>9</td>
<td>Agriculture, settlement, stalls, and restaurants</td>
</tr>
<tr>
<td>10</td>
<td>Cage, farm, settlement, and stalls</td>
</tr>
<tr>
<td>11</td>
<td>Mosque, agriculture, settlement, stalls, and market</td>
</tr>
</tbody>
</table>

The pollutant load is obtained by multiplying the discharge and the level of elements entering the river. Regarding potential resources, BOD, COD, nitrate, and phosphate comes from domestic, agricultural, and industrial waste and are analyzed. The level of organic pollution occurs due to the excessive amounts of organic materials, which are usually monitored by measuring the BOD and COD values in the river. High BOD level reduces river water quality by the rapid decomposition of organic materials, which is degraded and depleted with the subsequently dissolved oxygen, while COD simply represents the total organic materials [11]. The pollutant load of BOD in downstream segment of Citarum River can be seen in Fig. 1.

![Fig. 1. The BOD Pollutant Load in the Citarum River Downstream Segment](image1)

![Fig. 2. The COD Pollutant Load in the Citarum River Downstream Segment](image2)

According to Figures 1 and 2, the conditions of BOD and COD pollutant load fluctuates during the three observation periods. The BOD pollutant load ranged between 10029.35 kg/day – 67496.73 kg/day, while the COD was 52438.75 kg/day –
The high pollutant load of both was caused by the settlement activities directly disposed into the river body. The wastewater that comes from households, stalls, and restaurants contains organic materials. Furthermore, water pollution by organic waste causes high values of BOD and COD [12]. Industrial activities along the watershed also contributed significantly to increasing their pollutant load. According to the data from the Coordinating Ministry of Maritime Affairs of the Republic of Indonesia, in 2017, around 90% of the 3236 textile industries did not have wastewater treatment plants (WWTPs), with a total of 280 tons of chemical and medical waste disposed into the Citarum River per day [13]. Big factories located in the upstream and downstream watershed such as textile, footwear, and food industries also played a role as contributors of waste in the sub-watershed of the Citarum River, along with micro small and medium enterprises [13]. The BOD and COD pollutant load of the river shows the amount of organic pollution in the water [14]. Both values are a measure of the relative oxygen depletion effects of the waste contaminants and have been widely adopted as a measure of the pollution effects. BOD sources in the waters include leaves and wood debris, dead plants and animals, animal manure, industrial waste, wastewater treatment plants, feedlots, food processing factories, failed septic systems, and urban rainwater runoff [15]. High BOD values indicate a decrease in DO because the oxygen available in water is being consumed by bacteria, thereby making fishes and the other aquatic organisms unable to survive in the river [16]. The high concentration of COD causes oxygen depletion due to microbial decomposition and to a level that is harmful to aquatic life [17]. Nitrate is a plant nutrient required for protein synthesis. It is responsible for plant growth and nitrogen fixation. Nitrate is found in nature as a final product of the aerobic decomposition of organic nitrogen materials and microorganisms [18]. Also, it is the most common water contaminant not volatile and may remain inside until plants or other organisms consume it. Due to its stability and solubility, the increased level of nitrate in the water also indicates the presence of other contaminants, pathogenic microbes, and pesticides. Furthermore, its concentration depends on the soil type and land-use practices [19]. According to Figure 3, the river nitrate pollutant load further increases due to the waste from agricultural activities and settlements. Nitrate pollutant load during the 3 observation periods has a range between 617.21 kg /day - 5545.57 kg /day with an average of about 2072.38 kg /day. Nitrate is the key element in the nitrogen cycle because of the relationship between the nitrification and denitrification processes. Its level in water fluctuates according to the season, with higher levels occurring after heavy rains [20]. Nitrate (NO$_3^-$) is a form of a stable compound where the origin of its presence tends to come from agricultural waste, use of fertilizer, domestic activities, and animal manure. However, it does not last long enough, and a temporary condition of the oxidation process between ammonia and nitrate occurs in the river water [21]. The pollutant load of nitrate in downstream segment of Citarum River can be seen in Fig. 3.

Pollutant sources that come from urban, industries, and agriculture are the main factors for high concentrations of nitrate. Furthermore, climate change also affects its movement into the waters in a complicated way. Climate change accompanied by temperature, quantity, and distribution of the rainfall and higher concentration of CO$_2$ in the atmosphere affects the sources of nitrate [22]. Phosphorus is available in wastewater in a form which includes organic and inorganic bound phosphate. Organically bound phosphate in wastewater comes from human feces and urine. Also, waste with excessive phosphorus is the leading cause of eutrophication in surface water bodies such as in lakes and rivers [23]. Phosphorus content varies in various bodies of water, for example, phosphate is found in higher concentrations near the mouth of the river because of the destructive effects of waves on its banks. However, in less polluted natural waters, the phosphorus concentration varies from 0.1 to 1000 μg L-1 [24]. Its level in the waters is significant, as it helps in protein formation and organic metabolism. However, a high level of phosphate in the waters causes an explosion in the number of algae (blooming) that have adverse impacts on aquatic biota [25]. The value of phosphate pollutant load ranged between 1653.60 kg/day – 13457.56 kg/day with an average of 5719.98 kg/day. The phosphate pollutant load is high due to the amount of waste entering into the river from domestic and agricultural activities. The household waste which disposes directly into the river, from washing activities in the form of detergent is one of the causes of high phosphate level. The pollutant load of phosphate in downstream segment of Citarum River can be seen in Fig. 4.
Phosphorus (P) is an essential nutrient for organisms in aquatic food webs. A simple increase, under the right conditions, increases the primary production, and biomass, while potentially reducing the dissolved oxygen (DO) that is eutrophication. Both natural and anthropogenic phosphate sources come from the soil and rock mineralization, the effluents from the wastewater treatment plants, use of fertilizer, agricultural/animal runoff, septic system failure, and laundry waste [26].

4 CONCLUSION
The high pollutant load of BOD, COD, nitrate and phosphate in the Citarum River downstream segment is caused by waste generated from domestic, farm, agricultural and industrial activities. The BOD ranged between 10029.35 kg/day – 67496.73 kg/day, while the COD was 52438.75 kg/day – 199866.92 kg/day. However, the nitrate pollutant load value ranged between 13457.56 kg/day – 13457.56 kg/day. Out of the four pollutant load parameters, the pollutant with the highest value is COD pollutant, while nitrate has the lowest. Based on the analysis conducted that the pollutant load of all parameters is increasing when it gets closer to the river downstream. This occur due to the accumulation of pollutants is caused by the flow of the velocity that becomes slower when it gets closer to the river downstream.

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