The Removal of Organic Materials and Nutrients with Addition of Artificial Supporting Materials in The Water Body (A Case Study of Cikapayang River, Bandung City Hall)

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Abstract. Cikapayang River is a branch from Citarum River that flows across Bandung City, starting from Dago to Riau Street. Ninety percent of the community living around the river dispose of domestic wastewater directly into a water body without any treatment. This condition causes a decline in river quality. Various technological efforts have been made to enhance the water quality in the river, including efforts in dealing with pollution prevention from the source treatment in the water body. One of the technical options in providing therapy in the water body is using the filtration with supporting materials. It is hoped that through this supporting material, physical, chemical, and biological processes will occur, so that organic material and nutrients can be eliminated. In this study, removal of organic materials and nutrients was carried out by using artificial supporting materials in Cikapayang River with two different sizes, Block I is 350x15x100 cm, and Block II is 325x15x100 cm. Cikapayang River quality is classified as lightly polluted based on PI calculation. The average removal efficiency of Block I is 50% COD, 33% TSS, 23% TP, and 39% TN, meanwhile Block II has a removal efficiency of 38% COD, 30% TSS, 28% TP, and 49% TN. The difference in material surface area between the two materials causes different removal efficiency. But these results indicate that the content can be used to remove organic materials and nutrients. The addition of artificial support material in Cikapayang River can reduce IP value, from 4.74 to 3.71.

Keywords: cikapayang river, artificial supporting material, organic matter, and nutrient.

1. Introduction
Wastewater is produced by human activity that is very closely related to daily life. Based on the source, wastewater can be divided into wastewater from industrial (industrial wastewater) and wastewater from household activities (domestic wastewater). Domestic wastewater is generally contaminated and contains pollutants. It can come from the kitchen, bathroom, and washing water. The contamination that occurs can be physical, i.e., the water is cloudy, smelly, and solid contains; chemical, organic materials,
and nutrients; or biological, i.e., pathogenic microorganisms that can endanger the environment, especially human health [1].

The city, as the center of human activities, should provide sufficient facilities and infrastructures to support sustainability. Regarding the problem of wastewater, supporting facilities are needed, including sewerage and treatment. Even though wastewater treatment facilities are lacking, there are still many people who dispose of wastewater that they produce, into river bodies without being treated even though the river is one of the natural water resources that must be protected from materials that cause pollution [2].

The environmental condition around the Citarum River in West Java has changed a lot since 1980. The results of the 2012 quality testing by the West Java Environmental Management Agency, or called BPLHD, stated that 90% of Citarum River was heavily polluted. Based on 75 samples of water sample test points, 68 of them showed inferior or substandard results that were permitted. This is due to Citarum tributaries being contaminated with domestic wastewater from community settlements that made the river flow for local wastewater disposal from their daily activities [3].

Various efforts have been made to deal with the local system in handling domestic wastewater. However, there are still some weaknesses such as the malfunctioning of communal Wastewater Treatment Plants (WWTP), low standards of manufacturing WWTPs available, and limitations of Human Resources (HR) to operate and manage available facilities. This is the cause of its potential and the severity of pollution of water body caused by domestic wastewater which is increasingly out of control [4].

While big effort is still required as pollution prevention of the river, the treatment or purification of river water becomes the other solution to enhance water quality in the river. This solution becomes more urgent because the river is the main water resources use for drinking water supply. One of the technological efforts is to do water treatment in water body using artificial material. It is expected that through these supporting materials; a physical, chemical, and biological process will occur, so that organic materials and nutrients can be removed. The technology of adding supporting materials in the water body to reduce pollution is very useful, especially if it is planned in an integrated manner in designing a landscape for a park in urban areas to improve the existence of public facilities, such as has been done in one part of Cikapayang River at Bandung City Hall.

Aims of this research are to determine the effectiveness of the addition of artificial support material into the water body and assess the removal efficiency of types of material used.

2. Methodology

2.1. Artificial supporting material

This study uses artificial supporting material in the form of mineral wool. This material is called mineral wool because it contains elements, such as O, Si, Al, Ca, Fe, and Mg. Mineral wool is an inert chemical substrate obtained from volcanic and has porosities more than 90%. Inert chemicals in material make it possible to supply nutrients, provide a balance of air supply and oxygen concentration in water body [5]. Mineral wool has the capacity to adsorb and contact surface material is quite high, low density, and easy to apply in the field. The following in Figure 1 is a visual description of artificial supporting material which is ready to be applied in water body using cages made from iron coated with stainless paint. Figure 1 also shows mineral wool as artificial supporting material specification used in this study and dimensions of the material applied in Cikapayang river.
Figure 1. The Confinement Design of Artificial Supporting Material

Figure 1 stated Mineral wool has a density of 120 kg/m³. Mineral wool has many types and uses. In this study, the material used is mineral wool with rough and rigid type to treat and can store water up to 92%. This study makes the material in two different sizes, namely 350x15x100 cm as Block I and 325x15x100 cm as Block II. Based on these dimensions, it appears that Block I and II has a length difference. With this size, known that “Block” I have a wider surface area. The height of the materials is made 20 cm more from the maximum height of water to ensure that water flowing through materials and pollutant removal process occurs.

A filter removes both inorganic and organic solids from a water stream by filtration, effectively separating the SS from the fluid (water). The filtration theory mentions that SS removal is summarized by three different mechanisms. The first mechanism is transportation. It starts when a solid particle filter and ends when it settles on a drain fiber. This is a phase describing the forces holding a particle on artificial supporting material. Finally, during the transformation. Whereas over time, inorganic SS accumulates on top of each other, organic SS is broken down into smaller aggregates which are then oxidized to carbon dioxide, water and inorganic salts [6].

Another mechanism consists of adsorption forces and a biofilm layer. Adsorption occurs when the solid particle touches the filter material. The two forces responsible for holding the particle on the drainage are van der Waals' and electrostatic forces. Both forces are directly proportional to the distance between solid particles [6]. The Heavier the Mass, the stronger the attraction. Electrostatic forces can either be attractive or repulsive depending on the charge of the particle. In general, both mineral wool and SS have a negative charge and repulsion takes place. These repulsive forces can be reduced by the active charged metal elements, such as magnesium ions, to the solid particle [7]. This decreases the particle's suspension stability, making it easier for them to aggregate together or adsorb to artificial supporting material. As organic particles settle on the material fibers, the biological activity occurs, which stimulates the growth of bacteria and microorganisms, resulting in a sticky layer around the Drainblock fiber [6].

2.2. Location
Cikapayang River on Bandung City Hall has been restored since 2015. The restoration are including the establishment of treatment units on upstream. The treatment unit consists of equalization basin equipped with coagulation and filtration unit using silica sand. The river design is made winding and made steep with varying heights. These efforts aim to increase the possibility of river water flowing in contact with air so that it is expected that dissolved oxygen in the water can increase. Segments for the installation of artificial supporting material in Cikapayang River are on segment 8 and 9, as shown in Figure 2 as follows.
2.3. Sampling

Sampling was done by grab sampling before (inlet point) and after (outlet point) passing artificial supporting material on segment 8 and segment 9 (Figure 2). Parameters measurement includes on-site measurement consists of temperature, pH, Dissolved Oxygen (DO), water level, velocity, and flow rate, and laboratory measurement includes Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Volatile Suspended Solid (VSS), turbidity, Total Dissolved Solid (TDS), conductivity, Total Phosphate (TP), Total Nitrogen (TN), nitrate, and nitrite. The sample for laboratory measurement is preserved according to Standard Nasional Indonesia (SNI) 6989.58:2008 in Table 1.

| Type        | Parameter                        | Analysis Requirement                                      | Treatment                                           |
|-------------|----------------------------------|----------------------------------------------------------|-----------------------------------------------------|
| Physical    | TSS, VSS, turbidity, TDS, and conductivity |                                            | Cooled at 4 ± 2°C                                   |
| Chemical    | COD, TP, TN, nitrate, and nitrite |                                            | Adding H₂SO₄ until pH <2, cooled at 4 ± 2°C         |

2.4 Data Analysis

Data from laboratory analysis are compared with the water quality standard, namely the Republic of Indonesia Government Regulation No. 82 of 2001. Determination of water quality status using Pollution Index (PI) method in accordance with the Decree of Environment Minister No. 115 of 2003.

\[
PI = \sqrt{\left(\frac{C_{ij}}{L_{ij}}\right)^2 M + \left(\frac{C_{ij}}{L_{ij}}\right)^2 R} \tag{1}
\]

Where, \(C_i\) is the concentration of water quality parameter I, \(L_{ij}\) is the concentration of water quality parameter I listed in the standard water j, while \(M\) is maximum, and \(R\) is average.

This method connects the level of pollution on a river that is used for certain purposes with certain parameter values, as shown in Table 2.

| PI Value | Water Quality         |
|----------|-----------------------|
| 0 – 1.0  | Good condition        |
| 1.1 – 5.0| Lightly polluted      |
| 5.0 – 10.0| Medium polluted     |
| >10,0    | Heavily polluted      |

After obtaining supporting data such as segment width (w), depth or water level (h), and velocity (v), then flow rate (Q) can be calculated which is the total velocity each segment.
\[ Q = w \ h \left( \frac{v_1 + v_2 + v_3 + ... + v_n}{n} \right) \]  \hspace{1cm} (2)

Pollutant removal efficiency can be calculated by considering influent concentration \( (C_i) \) and effluent concentration \( (C_e) \) using the following equation.

\[ \text{Removal} \% = \frac{C_i - C_e}{C_i} \times 100\% \]  \hspace{1cm} (3)

3. Result and Discussion

3.1 Cikapayang River Characteristic

Cikapayang River that crosses Bandung City Hall has a total length of 500 m which is divided into several segments. The upper side of the river is on the east side of Historical Park, while the downstream is in the southeast of Badak Park. Figure 3 shows the existing condition of segment 8 and 9, which were selected locations for adding artificial support materials and taking water samples before and after passing the material. Table 3 showed the result of measuring the quality of Cikapayang River on Bandung City Hall, on segment eight and segment nine within four months from September 2018 until January 2019. Sampling is done seven consecutive days within two weeks at the inlet of each segment.

![Figure 3. The existing conditions of segment (a) 8 and (b) 9 in Cikapayang River, Bandung City Hall](image-url)

| Type          | Parameter  | Unit | Result  | Average |
|---------------|------------|------|---------|---------|
| Physical      | Temperature| °C   | 23 – 27 | 24      |
|               | TSS        | mg/L | 7 – 66  | 25      |
|               | VSS        | mg/L | 0.5 – 1.5 | 1.0    |
|               | Turbidity  | NTU  | 7 – 533 | 23      |
|               | TDS        | mg/L | 144 – 4090 | 618   |
|               | pH         | -    | 5.6 – 9.8 | 7.3    |
|               | Conductivity| um/ms| 3.4 – 6990 | 973   |
|               | DO         | mg/L | 0.5 – 5.0 | 2.46   |
|               | COD        | mg/L | 26 – 179 | 77      |
|               | TP         | mg/L | 0.08 – 0.78 | 0.39  |
|               | TN         | mg/L | 2.40 – 22.80 | 15    |
|               | Nitrate    | mg/L | 0.03 – 2.84 | 0.81  |
|               | Nitrite    | mg/L | 0.02 – 3.75 | 0.73  |
| Supporting Data| Water level| m   | 0.6 – 0.9 | 0.84   |
|               | Velocity   | m²/s | 0.3 – 3.7 | 1.8    |
|               | Flow rate  | m³/s | 0.5 – 6.6 | 2.98   |
Based on Table 3, the concentration of parameters observed had fluctuated from time to time. The quality of Cikapang River is influenced by the existence of a treatment unit, also supported by a restored river design. River walls are made winding and are added waterfall with a different height at each segment. Chanson (1994), indicated that the overflow is plastered, turbulence will occur, which results in an increased oxygen transfer, so that DO concentration will be increased. The availability of sufficient oxygen also provides an opportunity to accelerate the degradation process of pollutant [5].

The existing of the waterfall in Cikapayang River is designed multilevel and surface textured made of stones with an average diameter are 10 cm. The stone can increase contact between river water and air. Stone profiles can also help remove organic materials and nutrients when biofilm have been created. The small size of the rock makes the surface area will be greater. So that the biofilm is formed also become wider, and the efficiency of organic pollutant removal will be increased. This is a natural condition that also can help remove pollutants in water bodies [1].

Based on Government Regulation No. 82 of 2001, water resources are classified into four classes. Table 4 is a comparison of measurement results of Cikapayang River quality with water quality standard. By comparing the result of river quality measurements based on its class, it is known whether the current river quality is still able to support the allocation as planned, or the existing conditions need improvement efforts due to the concentration of pollutant parameters observed exceeding the required quality standard.

**Table 4.** Cikapayang river toward water quality standard

| Parameter | Unit | Result | Class I | Water Quality Standard | Class II | Class III | Class IV |
|-----------|------|--------|---------|------------------------|---------|-----------|---------|
| Temperature | °C | 24 | Deviation 3 | 6-9 | Deviation 3 | 6-9 | 6-9 | 5-9 |
| pH | - | 7.3 | 6-9 | 6-9 | 6-9 | 5-9 |
| DO | mg/L | 2.46 | 6 | 4 | 3 | 0 |
| TSS | mg/L | 25 | 50 | 50 | 400 | 400 |
| TDS | mg/L | 618 | 1000 | 1000 | 1000 | 1000 |
| COD | mg/L | 77 | 10 | 25 | 50 | 100 |
| TP | mg/L | 0.39 | 0.2 | 0.2 | 1 | 5 |
| Nitrate | mg/L | 0.81 | 0.5 | (-) | (-) | (-) |
| Nitrite | mg/L | 0.73 | 0.06 | 0.06 | 0.06 | (-) |

Based on observation, the main function of Cikapayang River is as part of public space and education to improve public awareness from the importance of the river for human life. According to this condition, Cikapayang River can be categorized into class II. Refers to Government Regulation No. 82 of 2001, class II is for recreational activities or water infrastructure, cultivation of freshwater fish, livestock, water to irrigate plantations or the other designations that require water quality equal to the usefulness. Based on Table 4, known that the existing of Cikapayang River quality is not able to support its designation as a part of public space, i.e. recreation. The analysis result shows that Cikapayang River quality is more likely to be class III. This is because some parameters are observed, such as DO, COD, TP, nitrate and nitrite that exceed the quality standard required in class II. It is permissible for the cultivation of freshwater fish, livestock, water to irrigate crops or other designations which require the same water quality as those used. It is feared that with some chemical parameters exceed class II water quality standard, it is not recommended for activities where humans and river water contact directly.

Water quality status is the level of water quality condition that indicates total pollutions in a water source that are measured based on certain parameters and methods by comparing with specified water quality standard. The result of the analysis of physical and chemical parameters was analyzed by class II water quality standard. The result of the calculation of PI value is in accordance with the Decree of the State Minister of Environment No. 115 of 2003 concerning Guideline for Determining Water Quality Status. In this PI calculation, some parameters such as VSS, turbidity, and TN, are not the calculation
parameters because there is no standard quality value of each of these parameters. Determining Cikapayang River quality status can be seen in Table 5.

### Table 5. Cikapayang River quality status for class ii water criteria

| No. | Parameter | C<sub>i</sub> | L<sub>ij</sub> | C/L<sub>ij</sub> | New C/L<sub>ij</sub> | PI  | Quality Status     |
|-----|-----------|-------------|--------------|----------------|--------------------|-----|-------------------|
| 1.  | Temperature | 24          | 25           | 1.14           | 1.28               |     |                   |
| 2.  | pH        | 7.3         | 6-9          | 0.15           | 0.15               |     |                   |
| 3.  | DO        | 2.46        | 4            | 1.51           | 1.89               |     |                   |
| 4.  | TSS       | 25          | 50           | 0.50           | 0.50               |     |                   |
| 5.  | TDS       | 618         | 1000         | 0.62           | 0.62               | 4.74| Lightly Polluted  |
| 6.  | COD       | 77          | 25           | 3.08           | 3.44               |     |                   |
| 7.  | TP        | 0.39        | 0.2          | 1.95           | 2.45               |     |                   |
| 8.  | Nitrate   | 0.81        | 0.5          | 1.62           | 2.05               |     |                   |
| 9.  | Nitrite   | 0.73        | 0.06         | 12.17          | 6.43               |     |                   |

Even though some parameters have exceeded class II water quality standard, in general, the index of the water quality in Cikapayang River is classified as lightly polluted. By using measurement data from temperature, pH, DO, TSS, TDS, COD, TP, nitrate, and nitrite, so PI value calculation is 4.74. This can be supported by the absence of several parameters in the calculation. But with this value, it is almost close to a more serious pollution condition if the PI value is more than 5. Nitrite is one parameter that has a value that looks very exceeded beyond the required quality standard. Nitrite (NO<sub>2</sub>) is a transitional form between ammonia and nitrate (nitrification), between nitrate and nitrogen gas (denitrification) therefore nitrite is unstable in the presence of oxygen. Nitrite levels of more than 0.06 mg/L are toxic to aquatic organisms. The presence of nitrite describes the ongoing biological process of reforming organic materials which has a low DO level.

COD values are a measure of water pollution by organic material which can naturally be oxidized through microbiological processes and result in reduced DO in water. In the upstream is often found garbage floating on the water surface. The appearance of the river is also cloudy and the amount of foam that is possible due to wastewater from washing activities using detergent. This finding is supported by measurement data, it is very possible that Cikapayang River is to be domestic wastewater disposal site. The characteristic of measured COD value generally shows a value greater than the required quality standard. The high value of this COD can be a negative impact on the aquatic ecosystem balance.

#### 3.2. Block I

Filter media gave higher removal efficiency when it has a large cross-section area to pass. To get a larger cross-section, this artificial supporting material as media that used in this study is by placing it in slanted in the water body. Thus the surface of the filter should be as small as possible to improve the oxygen concentration by creating more turbulence. Block I has longer size than Block II. The difference is to prove whether the wider cross-sectional area affected the results of the removal that is getting better. Figure 4 showed the result of measurements of COD, TSS, TP, and TN on segment 8 due to the addition of artificial supporting Block I to 124<sup>th</sup> days observation.
Based on the measurement result, the addition of Block I can remove suspended solids in water body. But over time, the removal for TSS parameter shows the value between measurements inlet and outlet being stable (steady-state). TSS is in a steady-state condition which has a smaller efficiency. The difference in value between the inlet and outlet becomes insignificant. Unlike the physical parameter, the removal of organic materials and nutrients represented by COD, TP, and TN, showed increasingly significant efficiency after 80th days. The efficiency of COD and TP removal shows a very fluctuating condition in 40-80th days previously. After 80th days, COD removal becomes steady-state with 50-60% removal efficiency. Lower efficiency occurs in TP with the results of the average removal in the range of 20-30%. While TN has 30-40% removal performance.

3.3. Block II
Figure 5 showed the result of the measurement of chemical parameters on segment 9 due to the addition of artificial supporting material which includes COD, TSS, TP, and TN up to 146th days. Block II that applied on segment 9 has the same characteristic as the material is on segment 8. The difference is only in length and total volume. The flow of water which becomes the inlet of segment 9 is water that has passed through and experienced removal by Block I. In addition, between segments 8 and 9 there is a separator in the form of two-level waterfalls which has a different height. The first level has a height of

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**Figure 4.** Measurement of (a) COD, (b) TSS, (c) TP, and (d) TN on Block I

| with: |  |
|-------|---|
| =     | Quality parameter before passing artificial supporting material (inlet) |
| ,     | Quality parameter after passing artificial supporting material (outlet) |
50 cm, while the second level has a height of 30 cm. Therefore, the water flowing into segment 9 inlet also get a natural aeration process.

![Graphs showing COD, TSS, TP, and TN over time](image)

**Figure 5.** The measurement of (a) COD, (b) TSS, (c) TP, and (d) TN on block II

with:

- **=** Quality parameter before passing artificial supporting material (inlet)
- **=** Quality parameter after passing artificial supporting material (outlet)

Based on Figure 5 after the 100th days, the measurement of each parameter, that is COD, TSS TP, and TN shows the difference in concentration between inlet and outlet passing artificial support material to be relatively stable which is possible already in steady-state conditions. Unlike the conditions before the 100th days, the efficiency of the removal is very fluctuating with a range of values that is quite different from one another's observations. With increasing time, the biofilm layer formed on artificial supporting material on segment 9 becomes thicker and results in a decrease in COD value. Decreasing COD concentration indicates the success of biofilm in reducing the concentration of organic pollutants in the water body.

### 3.4 Evaluation of Removal Performance

Mineral wool which is applied in Cikapayang River is only used as an artificial supporting material. Thus, the allowance produced will not be like a complete processing unit that has an average removal efficiency approaching 100%. Table 6 shows showed the ability to remove organic materials and nutrients by artificial supporting materials in Cikapayang River.
Based on Figure 6 known the measurement result shows that the Block I has a better ability to remove organic materials, but not with nutrient removal when compared with supporting materials II. The difference in COD removal is up to 12%. The difference in cross-sectional area is a very influential factor. While, TSS removal by artificial supporting materials in the form of mineral wool ranges from 30-33% in Cikapayang River. Values of pH, temperature, and DO are supporting factors for nutrient removal in the water body. Getting closer to the ideal value, nutrient removal can be eliminated optimally. The difference removal efficiency for TP and TN by artificial supporting Block II toward I is 5 and 10%. Table 7 shows decreased IP values before - after the addition of artificial support materials in Cikapayang River.

Based on the decrease in IP value (before-after) which shows the quality status of the body is getting better, it can be seen that mineral wool as an artificial supporting material can help to remove some pollutants in the form of organic materials and nutrients in the water body. A decrease in IP value from 4.74 to 3.71 (almost 1 scale).

4. Conclusion

a. The improvement of Cikapayang River water quality has relied on treatment unit which exists in upstream and design of river restoration. The existing condition of Cikapayang River quality has exceeded Class II water quality standard. The Republic of Indonesia Government Regulation No. 82 of 2001, such as DO, COD, TP, nitrate and nitrite. Based on the calculation results using PI,
the pollution that occurs is still within the light limit. However, the value is closer to the more serious contaminated limit.

b. Block I that have a larger surface area than Block II, can remove organic materials better. Whereas nutrient allowance has lower efficiency. This answers that the surface area influences the removal of organic materials but not nutrients.

c. Mineral wool as artificial supporting materials can be used to remove organic materials and nutrients. The addition of mineral wool in Cikapayang River can reduce IP value, from 4.74 to 3.71, almost 1 scale.

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