Environmental factors associated with decomposition of organic materials and nutrients availability in the water and sediment of Setail River, Banyuwangi, Indonesia

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Abstract. This study was aimed to know the environmental factors influencing the decomposition of organic materials and nutrient availability in the water and sediment of Setail River. The sediment sample was collected from five locations (SR1, SR2, SR3, SR4, and SR5). The water sample was analyzed for total organic matter (TOM), ammonia, nitrate, phosphate, dissolved oxygen (DO), chemical oxygen demand (COD), turbidity, total suspended solids (TSS), total dissolved solids (TDS), and pH. The sediment sample was analyzed for organic carbon, total nitrogen, C/N ratio, and total bacterial number. The results showed that the decomposition of organic materials in the water was influenced by several environmental factors, such as DO and COD. The organic carbon, total nitrogen, and total bacterial number in the sediment might also affect the amount of organic materials and nutrients in the water. It was suggested that decomposition of organic materials in the Setail River seemed to be related to the ammonification and nitrification process.

1. Introduction

The decomposition of organic materials plays a crucial role in the nutrient cycle in an aquatic ecosystem. Organic materials come from natural and anthropogenic activities that may cause several problems in the aquatic environment [1]. The organic materials should be immediately decomposed to inorganic form to be able to be used by aquatic plants, including macrophytes and planktonic plants [2]. Ammonification usually takes place by ammonification bacteria to degrade the organic materials in ammonia form. After that, the next process is carried out by several nitrifying bacteria, by converting ammonia to nitrite and nitrate [3]. The compound generally used by aquatic plant for growth is nitrate. However, the accumulation of nitrate in the water may cause the overgrowth of aquatic plant that may lead to eutrophication and decrease the quality of the ecosystem [4].

Setail River is one of the most significant rivers in the District of Banyuwangi, East Java Province, Indonesia. This river receives a lot of anthropogenic activities, such as agriculture, residence, and home industries. Since Banyuwangi District takes place as the fifth densest district in East Java Province, a high amount of domestic waste is accumulated in several rivers in Banyuwangi, including Setail River. The accumulation of household waste in the Setail River may cause degradation of its
A high amount of organic materials needs a large amount of oxygen in aerobic condition to be degraded by aerobic bacteria [5]. Higher concentration of organic materials existed in the water of the river; the higher oxygen depletion might occur in this ecosystem. Another anthropogenic activity influencing Setail River is an agricultural activity, which consumes a high number of inorganic fertilizers, such as ammonium nitrate and super phosphate. The unused inorganic fertilizers might be released to the stream and river. Therefore, it is essential to observe the environmental factors related to the decomposition of organic materials and nutrients. This study aimed to determine the ecological factors associated with the organic materials and nutrients in the Setail River. The finding of this study was expected to give any contribution to the aquatic environmental management, by giving database of environmental status in the Setail River.

2. Materials and method

2.1. Site location

This study was carried out in Setail River, located in the Banyuwangi District, East Java Province, Indonesia. Water and sediment sampling was carried out at five sites: Sub district Genteng (SR1), Sub district Gambiran (SR2), Sub district Kradenan (SR3), Sub district Wringin Pitu (SR4), and Sub district Wringin Putih (SR5) as described in Figure 1.

![Figure 1. Sites location](image)

2.2. Analysis of water quality

The dissolved oxygen (DO) of the river water was measured using the Winkler method (SNI: 06 6989.14-2004). Total organic matter (TOM) was measured using a permanganate-based titrimetric method (SNI 06-6989.22-2004). The Chemical Oxygen Demand (COD) of water sample was analyzed using the Dichromate method based on SNI 6989.73:2009. Total suspended solids in the water sample were analyzed using the Gravimetric method (SNI 06-6989.3-2004). Total Dissolved Solid (TDS) of water sample was measured using TDS meter, while water acidity was measured using pH meter. The ammonia level in the water was analyzed using the indophenol blue method based on SNI 19-7119.1-2005. The nitrate content in the water sample was analyzed using the Brucine solution.
2.3. Analysis of sediment properties

The content of organic carbon in the sediment was analyzed using Walkley-Black method [6]. Total nitrogen in the sediment was measured using Kjeldahl distillation method (SNI 4146:2013). The total bacteria were analyzed using a Total Plate Count (TPC) method using plate count agar.

3. Results

3.1. Water quality

The results of the study showed that the water quality of Setail River was varied among sites (Table 1). Total organic matter in the water was ranging from 3.2 to 8.8 mg/L, while ammonia was ranging from 0.16 to 0.45 mg/L. Measurement of nitrate also showed varied results, ranging from 9 to 12 mg/L. The value of phosphate was ranging from 0.6 to 3.1 mg/L. The highest DO was shown at SR1, while the lowest DO was found at SR5. The turbidity of water was increased from 4.2 to 35.4 NTU. The increase of water turbidity was seemed to be related to the increase of TSS and TDs of the water (28 to 55 mg/L and 144 to 256 mg/L, respectively). The value of water acidity decreased from 7.9 to 6.6. These results indicated that water quality tends to decrease from upstream to the downstream.

Table 1. Water quality of Stail River.

| Parameter     | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Quality Standard Class* |
|---------------|-------|-------|-------|-------|-------|-------------------------|
| TOM (mg/L)    | 3.2   | 3.5   | 7.9   | 8.2   | 8.8   | -                       |
| Ammonia (mg/L)| 0.16  | 0.22  | 0.28  | 0.32  | 0.45  | 0.5                     |
| Nitrate (mg/L)| 9     | 9     | 11    | 11    | 12    | 10                      |
| Phosphate (mg/L)| 0.6  | 1.2   | 1.6   | 2.3   | 3.1   | 0.2                     |
| DO (mg/L)     | 6.6   | 6.2   | 6.2   | 6     | 5.5   | 6                       |
| COD (mg/L)    | 10    | 11    | 24    | 25    | 27    | 10                      |
| Turbidity (NTU)| 4.2  | 10.9  | 19.3  | 30.6  | 35.4  | 4                       |
| TSS (mg/L)    | 28    | 35    | 44    | 48    | 55    | 50                      |
| TDS (mg/L)    | 144   | 163   | 172   | 190   | 256   | 1000                    |
| pH            | 7.9   | 7.5   | 7.5   | 6.9   | 6.6   | 6-9                     |

* National quality standard class based on Government Regulation No. 82 of 2001 on Management of water quality and water pollution control.

The result showed that the increase of total organic matter in the water was followed by the increase of ammonia, nitrate and COD. In contrast, the increase of total organic matter was followed by the decrease of DO in the water. These results indicated that most organic materials in the water were converted into ammonia and nitrate in the water. The conversion process causing high consumption of oxygen, and depleted the amount of oxygen in the water.

The correlation analysis showed that several factors were associated with the organic materials and nutrients in the water of Setail River (Table 2). Total organic matter was found to be highly correlated with ammonia ($R^2=0.97$), nitrate ($R^2=0.96$), and COD ($R^2=0.89$). In contrast, total organic matter was negatively correlated with the dissolved oxygen ($R^2=-0.59$) and pH ($R^2=-0.65$) in the water. The correlation analysis also showed that there was a positive correlation between TSS and turbidity in the water ($R^2=0.97$). The dissolved solids in the water were correlated with the amount of ammonia ($R^2=0.64$) and nitrate ($R^2=0.73$). The correlation between COD and pH showed a negative correlation (-0.65). These results indicated that the amount of ammonia and COD was influenced by the amount of total organic matter and dissolved oxygen in the water. The high correlation between TSS and turbidity indicated that the turbidity of water might be caused by suspended solids. In contrast, pH of water might be related to the oxygen consumption to degrade both organic and inorganic compounds in the water.
Table 2. Correlation among parameters.

| Parameter | TOM | Ammonia | Nitrate | Phosphate | DO | COD | Turbidity | TSS | TDS |
|-----------|-----|---------|---------|-----------|----|-----|-----------|-----|-----|
| TOM       | -   | -       | -       | -         | -  | -   | -         | -   | -   |
| Ammonia   | 0.97| -       | -       | -         | -  | -   | -         | -   | -   |
| Nitrate   | 0.96| 0.94    | -       | -         | -  | -   | -         | -   | -   |
| Phosphate | 0.77| 0.85    | 0.84    | -         | -  | -   | -         | -   | -   |
| DO        | -0.59| -0.70 | -0.70   | -0.94     | -  | -   | -         | -   | -   |
| COD       | 0.89| 0.98    | 0.96    | 0.77      | -0.59| -   | -         | -   | -   |
| Turbidity | 0.85| 0.93    | 0.87    | 0.97      | -0.84| -0.85| -         | -   | -   |
| TSS       | 0.85| 0.96    | 0.93    | 0.96      | -0.87| -0.89| 0.97      | -   | -   |
| TDS       | 0.57| 0.64    | 0.73    | 0.91      | -0.95| -0.57| 0.80      | 0.82| -   |
| pH        | -0.65| -0.77 | -0.71   | -0.97     | 0.92| -0.65| -0.94     | -0.88| -0.86|

3.2. Sediment properties

Analysis of the sediment of Setail River showed that organic carbon in the location was ranging from 0.5 to 0.7%, while total nitrogen was ranging from 0.03 to 0.04%. The total bacteria in the sediment were ranging from 0.23 to 0.33 × 10⁶ CFU. These results resulted in C/N ratio ranging from 15 to 17 (Table 3).

Table 3. Sediment properties in the Setail River

| Parameter                  | Site location |
|----------------------------|---------------|
|                            | 1  | 2  | 3  | 4  | 5  |
| Organic carbon (%)         | 0.5| 0.6| 0.6| 0.7| 0.7|
| Total nitrogen (%)         | 0.05| 0.04| 0.04| 0.04| 0.04|
| C/N ratio                  | 10 | 15 | 15 | 18 | 18 |
| Total bacteria (×10⁶ CFU)  | 0.23| 0.29| 0.31| 0.33| 0.33|

The correlation analysis showed that C/N ratio was highly correlated to the total bacterial number in the sediment of Setail River ($R^2=0.96$). The result also showed that total bacteria was correlated with organic carbon ($R^2=0.90$). These results indicate that total carbon and C/N ratio are the most critical factor for environmental bacteria in the sediment (Table 4).

Table 4. Correlation among parameter of sediment properties

| Parameter          | Organic carbon | Total nitrogen | C/N ratio | Total bacteria |
|--------------------|----------------|---------------|-----------|---------------|
| Organic carbon     | -             | -             | -         | -             |
| Total nitrogen     | 0.64          | -             | -         | -             |
| C/N ratio          | 0.95          | 0.83          | -         | -             |
| Total bacteria     | 0.90          | 0.84          | 0.96      | -             |

4. Discussion

Total organic materials in the water of Setail River were gradually increased from the upstream to the downstream. It might be caused by the accumulation of organic materials sourced from nature [7] [8] and anthropogenic activities [1] [9]. Organic carbons such as cellulose, hemicellulose, and lignin are the main component composing the plant [10]. Cellulose is a glucose-form polymer, while hemicellulose is composed of several types of polymers containing polysaccharides. The last component, lignin, is a component in the form of biopolymer. In addition, simple sugar and nonhumic-
bound polysaccharide are provided from the forests [11]. The other organic materials, nitrogen-based organic materials, are composed of amino acid, protein and humic substances, and other substances [12]. These components are often released to the aquatic environment through the stream [13] and accumulated in the sediment [14].

The particulate organic matter is broken down into dissolved organic matter in the water [15]. The nitrogen-based organic materials are decomposed by several kinds of bacteria to provide ammonia nitrogen in a process called ammonification. In the case of Setail River, the increase of total organic matter in the water is followed by the rise of ammonia level. This result might indicate the suitable decomposition of organic materials to ammonia nitrogen. According to [16], ammonification bacteria, such as *Azotobacter* sp., are responsible for degrading protein into ammonia nitrogen. Then, conversion of ammonia into nitrite might also be occurring, indicated by the positive correlation between ammonia and nitrate. In the nitrification process, several kinds of bacteria can convert the ammonia into nitrite and nitrite into nitrate. This conversion involves a gene called as ammonia monoxygenase (AMO), as shown in *Nitrospira* sp. and *Nitrosococcus* sp. [17].

Ammonification and nitrification are usually presence in aerobic conditions with high oxygen content. Our analysis showed that there was gradual oxygen depletion in the water from the upstream to the downstream. In contrast, there was a gradual increase of ammonia as a result of ammonification and nitrate as a result of nitrification. It is not surprising that the oxidation process during ammonification and nitrification consumes a high level of oxygen [18]. This result was supported by the fact that there was an increase in chemical oxygen consumption (COD). The pH of the water was also gradually decreased from upstream to the downstream. It might be related to the higher carbon dioxide released by ammonification and nitrifying bacteria during ammonification and nitrification [19]. The decomposition process in the sediment of Setail River was also observed during this study. The results indicated that there was a high correlation between total bacterial number and the C/N ratio. Based on this fact, decomposition of organic materials was not only occurred in the water, but also in the sediment of the river.

5. Conclusions

Environmental factors associated with the decomposition of organic materials and nutrient availability in the water and sediment of Setail River were studied in this study. Total organic matter and nutrients in the water are influenced by several environmental factors, such as DO and COD. The organic carbon, total nitrogen, and total bacterial number in the sediment might also affect the amount of organic materials and nutrients in the water. The decomposition of organic materials in the Setail River seemed to be related to the ammonification and nitrification process. This result may contribute as a database of river status in Banyuwangi, and can be used as consideration by policy makers to establish any appropriate regulations.

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