Study of shrimp pond effluent purification on mangrove ecosystem of River Pasir Jangkaran Village Kulon Progo Regency

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Abstract. The research is located in Pasir River, Jangkaran Village, Kulon Progo Regency. Landuse in Pasir River are dominated by shrimp ponds. Mangroves on the riverbank can reduce the concentration of nutrients in shrimp pond effluent. This study aims to determine the purification of shrimp pond effluent in the mangrove ecosystem by comparing the quality of shrimp pond effluent before and after passing through the mangrove ecosystem. The research method used is the field survey method and laboratory analysis. Water sampling and identification of mangrove characteristics were done purposively on 6 observation segments. Data analysis was performed graphically, descriptively, spatially, and comparatively. The results show that mangrove ecosystems can reduce concentration of nitrate and phosphate in shrimp pond effluent as evidenced by a decrease concentration of nitrate in segments 1 to 6. The nitrate concentration in the mangrove ecosystem and after passing through the mangrove are smaller than before passing the mangrove. The characteristics of mangroves that affect the purification process are species and density of vegetation. Species mangrove Rhizophora mucronata with higher vegetation density can reduce the concentration of nitrate in SPT 1 to 4 better than species Avicennia marina with lower density in segment 5.

1. Introduction

Water is one of the important natural resources. The main problem that currently occurs in water resources is a decrease of water quality. One of the factors causing the decrease in water quality is the presence of water pollution caused by the entry of pollutants into the water body [6]. Pasir River is located on the southern coast of Kulon Progo. Mangroves extends along the banks of the Pasir River. Besides being used as a mangrove forest, the Kulon Progo coastal area is also used as a shrimp pond fishery area.

Shrimp ponds fisheries activities in the Kulon Progo coast are one of the suppliers of waste originating from leftover feed and manure containing various nutrients. The entry of nutrients from pollutant waste not only affects water quality, but also impacts the ecological processes in the ecosystem. The amount of nutrient supply can affect ecosystem productivity, for example, eutrophication symptoms [4]. Symptoms of eutrophication can trigger algal explosions and disrupt aquatic life in the waters, as well as disruption of the food chain process of several aquatic organism.

Mangroves at the end of a large river act as the last reservoir for industrial waste in urban areas, upstream settlements that are carried by river streams, and pond waste in the surrounding areas. Mangroves can play a role in capturing sediments carried by the flow of water that has been mixed...
with various waste activities from the area above, including shrimp pond waste and absorbing elements in the sediment and water, such as carbon, phosphate, nitrate, and nutrient nutrients the other. Mangroves absorb elements that have the potential to pollute the environment needed in the formation of plant tissues such as nitrates and phosphates [3]. Because of its ability to absorb elements in the living environment, it is important to research the absorption of nutrient elements by mangrove plants and their relation to the ability to purify water that has been polluted by shrimp pond waste in the mangrove ecosystem of Jangkaran Village, Kulon Progo Regency. This research is important to be conducted to determine the purification nutrient of shrimp pond waste in the mangrove ecosystem.

2. Materials and Methods

2.1. Study area

The study was conducted in the Sand River connecting the Bogowonto River which is administratively located in Jangkaran Village, Temon District, Kulon Progo Regency and Jali River in Purworejo Regency, Central Java. Site selection is based on several considerations. Mangrove forests grow extensively along the river banks which are directly adjacent to intensive shrimp pond ponds that use artificial feed and additional nutrients, so that the resulting waste contains substances that have the potential to pollute river water. In addition, there has not been much research on the quality of wastewater and rivers in the study area, including research on the role of mangrove ecosystems in the wastewater purification process.

2.2. Data collection and analysis

This research was conducted in three comprehensive stages. The first stage is the identification of the characteristics of mangroves in the form and measurement of the density of mangrove vegetation in segments 1-6 of the study river. The second stage consists of measuring river and sewer discharge to determine the state of the flow and determine the distance of water sampling in each segment. The third stage is water sampling at several points in each segment of the river fragment and water quality testing in the laboratory. Mangrove species are identified by direct observation in the field to find out the most dominant mangrove species in each segment. Mangrove density is obtained by counting the number of trees in a 5 x 5 meter plot in each segment. Mangrove density is calculated using the formula:

\[
\text{Density} = \frac{(\text{number of trees (individual)})}{(\text{plot area (m}^2))}
\]  

(1)

The measurement of river discharge is carried out using the velocity area method with a current meter, while the discharge at each outlet of the waste channel is measured with a buoy. Quantitative descriptive analysis is performed on the results of the calculation of river flow velocity and flow. The calculation results are then used in determining the travel time of water flow up to a certain point so that the measurement of water quality at a point with a certain distance can be made referring to the results of this calculation. River flow discharge is calculated by the formula:

\[
Q = A.V
\]  

(2)

Information:
Q: cross-section discharge (m\(^3\) / s)
A: area of the entire cross-section (m\(^2\))
V: average speed of the whole cross-section (m / s)

Water quality sampling was carried out at several points from segment 1 to segment 6 of the river fragment. The results of water quality testing in the field and laboratory are analyzed descriptively quantitatively by comparing chemical parameters of water (nitrate and phosphate) in each segments. Bar graphs that present water quality data for nitrate and phosphate parameters at each location (pond...
sewage outlets, mangroves, riverbanks, and middle rivers) are used to analyze changes in water quality before and after passing through mangrove forests.

The research was carried out on a segment of river with a length of 1.80 km divided into 6 segments. The division of this segment is based on the presence of shrimp pond waste input channels around the river cut. The number of samples taken varies according to the conditions of each segment. The water samples taken in this study were 24 samples. Sampling was carried out in several places, namely at waste outlets, mangroves, riverbanks, and river centers. Discharge measurements are also carried out at each water quality sampling point, namely at the waste outlet and river body. The map of study area and sample point distribution are represented in Figure 1.

![Figure 1. Study area and sample point distribution](image)

3. Results

3.1. Water Discharge

The measurement of river water discharge is carried out in each river segment which amounts to 6 points. Some of the conditions for selecting the measurement location have been fulfilled are in a straight cut, there is no bend in the river, far from the disturbing plants, and there are no other obstacles that affect flow velocity. Figure 2 shows a graph of the value of water discharge for each river segment in the study area. The graph shows that the value of water discharge has increased from segment 1 to segment 6, which means that the further downstream the greater the value of water discharge. The largest increase in the value of water discharge is in segment 2. The value of river water discharge in segment 1 is 10 m$^3$/s and the value of discharge in segment 2 has increased to 23.51 m$^3$/s. The increase in discharge is due to the input of water coming from 2 shrimp pond sewage channels on the north and south sides of the river. The value of water discharge from segment 2 to segment 6 has increased, namely 35.08 m$^3$/s, 38.61 m$^3$/s, 43.96 m$^3$/s, until the highest discharge in segment 6 with a value of 54.14 m$^3$/s. The increase in the value of water discharge from upstream to downstream is due to the presence of water input coming from 5 sewers in one river cut. The increase in water discharge is also influenced by river morphometry factors, namely the width and depth of the river that increases from upstream to downstream. The width and depth factor of the river will affect the size of the river area so that the water discharge is getting bigger. Besides, the speed of the water flow in the downstream of the river in the estuary is influenced by the tides. Discharge measurements
carried out in conjunction with a period of low tide affect the flow of water which is getting faster at the downstream part of the fragment.

**Figure 2.** Graph of River Water Discharge

### 3.2 The Nitrate Concentration of Water Samples

Nitrate was chosen as a parameter of water quality testing in this study because nitrate is one of the nutrients present in natural waters such as rivers. The results of the laboratory analysis of samples taken at 24 points were analyzed for each segment in the study river fragment. Laboratory test results indicate that the water sample in segment 1 has a nitrate concentration <0.04 mg/L. River water with nitrate concentration <0.04 mg/L still meets grade 1 river water quality standards. Low nitrate concentrations in this segment can be caused by sampling locations that are at the upper reaches of the fragments and sampling locations in the middle river. Besides, the low concentration of water nitrate in segment 1 which is upstream can be caused because there is no input from shrimp pond waste or waste from other sources around the segment. The results of the water quality test in segment 1 serve as a control or indicate the initial conditions of the quality of the water sample before receiving pond waste input on the study river cut.

Figure 3(a) shows that the water sample at the SPT 1 waste outlet is the highest compared to water nitrate concentrations in other locations. The closer to the middle of the river, the lower the water nitrate content. Nitrate content of SPT 1 sewage outlet water samples was 4.5 mg/L and successively decreased at the location of mangrove ecosystems up to the river bank, ie 0.93 mg/L, 0.59 mg/L, and the lowest was <0.04 mg/L in the middle of the river. Water nitrate concentrations on the south side of the river also showed the same results. The highest concentration is at the SPT 2 waste outlet with a value of 4.43 mg/L and successively the value of the middle of the water nitrate content gets smaller, which is 2.15 mg/L on the south side mangrove and 1.77 mg/L on the river bank.

Figure 3(b) shows the comparison of nitrate concentrations in various sampling locations in segment 3 transversely from the SPT 3 waste outlet located on the north side of the river to the southern river bank. Laboratory analysis results presented in the graph show that the water sample at the SPT 3 waste outlet is the highest compared to the water nitrate content in other locations. Water nitrate concentrations are lower in locations that are getting closer to the middle of the river. Nitrate content of SPT 3 sewage outlet water samples was 4.5 mg/L and successively decreased at the location of mangrove ecosystems up to the river bank, namely 1.97 mg/L, 0.98 mg/L, and the lowest was <0.04 mg/L in the middle of the river. Water nitrate concentrations in the southern river banks show a different pattern, which is higher at the southern edge than water nitrate concentrations in the middle river. The water concentration of nitrate in the southern river is 0.86 mg/L. Higher nitrate concentrations at the southern riverbank location can be caused by the influence of waste disposal in segment 2.
Figure 3(c) shows the comparison of nitrate concentrations of water samples at various locations in segment 4 transversely from the SPT 4 waste outlet located on the north side of the river to the south bank of the river. The graph shows that the water sample at the SPT 4 waste outlet is the highest compared to water nitrate concentrations in other locations. The closer to the middle of the river, the lower the water nitrate content. Nitrate content of SPT 4 sewage outlet water samples was 4.19 mg/L and successively decreased in the location of mangrove ecosystems up to the river bank, namely 1.95 mg/L, 1.92 mg/L, and the lowest was <0.04 mg/L in the middle of the river. Meanwhile, nitrate concentrations in the southern river banks are higher compared to nitrate concentrations in the middle river, which is 0.82 mg/L.

Figure 3(d) shows that the water nitrate concentrations in all locations of segment 5 meet the class I river water quality standards, ie nitrates are below 10 mg/L in segment 5 the same as the chart pattern in the previous 3 segments. The graph shows that the nitrate content of the water sample at the SPT 5 waste outlet is the highest compared to the water nitrate concentration in other locations, and is getting lower to the middle of the river. Nitrate content of SPT 5 sewage outlet water samples was 2.07 mg/L and successively decreased at the location of mangrove ecosystems up to the river bank, namely 1.92 mg/L, 1.83 mg/L, and the lowest was <0.04 mg/L in the middle of the river. However, the nitrate content of water samples taken at the edge of the southern river is even higher compared to the center of the river. This can be due to the waste that flows from the upstream (segment 2) on the south side and accumulates in the lower part, namely segment 5.

Laboratory test results show that water samples in segment 6 have nitrate concentrations <0.04 mg/L. River water with nitrate concentration <0.04 mg/L still meets grade I river water quality standards. Low nitrate concentrations in this segment can be caused by sampling locations in the middle of the river. Low nitrate content in segment 6 which is at the most downstream part of the river fragment indicates that river water is still of good quality judged by the parameters of nitrate concentrations even though there are some waste inputs in the upper reaches of the river.
3.3 The Phosphat Concentration of Water Samples

Phosphate was chosen as a parameter of water quality testing in this study because phosphate is one of the nutrients contained in shrimp pond waste. Laboratory test results show that the water sample in segment 1 has a phosphate concentration of 0.383 mg/L. The concentration of phosphate water in segment 1 which is in the upper reaches of the river splinter has exceeded the grade 1 river water quality standard. High phosphate concentrations in the upper reaches of the river indicate water pollution caused by the inclusion of shrimp pond waste in the upper part of the location segment 1. The results of the water quality test in segment 1 serve as a control or indicate the initial conditions of the quality of the water sample before getting input to the pond waste in the river cut.

Figure 4(a) shows that the phosphate content of segment 2 is getting lower to the riverbank but the phosphate concentration is back up in the middle of the river. The phosphate content of the SPT 1 sewage outlet water sample was 0.675 mg/L and subsequently decreased in the location of the mangrove ecosystem to the river bank, which was 0.426 mg/L, 0.232 mg/L, and increased in the middle of the river, ie 0, 41 mg/L. Water for fate concentrations on the south side of the river also showed the same results. The highest concentration is at the SPT 2 waste outlet with a value of 0.752 mg/L and successively the value of the rivers is getting smaller, which is 0.55 mg/L in the mangrove section on the south side and 0.252 mg/L in the riverside.

Figure 4(b) shows that the water sample at the SPT 3 waste outlet is the lowest compared to phosphate concentrations in other locations. The pattern formed by the graph of phosphate content in this segment is different from the previous segment, namely at the river's edge the highest water phosphate content. Phosphate concentrations of SPT 3 sewage outlet water samples were 0.136 mg/L and respectively increased at the location of mangrove ecosystems up to the river bank, ie 0.386 mg/L and 3.187 mg/L. The concentration of water phosphate in the middle of the river is 0.316 mg/L and at the southern bank of the river the phosphate content becomes higher, which is 0.734 mg/L.

Figure 4(c) shows that the water phosphate concentrations in the mangrove and riverbank ecosystems are higher than the phosphate concentrations at the SPT 4. pond waste outlet. respectively 0.542 mg/L and 0.297 mg/L. Increased concentrations of phosphate also occur in the middle of the river, which is seen from the concentration of phosphate in the middle with a value of 0.471 mg/L. Meanwhile, phosphate concentrations at the southern edge are lower compared to phosphate concentrations in the middle of the river, which is 0.152 mg/L.

Laboratory analysis results presented in Figure 4(d) show that water phosphate concentrations in almost all segment 5 locations exceed class I river water quality standards, that is, phosphates are above 0.2 mg/L. Water quality that meets river I class quality standards is only found at the location of the southern bank of the river. The pattern formed by the graph of quality content transversely from SPT 5 outlet on the north side of the river to the south bank of the river in segment 5 is that the lower the river bank the lower the phosphate content. The graph shows that the phosphate content of the water sample at the SPT 5 waste outlet is the highest compared to the water phosphate concentration in other locations and is getting lower to the southern bank of the river. Phosphate concentrations of SPT 5 sewage outlet water samples were 0.548 mg/L and respectively decreased in the location of mangrove ecosystems, north river banks, middle rivers, to the south river banks, namely 0.318 mg/L, 0.301 mg/L, 0.299 mg/L and the lowest is 0.061 mg/L on the southern bank of the river.

Laboratory test results show that the water sample in segment 6 has a phosphate concentration of 0.291 mg/L. River water in segment 2 exceeds grade 1 river water quality standards. High concentrations of phosphate that exceed class I quality standards can be caused by the location of sampling in this segment which is at the most downstream part of the river fragment. river water in the downstream has been influenced by the flow of waste that enters the river flow at the top so that phosphate concentrations become accumulated at the downstream.
3.4 Purification Analysis of Shrimp Effluent in the Mangrove Ecosystem

Purification is characterized by changes in water conditions for the better, both in terms of physical, chemical, and biological parameters. Purification can be known by decreasing the nutrient content in water, such as nitrate and phosphate. Ecosystems can play a role in purifying shrimp pond effluent, especially for nitrate and phosphate parameters [1]. This study uses mangrove species Rhizophora mucronata. In addition to species, the density of mangrove vegetation also affects the water purification process in the mangrove ecosystem. The higher density of mangrove vegetation, the greater the absorption of nutrients contained in water.
The characteristics of mangrove in segment 2 are Rhizophora mucronata, both on the banks of the river north and south. The density of mangrove vegetation on the northern edge is 0.68 individuals / m², while the southern mangrove is denser, ie 1.16 individuals / m². Segment 2 has a pollutant source in the form of an SPT 1 pond waste channel located in the north of the river and SPT 2 pond sewage channel in the south. Figure 4.29 and Figure 4.30 show that water undergoes purification as evidenced by a decrease in water nitrate and phosphate concentrations in the mangrove ecosystem. Purification only occurs for the nitrate parameter in the northern segment 2, while for the southern segment both parameters, both nitrate and phosphate are purified. The reduction of nitrate concentrations in the north mangrove is 79% of the nitrate content of wastewater at SPT 1 outlet, while the nitrate and phosphate concentrations of water in the south mangrove are reduced by 51% and 76% of the initial condition of the waste at the SPT 2 outlet.

Mangroves that grow in segment 3 have Rhizophora mucronata types. The density of mangrove vegetation in this segment is 0.60 individuals / m². Segment 3 has a pollutant source in the form of an SPT 3 pond sewage channel located north of the river. Figure 4.31 shows that the concentrations of nitrate and phosphate have decreased in the mangrove ecosystem and the river banks. Water nitrate concentrations in the mangrove ecosystem were reduced by 56%, while water phosphate concentrations were reduced by 30% from the initial waste condition at the SPT outlet 3. Nitrate and water phosphate concentrations in the mangrove ecosystem experienced a decrease in the river banks, each by 50% and 47% of nitrate concentrations in mangrove ecosystems.

Mangroves that grow in segment 4 have a type of Rhizophora mucronata. The density of mangrove vegetation in this segment is 0.60 individuals / m². Segment 4 has a pollutant source in the form of an SPT 4 pond sewage channel located north of the river. Water nitrate concentrations in segment 4 have decreased in mangrove ecosystems and river banks, while for phosphate parameters there has been no decrease in mangrove ecosystems. Water nitrate concentrations in the mangrove ecosystem were

| Segment | 1 | 2    | 3    | 4    | 5    | 6    |
|---------|---|------|------|------|------|------|
| Species | Rhizophora mucronata | Rhizophora mucronata | Rhizophora mucronata | Rhizophora mucronata | Avicennia marina | Rhizophora mucronata |
| Density (/m²) | 1 | 0.68 | 1.16 | 0.6  | 0.6  | 0.48 |

**Figure 5. Mangrove Characteristic**
reduced by 53% from the initial waste condition at the SPT outlet 4. Nitrate and phosphate water concentrations in the mangrove ecosystem experienced a decrease in the river banks, namely 6% and 41% of the nitrate and phosphate concentrations in the mangrove ecosystem.

Mangroves that grow in segment 5 have Avicennia marina types. The density of mangrove vegetation in this segment is 0.60 individuals / m². Segment 5 has a pollutant source in the form of SPT 5 pond sewage channel which is located north of the river. Figure 4.33 shows that the concentrations of nitrate and phosphate have decreased in the mangrove ecosystem and the river banks. Water nitrate concentrations in the mangrove ecosystem were reduced by 7%, while water phosphate concentrations were reduced by 30% from the initial conditions of waste at the SPT outlet 5. Nitrate and water phosphate concentrations in the mangrove ecosystem experienced a decrease in the river banks, each by 4% and 11% of nitrate concentrations in mangrove ecosystems.

4. Discussions
Laboratory analysis results show that water nitrate concentrations at river bank sampling locations are lower than those taken at waste outlets. This shows that there is a decrease in nitrate concentrations in wastewater when the water is in the mangrove ecosystem and after passing through the mangrove ecosystem. Nitrate concentrations in the water also experience a decrease in the middle part of the river which can be caused by the dilution due to the addition of river discharge in the center which is getting bigger.

The segment of the study river that has mangrove with Rhizophora mucronata type is 1,2,3, and 4. Purification of wastewater that occurs in the mangrove ecosystem with Rhizophora mucronata is higher than that of segment 5 which is covered by Avicennia marina mangrove. The tight rooting of Rhizophora plants causes nutrients to accumulate in sediment deposition accompanied by the process of decomposition of organic matter [2]. Supporting root pores in the Rhizophora mucronata mangrove function in the exchange of mangrove gas in aerobic or anaerobic conditions [5].

Segments 2 and 3 are overgrown by mangrove plants which have a higher density compared to river banks segments 4 and 5. Similarly, the purification of wastewater that occurs in segments 2 and 3 is also higher than segments 4 and 5. Mangroves with higher concentration of mangrove density, the higher the absorption of nutrients and heavy metals in water [2]. Land with higher mangrove density will have higher mangrove crop biomass. The high plant biomass will help increase the rate of absorption of pollutants that enter with the absorption of nutrients by mangroves.

5. Conclusion
Mangrove ecosystems can reduce the concentration of nutrients in shrimp pond effluent. The concentration of nitrate in all segments after passing the mangrove ecosystem are better than those in the effluent outlet section. The concentration of nitrate in each river segment originating from sewage outlets have decreased in the mangrove ecosystem and the concentration reach a minimum value after passing through the mangrove. River segments that are covered by Rhizophora mucronata with higher vegetation density can reduce the concentration of nutrient better than segments that with Avicennia marina mangroves and lower densities.

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