The Role Of Wetland Ecosystems To Reduce The Concentration Of Nitrate In Groundwater

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Abstract. Nitrate is a compound very soluble in water. Ichikawa city is one of the cities that have a pear farming. In this city, there was a wetland where this area was surrounded by pear farming in upland areas. There were 3 sites (S4, R2, and S14) in this area. S4 and S14 were close to pear farming, but R2 was in the middle of wetland. We used piezometers with different depth (1m, 2m, and 3m) in each site. The focus in this study is identification the role of wetland ecosystem as a green infrastructure to reduce nitrate concentration. Groundwater flow in the wetland comes from pear farming with 2 flow direction. First, groundwater comes from S4 with average nitrate concentration was 185.73 mg/L and average DO concentration 6.37 mg/L. Second, groundwater comes from S14 with average nitrate concentration was 190.29 mg/L and average DO concentration 7.00 mg/L. All this direction flow to the middle of wetland (R2) with average nitrate concentration was 3.46 mg/L and average DO concentration 1.52 mg/L.

1. Introduction

Groundwater is a one of water resources flowing in the soil. Groundwater is important natural resources that are facing serious pollution\cite{4,3,5}. One of pollution is nitrate concentration. Nitrate contamination of shallow groundwater is a recognized problem resulting from diffuse or point sources associated with intensive agriculture\cite{1}. But, Wetlands in agricultural landscapes can reduce nutrient loadings and sediments, i.e., phosphorus and nitrogen\cite{10}. The World Health Organization sets a limit of 10 mg/L nitrate for drinking water\cite{11}. Two ecosystem processes have primarily been described to be relevant for nitrogen removal in wetlands. Firstly, plant uptake associated with incorporation into biomass and secondly, denitrification by anaerobic microorganisms in the soil\cite{8}. In this study, we are focus on the second ecosystem process. The purpose of this study is how the wetland ecosystem as a green infrastructure can reduce of nitrate concentration and how the relationship wetland ecosystem with nitrate concentration. So, we will be used linier regression as a method in this study.

2. Site Description and Methodology

2.1. Site description

This study was conducted at typical headwater wetland located in Ichikawa city with elevation about 16m above sea level. There were 3 sites (S4, R2, and S14) in this wetland with different depth (1m, 2m, and 3m). Every year, nitrogen load in pear orchard of the upland is estimated about 400 kg/ha.
2.2. **Sampling and analysis**

Water samples collected from piezometers in September 2015, October 2015, and December 2015. We collected 50 ml water samples in each site and brought back to laboratory for analyzing with Ion Chromatography (LC-10A, Shimadzu, Japan). Before analyzing, we stored water samples in refrigerator with temperature under 4°C. We used ion chromatography to determine the concentrations of Ca\(^{2+}\), K\(^{+}\), Mg\(^{2+}\), Na\(^{+}\), Cl\(^{-}\), NO\(_3\)^{-} and SO\(_4\)^{2-} and to determine the concentration of HCO\(_3\)^{-}, we filtered 20 ml water sample with a drop of mixing solution (1% bromocresol green in 95% alcohol and 1% methyl red in 95% alcohol were mixed with the volume ratio is 1:1) and then titration with 0.01 mol/L dilution hydrochloric acid in laboratory.

2.3. **Data analysis**

We used linear regression for data analysis in this study. Linear regression can determine the relationship parameter with nitrate concentration. We used DO and ORP as a parameter and identified the relationship with nitrate concentration.

3. **Result**

3.1. **Geochemical**

The average concentration of HCO\(_3\)^{-}, Ca\(^{2+}\), K\(^{+}\), Na\(^{+}\), Cl\(^{-}\), and SO\(_4\)^{2-} in each site was not too many different from September 2015 to December 2015. But, the average concentration of Mg\(^{2+}\) and NO\(_3\)^{-} was different. In site S4, the concentration of Mg\(^{2+}\) ranged from 30.04 to 45.44 mg/L and the concentration of NO\(_3\)^{-} ranged from 150.51 to 248.14 mg/L. In site S14, the concentration of Mg\(^{2+}\) ranged from 36.70 to 39.14 mg/L and the concentration of NO\(_3\)^{-} ranged from 181.08 to 203.56 mg/L. In site R2 the average concentration of Mg\(^{2+}\) and NO\(_3\)^{-} was very low. the concentration of Mg\(^{2+}\) was < 5.80 mg/L and the concentration of NO\(_3\)^{-} was < 4.69 mg/L (Table 1).
Table 1. Geochemical of the groundwater in the wetland

| Site | Depth (m) | Period | Anion | Cation |
|------|-----------|--------|-------|--------|
|      |           |        | HCO$_3^-$ | Cl$^-$ | NO$_3^-$ | SO$_4^{2-}$ | Na$^+$ | K$^+$ | Ca$^{2+}$ | Mg$^{2+}$ |
| S4   | 1, 2, 3   | Sep-15 | 227.77 | 50.66 | 248.14 | 9.98 | 17.39 | 1.30 | 86.11 | 45.44 |
|      | 1, 2, 3   | Oct-15 | 239.97 | 41.52 | 150.51 | 32.51 | 36.01 | 1.27 | 53.15 | 30.04 |
|      | 1, 2, 3   | Dec-15 | 254.21 | 41.59 | 158.54 | 37.83 | 17.70 | 1.71 | 85.30 | 44.75 |
| R2   | 1, 2, 3   | Sep-15 | 244.04 | 30.58 | 1.90 | 24.31 | 9.98 | 1.05 | 46.19 | 5.62 |
|      | 1, 2, 3   | Oct-15 | 92.53 | 26.60 | 150.51 | 37.83 | 15.00 | n.d$^a$ | 33.16 | 38.60 |
|      | 1, 2, 3   | Dec-15 | 97.62 | 27.13 | 186.22 | 15.00 | 14.49 | n.d$^a$ | 31.49 | 36.70 |
| S14  | 1, 2, 3   | Sep-15 | 89.48 | 22.44 | 181.08 | 12.19 | 16.13 | 0.27 | 39.14 | 39.14 |
|      | 1, 2, 3   | Oct-15 | 92.53 | 26.60 | 203.56 | 12.65 | 15.00 | n.d$^a$ | 33.16 | 38.60 |
|      | 1, 2, 3   | Dec-15 | 101.68 | 27.13 | 186.22 | 11.85 | 14.49 | n.d$^a$ | 31.49 | 36.70 |

*concentration = 0 mg/L

3.2. Environmental parameters

In site S4, the highest temperature was 20.5°C (September 2015), temperature of groundwater decreased 18.8°C in October 2015 and 12.4°C in December 2015, decreasing temperature of groundwater not only in site S4 but also in site R2 and S14. In all site, the pH value ranged from 6.85 to 7.22. In site S4 and site S14, The DO concentration were high. DO concentration ranged from 4.34 to 8.54 mg/L in site S4 and in site S14 ranged from 5.46 to 8.07 mg/L. But, The DO concentration in site R2 was low with ranged from 1.98 to 4.22 mg/L. The average ORP in site S4 and site S14 were >156 mV, but in site R2 the average ORP ranged from -24 to 16 mV. The EC of groundwater ranged from 26.6 to 77.9 μs/m (Table 2).

Table 2. Environmental parameters of the groundwater in the wetland

| Site | Depth (m) | Period | Average parameters |
|------|-----------|--------|--------------------|
|      |           |        | EC (μs/m) | ORP (mV) | DO (mg/L) | pH | Temperature °C |
| S4   | 1, 2, 3   | Sep-15 | 77.9 | 228 | 5.85 | 7.22 | 20.5 |
|      | 1, 2, 3   | Oct-15 | 60.5 | 194 | 4.34 | 7.08 | 18.8 |
|      | 1, 2, 3   | Dec-15 | 56.9 | 190 | 8.54 | 6.90 | 12.4 |
| R2   | 1, 2, 3   | Sep-15 | 26.6 | 13 | 1.37 | 7.21 | 21.3 |
|      | 1, 2, 3   | Oct-15 | 27.1 | 16 | 1.98 | 6.90 | 18.5 |
|      | 1, 2, 3   | Dec-15 | 31.7 | -24 | 1.22 | 6.93 | 12.0 |
| S14  | 1, 2, 3   | Sep-15 | 47.2 | 287 | 6.11 | 6.64 | 19.4 |
|      | 1, 2, 3   | Oct-15 | 47.0 | 156 | 5.46 | 6.87 | 17.2 |
|      | 1, 2, 3   | Dec-15 | 77.3 | 201 | 8.07 | 6.85 | 12.8 |

3.3. Groundwater flow, distribution of nitrate and DO

Groundwater flow direction in September 2015, October 2015, and December 2015 were same. Groundwater flow has 2 direction. First direction was from site S4 to R2 and second direction was from site S14 to R2. Distribution of nitrate (Figure 2) and DO (Figure 3) always
follow the groundwater flow direction. We choose September 2015 data for knowing the distribution of nitrate and DO, because the pattern of distribution in another period was same.

Figure 2. Groundwater flow and distribution of nitrate concentration

Figure 3. Groundwater flow and distribution of DO concentration

3.4. Relationship analysis

This analysis for identified the relationship nitrate concentration with DO concentration and ORP. There is a positive relationship nitrate concentration with DO concentration (Figure 4.) and ORP (Figure 5.). When DO concentration and ORP were high then nitrate concentration was high and when DO concentration and ORP were low then nitrate concentration was low.

Figure 4. Relationship nitrate concentration with DO concentration

Figure 5. Relationship nitrate concentration with ORP

4. Discussion

We found that groundwater flowing from upland area (pear orchard) as a recharge area to wetland as a discharge area and groundwater flow has 2 direction, first direction from S4 to R2 and second direction from S14 to R2. In groundwater flow, we can understand not only movement of groundwater but also movement of concentration. We found that According to some previous study that groundwater flow systems have been found to be related to many aspects such as geological, chemical and biological processes [2,6,9]. In denitrification process, microbial was very important to remove nitrate and microbial growth requires low oxygen content or no oxygen. Denitrification process would be restricted when DO concentration was lower than 2 mg/L [7].

We found in site R2 DO concentration was lower than 2 mg/L and when DO concentration was low, nitrate concentration was low too. We found that nitrate concentration was lower than 5. In first direction, total average of nitrate concentration (September 2015, October 2015, and December 2015) was 185.73 mg/L with total average of DO concentration 6.37 mg/L in site S4
become decreased in site R2 with total average of nitrate concentration was 3.46 mg/L and total average of DO concentration 1.52 mg/L. In second direction, total average of nitrate concentration was 190.29 mg/L with total average of DO concentration 7.00 mg/L and when groundwater flowing to site R2 total average of nitrate concentration and DO concentration become decreased. A positive relationship nitrate concentration with DO concentration ($R^2 = 0.993, P<0.05$) and ORP ($R^2 = 0.999, P<0.05$) proved that there is a function of microbial in this ecosystem, so that it can reduce the nitrate concentration in groundwater.

5. **Conclusion**

In this study, we found that one of ecosystem services in the wetland was reduction process of nitrate concentration. Wetland ecosystem as a green infrastructure can decreasing nitrate concentration from agriculture area and increasing the water quality. This function was affected by environmental parameters in wetland. We found that a positive relationship of NO$_3^-$ concentration between ORP and DO concentration proved that there was a role microbial in wetland.

**Acknowledgment**

This study was supported by Wetland Park of Ichikawa city. Wetland Park of Ichikawa city have contributed in giving permission to use the wetland as a study area.

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