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The improvement of the nitrogen removal capacity in wetlands

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ABSTRACT

We are studying the nitrogen removal function of wetlands (rice paddy fields). The site of our investigation was polluted by nitrogen ground water from upland fields in which nitrogen fertilizer and animal manure were overused. We carried out an experiment with the aim of improving the purification capacity of these fields from 2006 to 2008. Two test plots were used. Both had been non-vegetation plots since 1991. A temperature rise effect was higher in the tunnel plot than in the open-air plot. Temperatures were observed at 1-h intervals by automatic record thermometers. The average temperatures were 18.9°C for the tunnel plot and 16.6°C for open-air plot. The average amount of nitrogen removal was 557.4 kg ha^{-1} y^{-1} in the open-air plot and 661.8 kg ha^{-1} y^{-1} in the tunnel plot. The amount of nitrogen removal in the tunnel plot reached a level 104.4 kg ha^{-1} y^{-1} larger than the open-air plot. This means that the thermal effect of the tunnel plot was higher than in the open-air plot. The denitrification and ANAMMOX activity ratio in August was 5:1 in the open-air plot, but there was no ANAMMOX activity in the tunnel plot.

Keywords: Nitrogen removal; Water temperature; Wetland; Denitrification; ANAMMOX

1. Introduction

We investigated the removal of nitrogen from water. Our college is located in the Lake Kasumigaura basin. The lake is the second largest in Japan, and it has a serious eutrophication problem. One of the causes of this is the overuse of agricultural and animal waste fertilizer in upland fields. We have been researching low cost and low energy methods of nitrogen removal. We have thus conducted nitrogen removal experiments at wetlands for over 10 years. At first we investigated and compared a vegetated and a non-vegetated plot, but there was no big difference between them in nitrogen removal [1]. Vegetation keeps the water temperatures lower because direct sunshine is interrupted. Therefore, the denitrifying activity decreases, and there is no difference in total with the vegetation uptake. However, the capacity of nitrogen removal decreased gradually in both plots. The nitrogen removal phenomenon is mainly denitrification in the non-vegetated plot, and its factors are NO_3-N concentration, the amount of organic matter, and water temperature condition. We realized that in order to raise the capacity of nitrogen removal, we had to pay attention to water temperature.

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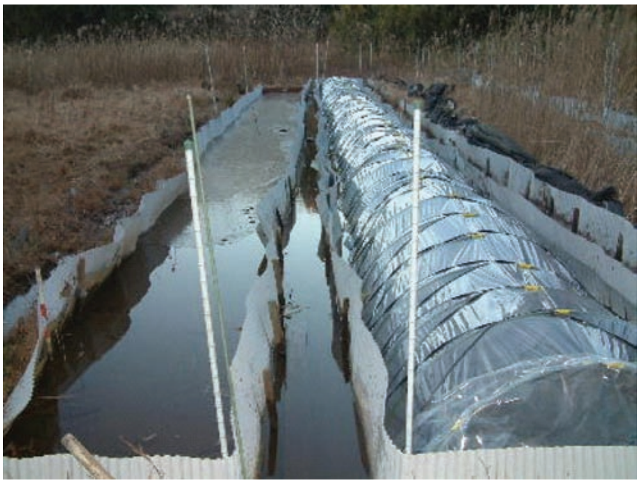

Fig. 1. The open-air (left side) and the tunnel (right side) experimental plots.

Table 1
Water temperature averages (°C).

	Tunnel	Open-air	Difference
2006	17.7	15.7	2.1
2007	20.1	17.9	2.2
2008	18.9	16.2	2.6
Average	18.9	16.6	2.3

2. Materials and methods

There are many methods of raising the water temperature (for example cold summer damage measures etc.). We used a plastic tunnel (tunnel plot). It would have been very difficult to cover the area of an entire paddy field. However, tunnel plots are a simple and easy way only to influence the water temperature, and if was easy to set one up in the small plot where we planned to investigate.

We used two side by side plots [1,2] as shown in Fig. 1. Both plots had been non-vegetation since 1991. The tunnel plot was shaded from the sun from 1997 to 2005 and covered by a plastic film since 2006. Each plot size was 25 m × 1.4 m. Measurements were taken every week at about 14:00. We measured EC, pH, DO concentrations, water and air temperatures (weekly and at 1-h intervals by data logger), and T-N, NH_4-N, NO_2-N, NO_3-N, COD, TOC concentrations.

3. Results and discussions

The average water temperature is shown in Table 1 and the changes in water temperature are shown in Fig. 2. The water temperature averages were 18.9°C for the tunnel plot and 16.6°C for the open-air plot. The difference in average temperature was 2.3°C. The temperature in the tunnel plot was higher than in the open-air plot. The averages of pH and DO concentrations are shown in Table 2. The pH and DO concentration averages in the tunnel plot were larger than in the open-air plot. The photosynthesis of algae raised the pH and DO concentrations. This is because a larger amount of algae grew in the tunnel plot than in the open-air plot in the tunnel plot.

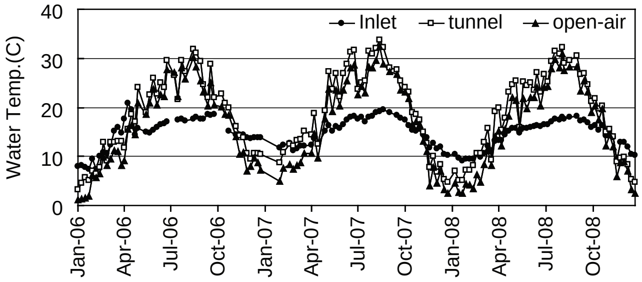

Fig. 2. The change in water temperature average.

Table 2
pH and DO concentration averages.

	pH		DO concentration (mg/L)	
	Tunnel	Open-air	Tunnel	Open-air
2006	8.4	8.3	15.5	13.3
2007	9.0	8.8	14.5	11.6
2008	8.7	8.3	13.7	11.5
Average	8.7	8.5	14.5	12.1

Fig. 2 shows that a large difference is not recognized easily between the tunnel plot and the open-air plot. On the other hand, the water temperature in the tunnel plot rose remarkably from the winter to spring. The following can be understood from this. The effect of the plastic film was heat insulation, and this was greater than the water temperature rise effect. The plastic film did not let the heat escape easily.

The changes in TN concentration from 2006 to 2008 are shown in Fig. 3. Inlet TN concentration decreased gradually. The inlet TN concentration decreased because of a decrease in fertilizer in the upland fields. The TN concentration of the tunnel plot was lower than in the open-air plot in summers. This influence is due to the water temperature. However in winters, the difference in TN concentration between both plots became significant.

The average amount of nitrogen removal is shown in Table 3. The difference in 2006 was smaller than in other years. The tunnel plot had been shaded from the sun from 1997 to 2005. As a result, there was little

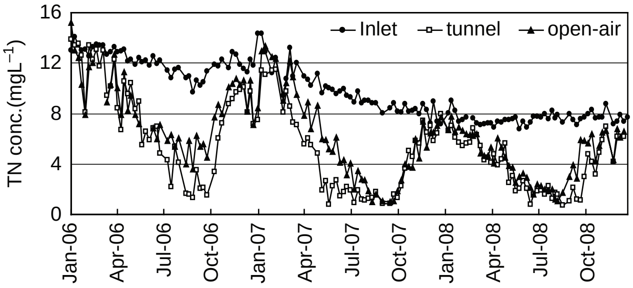

Fig. 3. The change in TN concentrations.

Table 3
Amount of nitrogen removal averages (kg ha^{-1}y^{-1}).

	Tunnel	Open-air	Difference
2006	667.1	583.1	84.1
2007	712.4	586.5	125.9
2008	605.8	502.5	103.3
Average	661.8	557.4	104.4

organic matter in the soil, and the nitrogen removal was very low. However, this phenomenon only appeared in the summer of 2006. The average amount of nitrogen removal then became 557.4 kg ha^{-1} y^{-1} in the open-air plot and 661.8 kg ha^{-1} y^{-1} in the tunnel plot.

The amount of nitrogen removal in the tunnel plot was 104.4 kg ha^{-1} y^{-1} larger than the open-air plot. There was not much difference in maximum water temperature between both plots during the daytime. However, the water temperature in the tunnel plot continued at a high value even at nighttime compared with the open-air plot. It is thought that the high water temperature of the tunnel plot at nighttime increased the amount of nitrogen removal.

The mechanism of nitrogen removal in wetlands is mainly denitrification. We found a new purification process for wetland [3]. This is the ANearobic AMMonium OXidation (ANAMMOX) reaction. Equation (1) shows that the ANAMMOX reaction NH_4-N and NO_2-N (or NO_3-N) makes N_2 gasses and H_2O. The reaction does not require organic matter as does denitrification. It is a very simple process, but its activity is very low compared to the denitrification.

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O \tag{1}$$

Either $^{15}NO_3^-$ or $^{15}NH_4^+$ is added to an O_2-free soil suspension. ANAMMOX produces $^{29}N_2$ specifically and denitrification can be recognized as $^{30}N_2$ production, which can be determined by GCMS. Experiments were carried out in duplicate.

On the denitrification and ANAMMOX activity ratio of this nitrogen removal experiment in August, there was a 5:1 ratio in the open-air plot, but no ANAMMOX activity in the tunnel plot. The denitrification activity increased if there was a rise in water temperature. Then, NO_2-N and NO_3-N were consumed in the soil. As a result, it is thought that the ANAMMOX activity is very low. We are now trying to understand this mechanism.

4. Conclusions

In this study, we examined the improvement of the nitrogen removal capacity in wetlands. The following results were obtained.

1. The average water temperature was 18.9°C in the tunnel plot and 16.6°C in the open-air plot, respectively.
2. The average the amount of nitrogen removal became 557.4 kg ha^{-1} y^{-1} in the open-air plot and 661.8 kg ha^{-1} y^{-1} in the tunnel plot, respectively. The amount of nitrogen removal in the tunnel plot was 104.4 kg ha^{-1} y^{-1} larger than the open-air plot.
3. On the denitrification and ANAMMOX activity ratio of this nitrogen removal experiment in August, there was a 5:1 ratio in the open-air plot but there was no ANAMMOX activity in the tunnel plot.

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