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Comparisons of Nitrogen and Phosphorus Removal Capacity of Four Macrophytes

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ABSTRACT: To evaluate the water purification capacity of 4 emergent macrophytes in 4 tributaries of Mankyung River, nitrate reductase activity (NRA) and nutrient removal capacity were determined. Higher NRA occurred in emergent macrophytes such as *Persicaria thunbergii* and *Oenanthe javanica* with 7.8 and 5.4 μmol NO_2 g^{-1}d.wt. h^{-1}, respectively. The nitrogen removal capacity of emergent macrophytes displaying higher NRA fell within the range of 0.85 to 1.95 mg g^{-1}d.wt. day^{-1} and was higher in the order *Phragmites communis* > *Persicaria thunbergii* > *Oenanthe javanica* > *Zizania latifolia*. The phosphorus removal capacity was within the range of 0.07 to 0.12 mg g^{-1}d.wt. day-1 and was higher in the order *Phragmites communis* > *Oenanthe javanica* > *Persicaria thunbergii* > *Zizania latifolia*. In all the domestic, industrial and agricultural wastewaters, *Phragmites communis* showed the highest nitrogen and phosphorus removal capacity; 1.36 and 0.0088 mg g^{-1}d.wt. day^{-1}, respectively. Among the 4 macrophytes, *Phragmites communis* was the most suitable species for water purification in 4 tributaries of Mankyung River.

Key Words: Macrophytes, Nitrate reductase activity (NRA), Nitrogen and phosphorus removal capacity, *Pharagmites commusis.*

INTRODUCTION

The anthropogenic pollutants in rivers come from agricultural, industrial and domestic effluents. Especially, loading of nitrogen and phosphorus has leaded to serious river pollution, and heavy metal input by industrial wastewater has an important effect on food chain related to human (Cornwell *et al.* 1977, Smilde 1981, Jackson *et al.* 1990).

Researchers have found that some macrophytes can scavenge nitrogen, phosphorus and heavy metals from water (Boyd 1968, Wolverton and McDonald 1979, Reddy *et al.* 1983, Busk *et al.* 1989). In temperate regions several macrophytes absorbed 70% ~ 90% of nitrogen and phosphorus in streams (Aoyama *et al.* 1986). The macrophytes absorb the dissolved materials and incorporate them into their own structure. Effluent renovated by the plants is stripped of its pollutants and, when released into waterways, causes less environmental damage. The plant culture units clean water so rapidly and effectively that they are now seriously being considered for use as a final polish in sewage treatment. The clean water produced is, in most situations, suitable for re-use in irrigation and industry. Furthermore, macrophytes themselves can be harvested and used, thus providing additional benefit.

An macrophyte water-treatment system can be inexpensive to build and maintain and, if it is situated where gravity delivers the wastewater, has virtually no energy costs other than for planting and harvesting the plants (Lakshman 1979, Tripathi *et al.* 1991). In a sense the plants are an agricultural crop utilizing the solar energy and growing on the nutrients in the wastewater. The harvested plants can be used to feed herbivorous fish, waterfoul and cattle, or to provide raw material for making processed animal food, soil additives, methane gas, and other products (Gaudet 1974).

In this study, we evaluated the water purification capacity of 4 macrophytes distributed in Mankyung River, by measuring nitrate reductase activity (NRA) and nutrient removal capacity as indicator for an improvement of water quality, which are useful for the conservation and restoration in the watersheds of Mankyung River.

STUDY AREA

Mankyung River is located in the northern part of Chollabukdo province, Korea. This river is 99 km in length and 16 m in width and its watershed contains approximately 1,047 km^2. Forest area, farmland, housing area and others occupy 58.69 %, 26.12 %, 9.54 % and 5.65 % of the watershed, respectively. Mankyung River consists of 4 major tributaries of Gosanchon, Soyangchon, Chonjuchon and Iksanchon. Those are characterized according to source of pollutants. Gosanchon and Soyangchon are affected mainly by agricultural effluents, Chonjuchon by domestic effluents and Iksanchon by industrial effluents.

Means of over 10 years from Kunsan Meteorological Station show that the total annual precipitation is around 1,236 mm, 45~60 percent of it comes in summer, and only 3~10 percent in winter. Mean maximum and minimum temperatures are 33.9℃ for August and -9.8℃ for January.

METHODS

Distribution of macrophytes and cultivation

Distribution of macrophytes was determined in 4 tributaries of Mankyung River at monthly intervals from June to October 1998. Actual vegetation map was drawn in 4 tributaries of Gosanchon, Soyangchon, Chonjuchon and Iksanchon.

In order to determine nitrate reductase activity (NRA) and nitrogen and phosphorus removal capacity, seedlings of 4 dominant species with constant size were transplanted from field in June, 1998 and were grown in a controlled growth room equipped with white fluorescence lamps at 400 μmol m^{-2}s^{-1} quantum flux density, 25±2℃ in temperature and 14h/10h in photoperiod. The plants were grown in culture tank (20 cm in diameter × 40 cm in height) for 2 weeks including Hoagland's solution.

Measurement of nitrate reductase activity (NRA) and nitrogen and phosphorus removal capacity

To understand the nitrate reduction capacity of macrophytes, nitrate reductase activity (NRA) of leaves was determined, after two weeks exposure to Hoagland's solution as described by Ihm *et al.* (1996). Each measurement consisted of 3 replicates.

After the plants were transplanted into culture tank, including agricultural wastewater of Gosanchon, industrial wastewater of Iksanchon and domestic wastewater of Chonjuchon, water samples of culture tank were collected every three days for three weeks. NO_3-N, NH_4^+-N and PO_4-P were measured according to the methods described in APHA (1985) and nutrient removal capacity was determined by the equation of Tripathi *et al.* (1991):

$$C = (I - F) / (T \times D)$$

C: Nutrient removal capacity
I: Initial concentration in culture solution
F: Final concentration in culture solution
T: Time for nutrient removal
D: Plant dry weight

RESULTS AND DISCUSSION

Distribution of macrophytes

In the 4 tributaries of Mankyung River, major macrophytes in Gosanchon and Soyangchon were *Phragmites japonica*, *Persicaria thunbergii*, *Paspalum distichum*, *Zizania latifolia*, which were

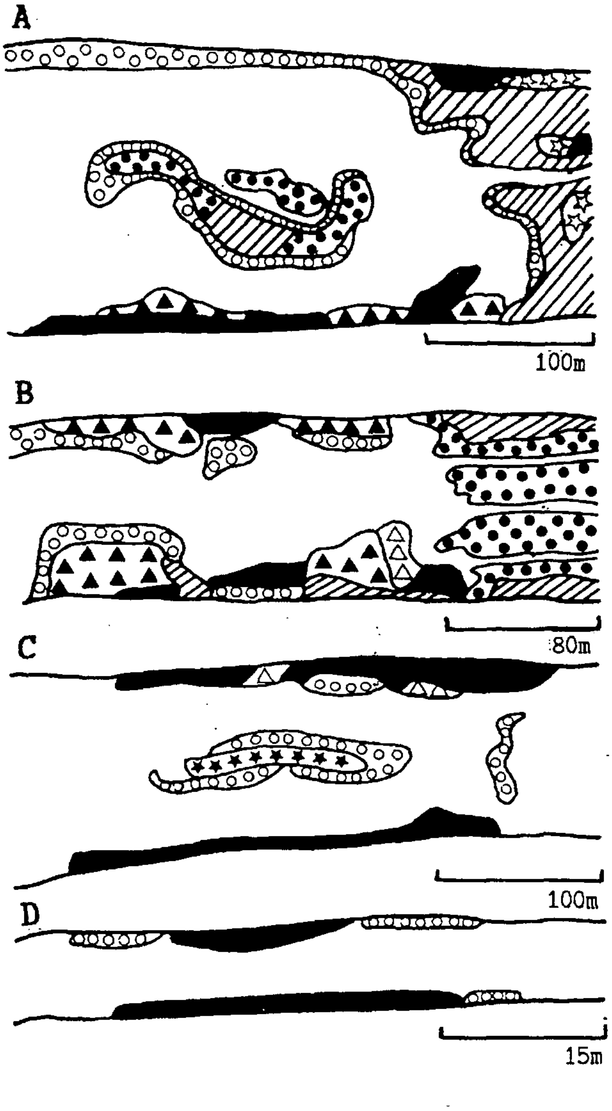

Fig. 1. Actural vegetation map in tributaries of Mankyung River

☆: *Salix gracilistyla* commumity
★: *Xanthium strumarium* community
▨: *Phragmites japonica* community
■: *Phragmites communis* community
○: *Phragmites distichum* community
△: *Typha orientalis* community
▲: *Zizania latifolia* community
●: *Phragmites thunbergii* community

very widely distributed. While dominant macrophytes in Chonjuchon and Iksanchon were *Phragmites communis* and *Paspalum distichum*, which were disturbed by human interference.

The pollutant loading of Gosanchon and Soyangchon near rural area were lower than those of Chonjuchon and Iksanchon near urban areas (Lee *et al.* 1999). Macrophyte distribution areas in Chonjuchon and Iksanchon were narrower than those of Gosanchon and Soyangchon. This indicates that the local disturbances such as industrial and domestic effluents may lead to a change in species distribution area (Hobbie *et al.* 1993). Pollutant loading in Iksanchon was highest due to increase of industrial effluents from Iksan Gem Industrial Complex and species diversity index was lowest (Lee *et al.* 1999). Enrichment of pollutant loading may be the primary cause of the ecological imbalance that has led to the decline of macrophytes (Cho and Kim 1994, Back *et al.* 1977). Decrease of macrophytes in Iksanchon might be attributed to an increase of pollutant loading by industry and sewage effluents on the watershed.

Nitrate reductase activity (NRA) of macrophytes

Nitrate is the major nitrogen source for most higher plants and nitrate reductase activity is the first enzyme in the nitrate assimilation pathway. The determination of nitrate reductase activity was used as a reporter to indicate nitrogen availability in plant physiology (Campbell 1988).

The higher NRA occurred in *Persicaria thunbergii* and *Oenanthe javanica*, with 7.8 and 5.4 NO_2 μ mol g^{-1}d.wt. h^{-1}, respectively, and the lower NRA was found in *Oenanthe javanica* and *Persicaria thunbergii* (Fig. 2).

There is a strong correlation between increase rates of nitrate uptakes and nitrate reducting activity (Margaret *et al.* 1991). The plants with higher NRA have so large nitrogen absorption capacity that they are regarded as plants having higher nitrogen removal capacity (Press and Lee 1982, Scott *et al.* 1989, Lee *et al.* 1996).

Nitrogen and phosphorus removal capacity

The nitrogen and phosphorus removal capacity of *Phragmites communis* displaying the highest values were 1.36 and 0.0088 mg g^{-1}d.wt. day^{-1}, respectively, and was higher in the order *Phragmites communis* > *Persicaria thunbergii* > *Oenanthe javanica* > *Zizania latifolia* (Fig. 3).

Kim and Cho (1991) studied annual net production and distribution area of emergent macrophytes, floating-leaved macrophytes and submersed macrophytes. They found that annual net production was higher in the order of emergent macrophytes > floating-leaved macrophytes > submersed macrophytes and distribution area was wider in the order of emergent macrophytes > submersed macrophytes > floating-leaved macrophytes. Sakurai (1988) reported that nutrient removal capacity of emergent macrophytes, floating-leaved macrophytes and submersed macrophytes were 21,611, 1,853 and 8,491 kg/year, respectively, for nitrogen and 3,064, 193 and 1,123 kg/year, respectively, for phosphorus. Emergent macrophytes showed the highest water purification capacity. The above results are in accordance with higher water purification capacity of emergent macrophytes in our study. During the growing seasons aquatic macrophytes absorb

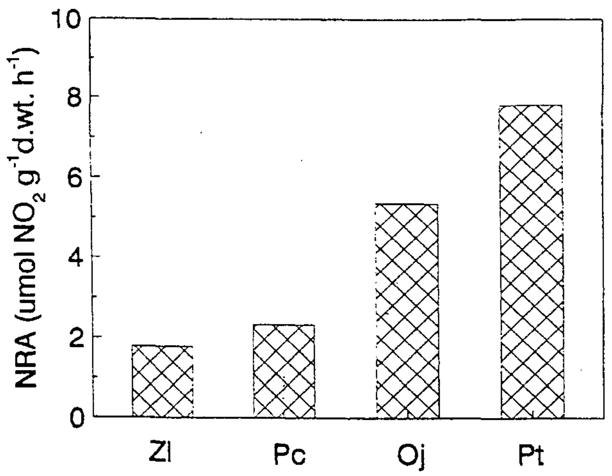

Fig. 2. Nitrate reductase activity (NRA) of 4 macrophytes. (Zl: *Zizania latifolia*, Pc: *Phragmites communis*, Oj: *Oenanthe javanica*, Pt: *Persicaria thunbergii*) (n=3)

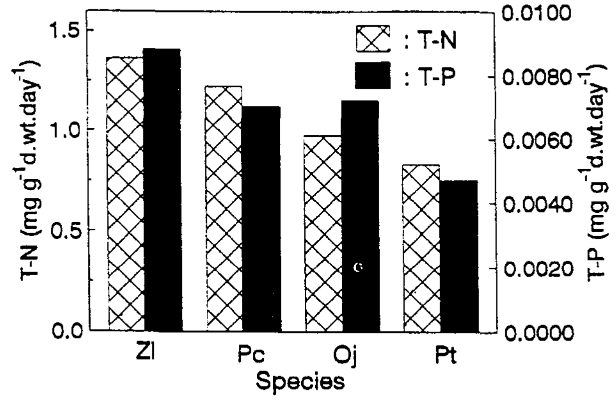

Fig. 3. Total nitrogen (T-N) and total phosphorus (T-P) removal capacity of 4 macrophytes. (Pc: *Phragmites communis*, Pt: *Persicaria thunbergii*, Oj: *Oenanthe javanica*, Zl: *Zizania latifolia*) (n=3)

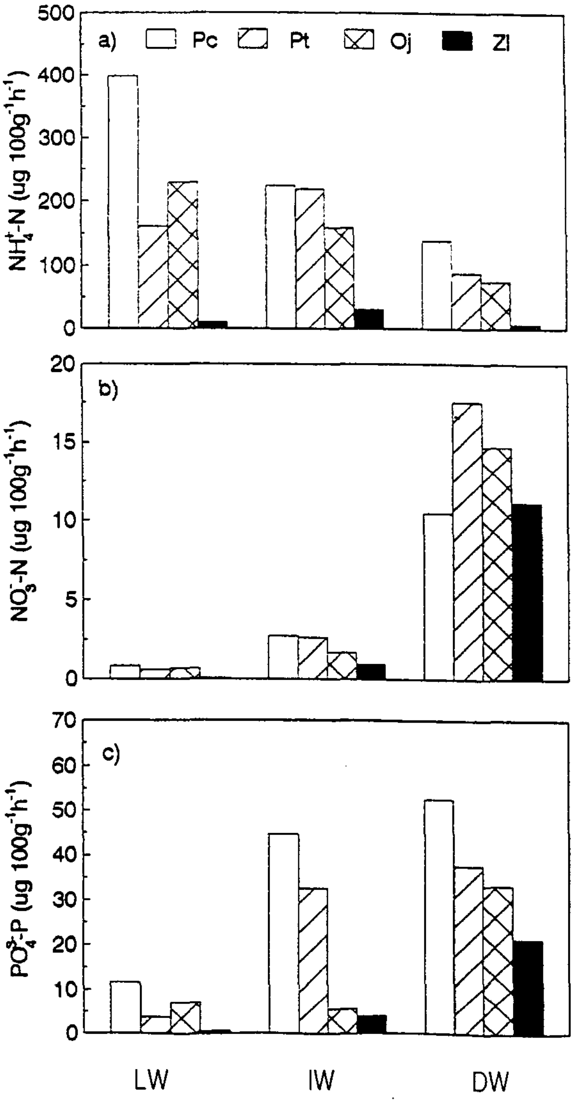

Fig. 4. Nutrient removal capacity of NH_4^+-N (a), NO_3^--N (b) and PO_4^{-3}-P (c) of 4 macrophytes in agricultural wastewater (LW), industrial wastewater (IW), domestic wastewater (DW). (Pc: *Phragmites communis*, Pt: *Persicaria thunbergii*, Oj: *Oenanthe javanica*, Zl: *Zizania latifolia*) (n=3)

large amounts of nitrogen and phosohorus so that they contribute to water purification in streams, but after death they increase the concentration of nutrients in streams. Plants should be harvested in maximum growing season in order to increase water purification capacity in streams (Kim and Cho 1991, Tripathi *et al.* 1991).

Nitrogen and phosphorus removal capacity in anthropogenic pollutants

Nitrogen and phosphorus removal capacities of 4 macrophytes cultured in agriculturial wastewater, industrial wastewater and domestic wastewater were measured (Fig. 4). In domestic wastewater, the nutrient removal capacity of *Phragmites communis* showed the highest values and was higher in the order of *Oenanthe javanica* > *Persicaria thunbergii* > *Zizania latifolia* and the amount of absorption of each nutrient was higher in the order of NH_4^+-N > NO_3^--N > PO_4^{-3}-P. In industrial wastewater, the nutrient removal capacity of *Phragmites communis* showed the highest values and was higher in the order of *Persicaria thunbergii* > *Oenanthe javanica* > *Zizania latifolia* and the amount of absorption of each nutrient was higher in the order of NH_4^+-N > Po_4^{-3}-P > NO_3-N. In agricultural wastewater, the nutrient removal capacity of *Phragmites communis* showed the highest values and was higher in the order of *Persicaria thunbergii* > *Oenanthe javanica* > *Zizania latifolia* and the amount of absorption of each nutrient was higher in the order of NH_4^+-N > PO_4^{-3}-P > NO_3^--N.

The higher nitrogen and phosphorus removal capacity of aquatic macrophytes such as *Phragmites communis* may lead to wide distribution in estuaries or places with a large amount of organic wastewater and decrease pollutant concentration in rivers or estuaries (Lakshman 1979, Wolverton and McDonald 1979, Busk *et al.* 1989). Especially, *Oenanthe javanica* has been used as food and can be harvested easily and be used in water purification of rural areas and small cities (Reddy *et al.* 1983, Cho and Kim 1994, Ihm *et al.* 1994). In conclusion, *Phragmites communis* can be an optimum species for water purification of 4 tributaries of Mankyung River.

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