The influence of waterweeds in the removal of phosphorus in content aquatic environments

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Abstract. Over the last few decades phosphorus removal methods have increasingly been designed. One of the methods is using waterweed for uptake the phosphorus (P) from water and sediment. However, lack information of suitable waterweed for P removal. The goals of this research are to investigate the effect of waterweeds in the P removal and to find the suitable waterweeds for P removal. Five types of waterweeds (Phragmites australis, Egeria densa, Bacopa myriophylloides, Eichornia crassipes, and Limnobium laevigatum) were collected and cultivated in pots. Water and sediment were collected from natural small pond, and sampling were performed at 0, 7, 14, 21 and 28 days. The result showed that P of water and sediment were reduced during the experiment. E. densa accumulated highest TP (505 mg/kg). It was suggested that E. densa is suitable for phosphorus removal.

1. Introduction

In nature, phosphorus is mainly sourced from the natural cycle (rain water) and fertilizers. Phosphorus presents in the soil and leaches to the water before accumulating in the sediment of aquatic environments. Therefore, the amount of phosphorus is higher in the sediment than in the water. Phosphorus tends to be the limiting nutrient for the aquatic environment, but too high an amount of phosphorus in the water and sediment can be harmful to the aquatic environment. The high amount of phosphorus may cause an over supply of nutrients, causing eutrophication [1]. This condition decreases the oxygen demand and is followed by the increase of chemical oxygen demand in the water.

In terms of phosphorus removal, several waterweeds are known to have the ability to remove phosphorus from sediment by absorbing it for their growth. Waterweeds are aquatic plants that dominate wetlands, shallow lakes, and streams. They grow in or near water. Waterweeds can be classified as emergent, submerged or floating, based on their predominant growth forms. Emergent waterweeds are usually rooted or attached to the bottom. Their stems and leaves are located below the water surface (some plants may produce a few small floating or aerial leaves found at the water’s surface). Submerged species include Hydrilla, Egeria, Vallisneria and curly leaf pondweed. Emergent waterweeds grow in shallow waters, and most have leaves above the water surface. Representative species of emergent plants include Scirpus spp, Sagittaria spp, Sparganium spp, Typha spp, Phragmites australis and Lythrum salicaria. Floating waterweeds are free floating on the water surface; waterlily
and spatterdock are floating-leaved species, whereas water hyacinth and water lettuce are free-floating species.

Waterweeds play an important role in healthy ecosystems as primary producers of oxygen through photosynthesis, providing substrates for algae and shelters for fish and many invertebrates. As a result, they assist in nutrient recycling to and from sediments and aid in stabilizing river and stream banks. Waterweeds, therefore, have the potential to be used to clean the static water owing to their metabolic functions. The metabolic function of waterweeds consists of nutrient uptake and O₂ release from the roots into the rhizosphere [3]. The ability and capacity of waterweeds in the nutrient removal from water bodies are currently of concern among researchers since the last two decades [4, 5]. Xu et al. [6] found that duckweed (Spirodela oligorrhiza) was able to remove of 83.7 % TN and 89.4 % of TP from swine lagoon water during a period of eight weeks.

Waterweeds improve the nutrient condition. Previous studies have attributed plant uptake of phosphorus that is responsible for 12-73 % of total phosphorus removal [7]. However, there is lack of information on the most suitable waterweed to remove phosphorus from sediment. Therefore, it is necessary to study the features of waterweeds in order to remove the phosphorus from the water system effectively. This study aimed to find out which type of waterweed had the highest ability to remove phosphorus from the sediment and water of aquatic environments.

2. Methodology

Sediment and water samples were collected from Kitanoshin pond located in Kusatsu city, Shiga, Japan (N: 34°98”, E: 135°96”) in July 2016. Five types of waterweeds were also collected from the natural water area. The waterweeds of Phragmites australis, Egeria densa, Bacopa myriophyloides, Eichornia crassipes, and Limnobiurn laevigatum were cultivated in pots containing 2.5kg sediment and 4L water as the treatments. Each treatment was performed in duplicate. Water and sediment sampling were performed at 0, 7, 14, 21 and 28 days to analyze Total Phosphor (TP).

TP of water was measured according to De Lucas [8]. The water sample was digested using the sulfuric acid digestion method. One mL of phenolphthalein was added into 50 mL of water sample in the erlenmeyer flask. After 5M sulfuric acid solution was added, the sample was mixed until the color disappeared. After the solution color turned to clear, 0.4 g of ammonium persulfate was added and heated at 90°C for 40 minutes. The solution was then cooled down at room temperature for 1 hour. One mL of phenolphthalein was added into the solution, then titrated using 1 N sodium hydroxide. After the solution was volumed up to 50 mL with distilled water, TP in 50 mL of each water sample was analyzed by using the ascorbic-acid method. A 50 mL of digested sample was placed into the erlenmeyer flask, 8 mL of combined reagent was added and mixed into the solution. The mixture was kept at room temperature for 30 minutes. The absorbance was measured by using an atomic absorption spectrophotometer (U-1900 Spectrophotometer, Hitachi, Japan) at 880 nm.

TP in sediment and waterweeds were measured using the molybdenum blue method. 100 µL of kjeldahl extract was mixed with 100 µL of molybdate solution and L-ascorbic acid solution (5:1) and kept at 30°C for 30 minutes for color development. The absorbance was measured using an atomic absorption spectrophotometer at 710 nm.

3. Results and discussion

Figure 1 shows TP concentration of water over time. TP was decreased in all treatments. At the end of experiment, the lowest TP concentration was found in E. densa (0.19 mg/L). Analysis of the sediment showed that TP was decreased in all vegetated treatments (Figure 2), the lowest concentration of TP in the sediment was found in E. densa treatment on 28 days of experiment (2.5 mg/kg). Waterweed treatments presented lower TP at the end of experiment, suggesting that waterweeds are directly involved in TP removal from the water and sediment. Results in this study are consistent with those reported by De Lucas et al. [9] who described that vegetated treatments removed TP more efficiently than unvegetated treatments.
TP removal from water (figure 3) by vegetated treatments were greater than the control, this suggests that waterweeds are able to remove TP from water at up to 50%. TP removal from water by *P. australis*, *E. densa*, *B. myriophilloides*, *E. crassipes* and *L. laevigatum* were 27.0, 52.0, 32.7, 28.9, and 38.4 %, respectively.

A previous study DE Lucas [9] reported that 68.1 % of phosphorus was successfully removed using several waterweeds. The highest TP removal was found in the *E. densa* treatment (52 %). Figure 4 shows percentage of TP removal from the sediment. TP removal from sediment in vetetated treatments were higher than the control. TP removal from sediment by *P. australis*, *E. densa*, *B. myriophilloides*, *E. crassipes* and *L. laevigatum* were 18.6, 42.0, 30.2, 32.6, and 23.3 %, respectively.
Waterweeds were able to accumulate phosphorus into their tissue from the aquatic environment (water and sediment). TP accumulation in *P. australis, E. densa, B. myriophylloides, E. crassipes* and *L. laevigatum* were 445, 505, 465, 474, and 461 mg/kg, respectively. Among the waterweeds, the highest accumulation was found in the *E. densa* treatment. This result correlated with high TP removal by *E. densa* from water and sediment. Nutrient uptake of waterweeds were influenced by many factors such as water conditions, nutrient availability, plant species, and growth stage [10].

Waterweeds take up nutrients from water, sediment, or both [11]. Floating waterweeds generally obtain nutrients from water columns through the roots [12]. Submerged waterweeds generally acquire nutrients from both water and sediment [13], therefore, submerged waterweeds have important implications in the nutrient cycling within fresh water systems [14]. Floating-leaved waterweeds petioles hold the leaves floating on the water surface and are generally rooted in the sediment [12,13].
The five waterweeds could effectively be used in reducing TP concentration in the water environment. The TP concentration of sediment in the waterweed bed is often reduced, since waterweeds use sediment as their source of phosphorus and potassium [15]. The root of waterweeds are able to uptake TP and relocate from the root to the shoot [16].

As waterweed biomass wilts and decays, the P in biomass is released back into the water system [17]. Harvesting waterweed biomass is an effective and obligatory method to avoid the release of nutrient from waterweeds [6]. Apart from promoting continuous nutrient removal by plant uptake, the harvesting of waterweeds effectively prevents the release of nutrient from waterweed tissues into the water during decomposition by waterweeds senescence, wilting and decay in their decline phase and ultimately reduces the harmful effects to the treatment systems. The majority of the storage of P is temporary because plant tissues release nutrients to the water treatment systems when they die and decompose. If waterweeds are not harvested, most of the nutrients that have been incorporated into the plant tissue may be returned to the water during the decomposition processes.

4. Conclusion
The important contribution of waterweed uptake is the highest TP removal from aquatic environment and the lowest TP content in the aquatic environment. Present results point large TP removal from water and sediment of systems planted with E. densa. Therefore, E. densa is suitable for phytoremediation practice. TP removal from aquatic environments can be enhanced by utilizing wetland systems planted with E.densa.

5. References
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