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A comparison on the phytoremediation ability of triazophos by different macrophytes

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ABSTRACT

The strategy of choosing suitable plants should receive great performance in phytoremediation of surface water polluted by triazophos (O,O-diethyl-O-(1-phenyl-1,2,4-triazol-3-base) sulfur phosphate, TAP), which is an organophosphorus pesticide widespread applied for agriculture in China and moderately toxic to higher animal and fish. The tolerance, uptake, transformation and removal of TAP by twelve species of macrophytes were examined in a hydroponic system and a comprehensive score (CS) of five parameters (relative growth rate (RGR), biomass, root/shoot ratio, removal capacity (RC), and bio-concentration factor (BCF)) by factor analysis was employed to screen the potential macrophyte species for TAP phytoremediation. The results showed that *Thalia dealbata*, *Cyperus alternifolius*, *Canna indica* and *Acorus calamus* had higher RGR values, indicating these four species having stronger growth capacity under TAP stress. The higher RC loading in *Iris pseudacorus* and *Cyperus rotundus* were 42.11 and 24.63 μg/(g fw·day), respectively. The highest values of BCF occurred in *A. calamus* (1.17), and TF occurred in *Eichhornia crassipes* (2.14). Biomass and root/shoot ratio of plant showed significant positive correlation with first-order kinetic constant of TAP removal in the hydroponic system, indicating that plant biomass and root system play important roles in remediation of TAP. Five plant species including *C. alternifolius*, *A. calamus*, *T. dealbata*, *C. indica* and *Typha orientalis*, which owned higher CS, would be potential species for TAP phytoremediation of contaminated water bodies.

Introduction

Triazophos (O,O-diethyl-O-(1-phenyl-1,2,4-triazol-3-base) sulfur phosphate, TAP) is an efficient and broad-spectrum organophosphorus pesticide used as insecticide, nematicide and acaricide, which is widely used in Chinese agricultural industry to protect various crops like cotton, rice, fruits, oil seeds and vegetables (Qu et al., 2003; Gui et al., 2006; Li et al., 2008). The toxicity of TAP attracted considerable public attention over the last decades. It was reported that TAP has fairly high toxicity to aquatic creatures and shows threat to the water ecosystem health (Zhong et al., 2009; Naveed et al., 2010; Jain et al., 2011). Zhang et al. (2011) showed that TAP chronic dietary intake risk for aged persons and that an acute nutritional intake risk of TAP residues in apple, cabbage, rice and wheat meal reaches an unacceptable range in China.

In the past few years, phytoremediation is of great concern as a cost-efficient and eco-friendly technology

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that uses plants and their associated rhizosphere microbes to remove, transform, or contain contaminants located in soils, sediments, surface water, and ground water (Alkorta and Garbisu, 2001; Susarla et al., 2002; Gerhardt et al., 2009). Many authors have reported the role of plants in remediating soils and water contaminated with organic pollutants. Burken and Schnoor (1997) found that hybrid poplar trees could uptake, hydrolyze and dealkylate atrazine to less toxic metabolites. The study by Gao et al. (2000a) showed that selected aquatic plants have the potential to accumulate and metabolize organophosphorus compounds. The feasibility study of phytoremediation to TAP has also been proved. In our previous studies, plants play a leading role in removal of TAP in hydroponic systems and *Canna indica* shows the potential of phytoremediation of TAP from contaminated water (Cheng et al., 2007; Xiao et al., 2010a, 2010b). Consequently, phytoremediation is a sound approach to remediate TAP pollution from the ecosystem.

In recent years, differences in ability of phytoremediation among plant species were well recognized (Gao et al., 2000b; Hutchinson et al., 2001; White et al., 2005), therefore selecting suitable plants should receive great attention as an effective phytoremediation approach. Although there has been a growing interest in the purification efficiency of plants relative to remediate organophosphorus pesticides, little information is available regarding the plant species involving the phytoremediation of TAP and the effectiveness of these plants to remediate TAP from contaminated water. In this research, several macrophytes, which are available in China and commonly used in constructed wetlands, were chosen for experiment in a hydroponic system to study the ability of different plant species to remediate TAP. A comprehensive score (CS) was employed by factor analysis to compare the potential plant species for TAP phytoremediation.

1 Materials and methods

1.1 Materials and treatment

Twelve common macrophytes were collected from the East Lake of Wuhan (Hubei Province, China). These plants were *Acorus calamus* Linn., *Canna indica* Linn., *Cyperus alternifolius* Linn. subsp. *flabelliformis* (Rottb.) Kukenth., *Cyperus rotundus* Linn., *Eichhornia crassipes* (Mart.) solms, *Iris pseudacorus* Linn., *Phragmites australis* (Cav.) Trin. ex Steud., *Pontederia cordata* Linn., *Scirpus triangulates* Roxb., *Thalia dealbata* Fraser ex Roscoe, *Typha orientalis* Presl and *Vetiveria zizanioides* (Linn.) Vach. All plants were washed by deionized water and pre-cultivated in nutrient medium for 7–10 days before experiment. The nutrient medium consisted of (mg/L) KNO_3 (50.5), $Ca(NO_3)_2$ (118), $MgSO_4$ (24), KH_2PO_4 (13.6), HBO_3 (286), $MnCl_2{\cdot}4H_2O$ (181), $ZnSO_4{\cdot}7H_2O$ (22), $CuSO_4{\cdot}5H_2O$ (8), $H_2MoO_4{\cdot}H_2O$ (2), $FeSO_4{\cdot}7H_2O$ (28) and EDTA-Na_2 (37). TAP (emulsifying concentrate 80%) was purchased from Deshijia Chemical Pesticide Consultation Center (Shandong Province, China).

Plants with similar biomass were selected from each species and transplanted to conical flask containing 2 L nutrient medium, and twelve groups were set up with different plant species. Taking into account that the usual TAP residual concentration of soil leachate was lower than 1 mg/L (Bosch et al., 2005), control and three treatments with three replicates were set up, including 0, 1, 3, 5 mg/L of TAP, respectively. In addition, a non-plant group consisting of nutrient medium with 1, 3, 5 mg/L of TAP was set to calculate the TAP removal by photolysis, hydrolysis and microbial degradation in non-plant hydroponic system. All plants were cultivated under similar conditions with room temperature (25 ± 5°C) and natural illumination (light intensity 34.5 ± 7.1 μmol/(sec·m^2), 14 hr:10 hr of day/night). Water loss from evaporation and transpiration by plants was compensated by adding deionized water every five day.

1.2 Chemical analysis

Water samples for TAP analysis were sampled every 5 days and then pretreated according to the methods of Zhang et al. (2005). The samples were centrifuged at 15,000 r/min at 25°C for 10 min and a volume of 1.5 mL of the supernatants was prepared for the analysis of TAP concentration. TAP concentration was measured by high performance liquid chromatography (HPLC) (1100 serial, Agilent, USA), which was furnished with a DAD detector. Water RP-C18 column (5 μm, 3.9 mm × 150 mm inner diameter, Waters, USA) was used for separation. Analytes were eluted with water-methanol (3:7, *V/V*) mixture at a flow rate of 1.00 mL/min. UV detection was made at 246 nm for TAP and retention time was 6.79 min with the column temperature of 25°C.

The treatment lasted 20 days. The plants were harvested and were separated into three sections (roots, stems and leaves) for recording fresh weight, and then replicates of each section of each group in the same treatment were composited respectively for TAP determination in the end of experiment. TAP in plant samples was analyzed using the method of Xiao et al. (2010a). Plant samples were extracted with 0.01 mol/L $CaCl_2$ and methanol, and then freeze-dried, homogenized and extracted with acetone. The supernatant condensed and eluted through a chromatographic column. The eluent condensed and readied to post-HPLC detection. The method of TAP detection for plant organs was similar to the HPLC method described above, with several conditions adjusted as follows: the water-methanol ratio of mobile phase was changed into same size ratio (*V/V*) and the retention time for TAP was transformed into 17.57 min.