Available online at www.sciencedirect.com
SCIENCE DIRECT®
Bioresource Technology 97 (2006) 1050–1054
BIORESOURCE TECHNOLOGY

Phytoremediation of ethion by water hyacinth (*Eichhornia crassipes*) from water

Huilong Xia *, Xiangjuan Ma

College of Food Science, Biotechnology and Environmental Engineering, Zhejiang Gongshang University, No. 149 Jiaogong Rd., Hangzhou 310035, China

Received 8 March 2004; received in revised form 18 April 2005; accepted 18 April 2005
Available online 27 June 2005

Abstract

The potential of water hyacinth (*Eichhornia crassipes*) to remove a phosphorus pesticide ethion were investigated. The disappearance rate constants of ethion in culture solutions were 0.01059, 0.00930, 0.00294, and 0.00201 h^{-1} for the non-sterile planted, sterile planted, non-sterile unplanted, and sterile unplanted treatment, respectively, which were significantly different and implied that plant uptake and phytodegradation contributed 69% and that of microbial degradation took up 12% to the removal of the applied ethion. The accumulated ethion in live water hyacinth plant decreased by 55–91% in shoots and 74–81% in roots after the plant growing 1 week in ethion free culture solutions, suggesting that plant uptake and phytodegradation might be the dominant process for ethion removal by the plant. This plant might be utilized as an efficient, economical and ecological alternative to accelerate the removal and degradation of agro-industrial wastewater polluted with ethion.

Keywords: Water hyacinth; Ethion; Phytoremediation

1. Introduction

Phytoremediation is an emerging technology that is rapidly gaining interest and promises effective and inexpensive cleanup of hazardous waste sites contaminated with metals, hydrocarbons, pesticides, and chlorinated solvents (Macek et al., 2000; Susarla et al., 2002; Xia et al., 2003). The use of plants to degrade, assimilate, metabolize, or detoxify contaminants is cost-effective and ecologically sound. Four mechanisms are involved in phytoremediation of organic pollutants: direct uptake and accumulation of contaminants and subsequent metabolism in plant tissues; transpiration of volatile organic hydrocarbons through the leaves; release of exudates that stimulate microbial activity and biochemical transformations around the root system; and enhancement of mineralization at the root–soil interface that is attributed to mycorrhizal fungi and microbial concortia associated with the root surface (Schnoor et al., 1995). The economic success of phytoremediation largely depends on photosynthetic activity and growth rate of plants. Water hyacinth (*Eichhornia crassipes* Solms), due to its fast growth and large biogas production (Singhal and Rai, 2003), has potential to cleanup various wastewaters.

Inorganic contaminants such as nitrate, ammonium and soluble phosphorus (Reddy et al., 1982; Reddy, 1983), heavy metals (Muramoto and Oki, 1983; Zhu et al., 1999) can be removed efficiently by water hyacinth through uptake and accumulation. Organic pollutants such as phenols (Nora and Jesus, 1997) also can be absorbed, but whether those kinds of organic contaminants removed through uptake or an enhancement of mineralization due to the microbial concortia associated with the root surface is rarely studied and reported.

* Corresponding author. Tel.: +86 571 860 3999 8.
E-mail address: tuyying@mail.hz.zj.cn (H. Xia).

0960-8524/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biortech.2005.04.039

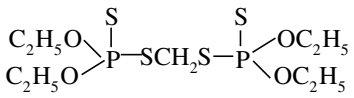

Fig. 1. Chemical structure of ethion.

Ethion (*O*,*O*,*O*′,*O*′-tetraethyl *S*,*S*′-methylene diphosphorodithioate, CAS numbered 563-12-2) was introduced in 1956 by the Food Machinery and Chemical Company (FMC) for use on plants and animals as an insecticide, acaricide and ovicide (Howard, 1991). Its chemical structure is presented in Fig. 1. Previous studies showed that ethion was even more persistent than parathion and lindane in natural water (Sharom et al., 1980). Ethion concentrations in dip sludges and surrounding soils remain unacceptably high, up to 45 g kg^{-1} (Foster et al., 2004). As a consequence of its high toxicity and persistence, remediation of environments contaminated with ethion is a priority. Due to its low water solubility (2 mg l^{-1}, 25 °C) and high octanol/water partition coefficient (5.07) (Eister and Levsen, 1996), phytoremediation of wastewater contaminated with ethion might be a promised alternative. The objective of the present study was to investigate the disappearance rates of ethion in non-sterile planted, sterile planted, non-sterile unplanted, and sterile unplanted culture solutions to determine the phytoremediation potential of water hyacinth for pesticide removal and assess the primary phytoprocesses involved in the removal of ethion contaminated water.

2. Methods

2.1. Preparation of live plants and culture solution

Plants of *E. crassipes* obtained from a fishery pond situated in Zhejiang University campus were cultivated with a nutrient solution in the greenhouse of Zhejiang University for at least 30 days before use. The nutrient solution was renewed once a week. The nutrient solution contained N (NH_4NO_3), 38 mg l^{-1}; P (KH_2PO_4), 3.5 mg l^{-1}; K (KCl), 30 mg l^{-1}; Ca ($CaCl_2 \cdot 2H_2O$), 9 mg l^{-1}; Mg ($MgSO_4 \cdot 7H_2O$), 7 mg l^{-1}; trace elements such as Fe, Mn, B, Zn, Mo, Cu, and Co at the concentrations of 3, 0.45, 0.12, 0.16, 0.05, 0.005, and 0.005 mg l^{-1}, respectively. To minimize the chemical oxidation–reduction reactions of ethion catalyzed by Fe, Fe was left off in the nutrient solutions used for ethion removal and phytodegradation experiments. The nutrient solutions with addition of 10 mg l^{-1} ampicillin (an antibiotic that at this concentration causes no visible damage to plants and minimizes bacterial growth, Chapin et al., 1993) and 1 mg l^{-1} ethion (with a purity of 95%) were set up as the sterile treatments, and nutrient solutions without the addition of ampicillin and dosed with 1 mg l^{-1} ethion were set up as non-sterile treatments.

2.2. Ethion removal by water hyacinth experiment

Plants of similar shape and size (weight of each plant, 10–11 g wet mass) were selected and washed several times using tap and distilled water. Each plant was transplanted and inserted in an upright position in 500-ml polyethylene terephthalate (PET) containers (7 × 12.5 cm i.d.) containing 250 ml of nutrient solution. Containers with one live plant in each containing ampicillin were set up as sterile planted treatments, and those containers with one live plant and containing no ampicillin were set up as non-sterile planted treatments. In order to differentiate the effect of sorption caused by the wall of the container, the natural hydrolysis and microbial degradation of ethion in culture solutions, treatments of both sterile unplanted and non-sterile unplanted culture solutions were also set up. Three replicates were set up for each treatment. All the treatments were placed into a growth chamber with a temperature of 25 ± 1 °C, with a 14-h day (light intensity 1400 lx) and 10-h night. The total volume of the solution in each container was kept constant by adding nutrient solution to compensate for water lost through plant transpiration and evaporation during the incubation.

Plants and/or culture solutions were sampled for three containers at 24, 72, 120, 168, and 240 h after incubation for each treatment. The concentrations of ethion in leaves and roots of water hyacinth, and the culture solutions were determined. For the planted treatments, each plant sample was rinsed with 20 ml nutrient solution to remove the chemical on the surface, and the elution was combined into the corresponding culture solution. After being divided into root and shoot segments, each unit of plant tissue was freeze-dried using a Savant SNL-216 V freeze drying system, then weighed and macerated in a glass mortar and pestle before extraction. The concentration of ethion in plant tissues was based on dried weight (DW). For both of the planted and unplanted treatments, culture solution samples were extracted twice (2 × 50 ml) with dichloromethane (Xia and Chen, 1989), the container was rinsed with 2 × 10 ml of dichloromethane to remove the ethion adsorbed on the internal surface, and the rinsed solvent was combined into the corresponding extract. The combined extract was filtered through anhydrous sodium sulfate and concentrated for ethion residue determination.

2.3. Phytodegradation of ethion in water hyacinth experiment

To determine the phytodegradation of ethion by water hyacinth, the following test was carried out. Water hyacinth plants (15–17 g wet mass) were cultivated in 2000 ml of nutrient solutions containing 0.01 mg l^{-1}, 0.1 mg l^{-1}, and 1 mg l^{-1} ethion, separately, maintained in 30 × 25 cm polyvinyl chloride (PVC) containers for 3