Decolorization of an Azo Dye Bismark Browny by Wood Plant—Pterocarya Stenoptera

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Abstract. Total colorant production in China is estimated to be above 420,000 tons per annum, which account for 42% of the total World colorant production. This situation made serious synthetic dyes pollution on both water bodies and soil. We investigated the removal ability and physiological response of Pterocarya stenoptera to simulated wastewater containing Bismark browny. The percent decolorization of Bismark browny by Pterocarya stenoptera to 100 mg/L, 400 mg/L, 800mg/L and in average was 97.80%, 88.88%, 85.37% and 90.69 respectively in 6 days. The values for the apparent TSCF of Pterocarya stenoptera for t Bismark browny was 1.62. The NRT of Pterocarya stenopter growing in 100 mg/L Bismark browny dye increased during first 2 days, then it decreased less than 14% that of controls. At a concentration of 400 and 800 mg/L, Bismark browny decreased transpiration of Pterocarya stenopter more than 70% after 6 days. The result showed that Pterocarya stenoptea can resist 100mg/L Bismark browny. It is concluded that Pterocarya stenoptea can be used to phytoremediation of wastewater containing azo dyes.

Introduction

Synthetic dyes are widely used in textile, dyeing, printing and other industrial application. Total world colorant production is estimated to be about 800,000 tons/year. More than 100,000 dyes are commercially available and at least 10-15% of the used dyes enter environment through waste effluent [1, 2]. The dyes present in textile effluent impart persistent color to the receiving streams and interfere with photosynthesis of the phytoplankton [3]. Many dyes had mutagenic and possibly carcinogenic effect [4]. Synthetic dyes, especially textile dyes, have been a serious source of water contamination in many parts of the world. The traditional treatment techniques applied in textile waste water such as chemical coagulation/flocculation, membrane separation (ultrafiltration, reverse osmosis) or activated carbon adsorption only does a phase transfer of pollutants [5]. Moreover, because activated sludge and other types of bioreactor fail to remove sufficient color, COD, N, surfactants and other micro-pollutants present in the textile effluent, conventional waste water treatment plant relying on it is not adequate for the treatment of textiles [6]. Due to its cost effectiveness, aesthetically pleasing and easily operation, phytoremediation is a potential practical method in removing the synthetic dyes from wastewater. It entails the use of plants for uptake, sequestration, detoxification, or volatilization of inorganic and organic pollutants from soils, water, sediments, and possibly air [7]. Aquicultural plant system experiments showed that plants can decolorize wastewater containing dyes [8-13]. Some aquicultural plant system experiments further showed that plants can degrade dyes [11-13]. So far, wood plants have not used to decolorize dye containing wastewater. Pterocarya stenoptera is a hygrophilous tree species which is used as greening trees in valley or riverbank in north China. Therefore, the objective of this research is to explore the dye phytoremediation potential of Pterocarya stenoptera.
Materials and Methods

Reagent and Chemical Analysis

The Bismark Browny (CI, 21000) were purchased from Shanghai Huanlan chemical company. Seeds of *Pterocarya stenoptera* were gathered from one *Pterocarya stenoptera* tree in Mount Tai. The absorption maxima of Bismark Browny in water was looked up from Conn’s Biological stains [14]. The absorption values of samples and standards were determined by a Hitachi U-1100 Spectrophotometer. The standard curve of each dye was made. The remaining concentration of each dye was calculated through the standard curve regression equation.

Hydroponic Experiment

The hydroponic experiments were carried out from April, to September, 2009 at Shandong Agricultural University. *Pterocarya stenoptera* seeds were pregermination in fine sand moistened with distilled water in illumination box. After sprouting, the seeds were sowed in vermiculite moistened with half strength Hoagland’s hydroponic nutrient solution. Then, healthy *Pterocarya stenoptera* bare root seedlings were transplant in 250 mL conical beakers containing half strength Hoagland’s hydroponic nutrient solution. Those conical beakers covered by black plastic film to deter algal growth. The seedlings were suspended in the conical beakers using rubber plugs with a hole so only the roots were in contact with the hydroponic growth solution. The seedlings were cultured under 40-watt cool white fluorescent tubes with continuous light at room temperature (24-25°C) for 30 days.

Then, the decolorization of wastewater containing Bismark Browny by *Pterocarya stenoptera* seedlings was conducted. One seedling was placed in a conical beaker containing 250 mL half strength Hoagland’s solution only (control treatment) or spiked 100 mg /L, 400mg /L or 800 mg /L Bismark Browny. Each treatment has three replicates. The total weight of conical beaker, with solution and plant were recorded. During this period the total weight of the conical beaker with solution and plant was maintained nearly constant by adding fresh half strength Hoagland’s solution everyday. Two mL contaminate solution samples were taken after the addition of fresh half strength Hoagland’s solution to the conical beaker for dye’s concentration analysis every other day. After the measurement of the dye’s concentration, the samples were dumpling back to the conical beaker immediately.

The parameter percent decolorization was defined as:

\[
\text{Percent decolorization} = \frac{\text{Concentration of untreated dye} - \text{Concentration of treated dye}}{\text{Concentration of untreated dye}} \times 100
\]

Transpiration stream concentration factor (TSCF) represents the ratio of contaminant concentration in the xylem transpiration stream to contaminant concentration in the solution. Apparent TSCF was calculated according to Aubert [9]. Dye concentration in xylem transpiration stream was calculated as the amount of each compound removed from the medium divided by the amount of water transpired between the 4th and 6th days of experimentation in 100 mg /L dye treatment, thus avoiding the possible initial adsorption phenomena.

The normalized relative transpiration (NRT) of Bismark Browny was used to determine toxicity. The transpiration of the plants was determined by weighing the conical beaker system at the same time everyday. Inhibition of transpiration is a rapid measure for the toxic effect of a chemical or a substrate to sunflowers. The NRT is the change of transpiration of treated plants divided by the change of control plants:

\[
NRT(C,t)(\%) = \frac{\frac{1}{n} \sum_{i=1}^{n} T_i(C,t)/T_i(C,0)}{\frac{1}{m} \sum_{j=1}^{m} T_j(C,t)/T_j(C,0)}
\]
where \( C \) is the concentration (mg/L), \( t \) is the time period (day), \( T \) is the absolute transpiration (g/day), \( i \) is replicate 1,2,…,\( n \) and \( j \) is the control 1,2,…,\( m \) [15]. The NRT of the controls is always 100 %. Values of the treated plants below 100 % indicate an inhibition.

Results and discussion

Decolorization of Azo Dyes

The residual Bismark brown concentrations in the solution purified by \textit{Pterocarya stenoptera} declined sharply during the first 2 days, then, it decreased slowly during the other 4 days (Figure 1). The percent decolorization of Bismark brown by \textit{Pterocarya stenoptera} to 100 mg/L, 400 mg/L, 800 mg/L and in average was 97.80%, 88.88%, 85.37% and 90.69 respectively in 6 days (Figure 2), this result showed that it can be removed effectively by \textit{Pterocarya stenoptera}. The average Bismark brown percent decolorization in same concentration series by Sunflowers (\textit{Helianthus annuus L.}) was up to 96.0% observed on day 4 [8]. This results show that sunflowers are more efficiently than \textit{Pterocarya stenoptera} in phytoremediation Bismark brown. The maximum color removal by Narrow leaved Cattails (\textit{Typha angustifolia Linn.}) was 60% observed on day 14 [10]. Taking consideration of its large biomass and long growth period, \textit{Pterocarya stenoptera} is a good choice in phytoremediation azo dyes.
Apparent TSCF Measurement

The value for the apparent TSCF of *Pterocarya stenoptera* for Bismark browny was 1.62. The values for the apparent TSCF of sunflower for Bismark browny was 2.97. The apparent TSCF of rhubarb for several sulphonated anthraquinones were from 0.8 to 2.6 [9]. Because we cannot determine the dye concentration in the xylem, the values for the apparent TSCF was just a good estimation to TSCF.

Phytotoxicity Test

The phytotoxicity must be taken into account if plants are considered for removal of chemicals from soil, surface or groundwater. The three concentrations of Bismark browny dye had very different effect on the NRT (Figure 3). The NRT of *Pterocarya stenoptera* growing in 100 mg/L Bismark browny dye increased during first 2 days, then it decreased less than 14% that of controls. At a concentration of 400 and 800 mg/L, Bismark browny decreased transpiration of *Pterocarya stenoptera* more than 70% after 6 days. The results showed that *Pterocarya stenoptera* can resist 100mg/L Bismark browny. In fact, at a concentration of 800 mg/L, Bismark browny killed the snflowers after 7 days [8]. During textile processing, concentrations of azo dye in wastewater of 10 up to 80 mg/L have been reported [16]. The phytotoxicity test showed that *Pterocarya stenoptera* can be used to phytoremediation wastewater containing azo dyes.

![Figure 3. NRT of P. stenoptera in hydroponic solution at different concentration of dyes.](image)

Conclusions

The percent decolorization of Bismark browny in 6 days up to 97.8%. High concentrations of Bismark browny reduced significantly NRT of *Pterocarya stenoptera*. The percent of decline of NRT was more than 70% when concentration of Bismark browny was 400 mg/L or above. It is concluded that *Pterocarya stenoptera* can resist 100mg/L tested Bismark browny, so it can be used to phytoremediation azo dyes.

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References


