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Responses of pea and wheat to textile wastewater reclaimed by suspended sequencing batch bioreactors

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ABSTRACT

Availability of good quality water for crop irrigation is a big challenge in developing countries due to limited resources of clean water. Textile industry consumes a huge amount of water during dyeing process and consequently it releases high strength wastewater into wastewater streams. The present study was designed with the objective to use textile wastewater treated in sequencing batch bioreactor for irrigation purpose. Wastewater containing 100 mg/L reactive black-5 azo dye amended with different co-substrates was treated using mixed liquor suspended solids (MLSS) and two previously isolated dye-degrading bacterial strains (*Psychrobacter alimentarius* KS23 and *Staphylococcus equorum* KS26). About 90% color and COD removal in case of dye-containing wastewater amended either with mineral salts + yeast extract or only yeast extract was achieved in 24 h after treatment with mixed culture (MLSS + KS23 + KS26). The treated wastewater was applied for irrigation of pea and wheat plants under controlled conditions. Untreated dye-contaminated wastewater was used as a control for comparison. A significant positive effect of treated dye wastewater amended with different co-substrates on the seed germination index, root and shoot length and biomass was observed in response to application of dye-containing wastewater treated with MLSS and dye-degrading bacterial strains compared to untreated control. Results of this study reveal that the dye-degrading microbial cultures could be used to enhance the treatment efficiency of dye-contaminated wastewater that can be utilized for irrigation of crops and biomass production.

1. Introduction

Environmental pollution is a matter of great concern and has been accepted as a serious problem worldwide because of its adverse effect on human health, plants and animals. Plants being a vital part of ecosystem are highly receptive to biotic and abiotic environmental factors which induce stress in plants, affecting plant growth drastically (Garg and Kaushik, 2005).

Synthetic dyes are widely utilized for textile dyeing and paper printing where up to 50% of the applied dyes are released in effluents (Khalid et al., 2010). This wastewater is discharged directly into water bodies without treatment leading to surface and ground water and soil contamination. Contaminants present in water or soil may be up taken by plants (Manzur et al., 2006). Thus untreated textile industrial water causes accumulation of carcinogenic compounds in plants, which ultimately become a part of food chain. Besides this, deflocculation of soil particles, salinization, alkalization and outbreak of gastroschisis are manifestations of textile industrial wastewater (Root and Emch, 2010). Dyes in effluent can experience reductive process in aquatic environment ending in consequential formation of potentially carcinogenic compounds. Thus textile wastewater is more potent than any other industrial wastes (Nawaz et al., 2006). Existing effluent treatment procedures are unable to remove recalcitrant azo dyes from effluents completely because of color fastness, stability and resistance to degradation. Even chlorination treatment does not altogether eliminate genotoxic effects of azo dyes (Oliveira et al., 2010). It is crucial to study the impact of treated wastewater on growth of plants and crops grown adjacent to textile mill areas.

Bacterial biodegradation of contaminants in textile wastewater under certain environmental conditions has gained momentum as a method of treatment. It is considered inexpensive and eco-friendly, and can also be applied to a wide range of azo dyes (Khalid et al., 2009; Saratale et al., 2011). This study is planned with the objective to examine whether azo dye containing industrial wastewater can be used for irrigation purpose if treated with dye

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degrading bacterial strains prior to its discharge into wastewater streams. Response of pea and wheat plants to treated and untreated wastewater was observed under controlled conditions.

2. Materials and methods

2.1. Analytical procedures

For wastewater analysis, standard procedures described by APHA (2005) were followed. The methods used in the analysis for pH, DO and EC are electrometric method, COD close reflux method, moisture oven dry basis, nitrate nitrogen spectrophotometric method, organic method titration method, shoot length scale measuring method, Number of leaves and spikes count method, root/shoot ratio dividing method, dry biomass dry weight basis, fresh biomass fresh weight basis.

2.2. Wastewater treatment system

Suspended sequencing batch bioreactor was used for the biotreatment of dye-contaminated wastewater. Mixed liquor suspended solids (MLSS) between 5000 and 6000 mg/L were grown in the system as facultative microbes under aerobic-anaerobic cyclic conditions. Two previously isolated bacterial strains, namely *Psychrobacter alimentrius* KS23 and *Staphylococcus equorum* KS26, capable of decolorizing reactive azo dyes efficiently in liquid mineral salt medium (Khalid et al., 2012) were used to enhance the rate of color and COD removal. The bacterial culture was prepared in 250 mL conical flasks containing mineral salt medium and incubated at 30 °C for 48 h.

A batch scale completely anaerobic system was used to treat 100 mg/L concentration of reactive black-5 azo dye, with 1000 mg/L of MLSS, 20% (v/v) microbial culture and three co-substrates coded as C1 containing yeast extract with mineral salts (Khalid et al., 2008), C2 containing glucose in synthetic wastewater composition (Khan et al., 2010) and C3 having yeast extract only. Static batch conditions were maintained in the bioreactor. Each experimental study was carried out at 24 h hydraulic retention time (HRT) and repeated in triplicates. Sludge age was adjusted to 10 days by removing certain amount of sludge daily (Khan et al., 2010). The treated wastewater was characterized for color and COD removal. Reactor operations were followed as reported by Saba et al. (2011). Treatment performance was calculated in terms of percentage color and COD removal using simple mathematics.

2.3. Effect of treated dye-contaminated wastewater seed germination and plant growth

The treated wastewater was used for watering pea and wheat seedlings to examine its effect on seed germination and growth. Seeds of pea and wheat were placed over two sheets of filter paper (Whatman No. 42) after wetting with 3 mL of treated wastewater. Each treatment was repeated four times and incubated under dark at 30 °C for 96 h. Seed germination was recorded and germination index was calculated as described by Karaguzel et al. (2004).

To study impact of treated wastewater on plant growth, experimental soil was collected from a field (0–15 cm soil layer) of PMAS Arid Agriculture University Rawalpindi, Pakistan. The soil was clay loam having pH 7.95 ± 0.05, moisture 2.52%, ECe 430 ± 22 μS/cm, nitrogen 148 ± 10 μg/g soil, organic matter 0.97%. About 50 g sieved and air dried soil was applied to each plastic pot and three replicates were made to each treatment. Slightly germinated seeds of pea and wheat were sown in each pot. Control pots were established both for pea and wheat where untreated dye-contaminated water was applied. Water was supplied with 60% moisture level and stabilized for 5 days before sowing germinated seeds. Temperature was maintained at 25 °C in growth chamber. Plants were harvested after two weeks and measurements were recorded for root and shoot length and fresh and dry biomass. Root and shoot biomass was measured by drying plants at 60 °C till constant weight.

2.4. Statistical analysis

Data were entered in a Microsoft Excel 2010 spreadsheet, and means, standard deviations were calculated. Factorial ANOVA was applied for statistical analysis of the data using Satatistix 8 (v.8.1, ©1985–2005). The means were compared by using LSD test.

3. Results and discussion

3.1. Effect of treatment on color and COD removal

Maximum color removal (90%) from wastewater containing reactive black-5 azo dye was achieved in case of C1 (mineral salts with yeast extract as a co-substrate) when treated with strain KS23, which was followed in descending order by consortium with 88% color removal and strain KS26 with 75% color removal (Fig. 1). Up to 89% color removal was observed in case of C3 (yeast extract only). Synthetic wastewater composition (C2) with glucose as a co-substrate was the least effective treatment and showed maximum color removal up to 69% with strain KS23. Regarding COD removal, again C1 wastewater composition was the most effective and up to 85% and 82% COD removal was observed after 24 h treatment with strain KS26 and consortium respectively. In the presence of C2 co-substrate, maximum COD removal of 77% was achieved by treatment of wastewater with strain KS23. COD removal ranged from 70 to 75% as a result of biotreatment in the presence of C3 co-substrate. Yeast extract either alone (C3) or with mineral salts (C1) was found to be the best co-substrate to achieve the efficient color and COD removal compared to other co-substrate such as glucose. It very likely that yeast extract provides a complex organic substrate that can be used by microorganisms as an electron donor for reductive dechlorination of chlorinated ethenes and can also provide growth factors (Aulenta et al., 2005).

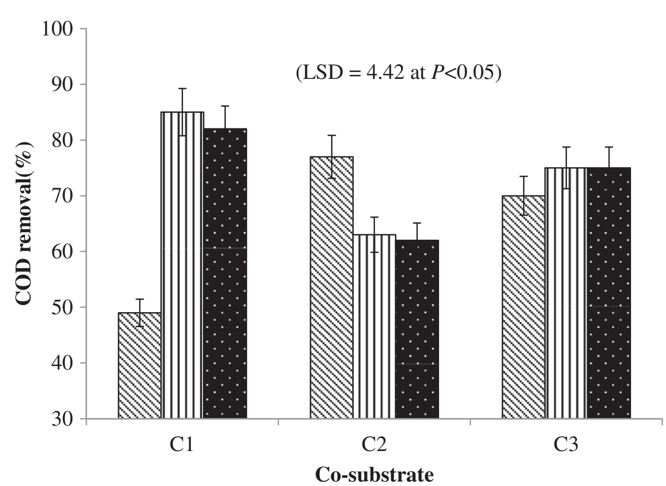

Fig. 1. Color and COD removal of dye-contaminated wastewater using different microbial cultures and co-substrates.