

Efficiency of *Phragmites australis* and *Typha latifolia* for heavy metal removal from wastewater

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ABSTRACT

A cost-effective and promising technology has been demonstrated for the removal of copper (Cu), cadmium (Cd), chromium (Cr), nickel (Ni), iron (Fe), lead (Pb) and zinc (Zn) from urban sewage mixed with industrial effluents within 14 days. With the help of *P. australis* and *T. latifolia* grown alone and in combination batch experiments were designed to assess the removal of heavy metals from the wastewater collected from 5 sampling stations. The results revealed that *P. australis* performed better than *T. latifolia* for Cu, Cd, Cr, Ni, Fe, Pb and Zn removal, while mixing of the plant species further enhanced the removal of Cu to $78.0 \pm 1.2\%$, Cd to $60.0 \pm 1.2\%$, Cr to $68.1 \pm 0.4\%$, Ni to $73.8 \pm 0.6\%$, Fe to $80.1 \pm 0.3\%$, Pb to $61.0 \pm 1.2\%$ and Zn to $61.0 \pm 1.2\%$ for wastewater samples from Raj Ghat. Negative correlation coefficients of Cu, Cd, Cr, Ni, Fe, Pb and Zn concentrations in wastewater with the retention time revealed that there was an increase in the heavy metal removal rate with retention time. *P. australis* showed higher accumulative capacities for Cu, Cd, Cr, Ni and Fe than *T. latifolia*. *P. australis* and *T. latifolia* grown in combination can be used for the removal of Cu, Cd, Cr, Ni, Fe, Pb and Zn from the urban sewage mixed with industrial effluents within 14 days.

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1. Introduction

The release of improperly treated urban sewage and industrial effluents containing heavy metals into rivers has become a serious environmental problem over the world. Consumption of contaminated river water having heavy metals poses a threat to human health. Removal of heavy metals through chemical precipitation, coagulation–flocculation, adsorption, ion exchange, membrane filtration and other advanced oxidation processes require high capital and operating and management costs (Kumari and Tripathi, 2014b). Henceforth, it was imperative to suggest an economic as well as eco-friendly technology to remove these heavy metals and improve the wastewater quality.

Aquatic plants are natural absorbers of heavy metals and other nutrients (Mukhopadhyay and Maiti 2010). Removal of heavy metals and other pollutants from wastewater with the help of aquatic plants has been reported as a low cost and effective technology (Rai, 2008). Aquatic plants or constructed wetlands were used extensively in a past few decades for the removal heavy metals and nutrients from wastewater (Allende et al., 2011; Caselles-Osorio and Garcia, 2007; Cui et al., 2011; Hua et al., 2013;

Kumari and Tripathi, 2014a,b). Of these aquatic plants, the emergent plants are able to accumulate metals in their tissues several times than their surrounding environment, which might be due to the metal uptake by plant tissues is by adsorption to anionic sites in the cell walls (Sheoran and Sheoran, 2006). *Phragmites australis* and *Typha latifolia* are well known hyperaccumulator emergent plants. They are capable to accumulate metals copper, cadmium, chromium, nickel and lead up to 0.1% and iron and zinc up to 1% of the plant dry weight (Kalra, 1998; Sasmaz et al., 2008). In recent years, *P. australis* and *T. latifolia* were used for heavy metal removal (Abou-Elala and Hellal, 2012; Bianchi et al., 2011; Bragato et al., 2009; Calheiros et al., 2009; Jacob and Otte, 2004; Laing et al., 2009; Yeh et al., 2009). However, there was a paucity of data regarding the evaluation of role of *P. australis* and *T. latifolia* when grown in association in the removal of heavy metals.

1.1. Research AIM

The aim of the present study was to evaluate the heavy metals removal efficiency of *P. australis* and *T. latifolia* grown alone and in association, which were achieved through the specific objectives: To determine (1) the removal of heavy metals by *P. australis* and *T. latifolia*; (2) the heavy metal removal in mixed culture of the two plants; and (3) the relationship between retention time and removal of heavy metals.

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2. Material and methods

Untreated urban sewage mixed with industrial effluents were collected from the five sampling stations i.e. Assi Ghat (AG), Harishchandra Ghat (HG), Rajendra Prasad Ghat (RPG), Manikarnika Ghat (MG) and Raj Ghat (RG) along the 10 km stretch of the river Ganga at Varanasi (25°18' N, 83°1' E), India and brought to laboratory for experimental use. In order to minimize the error from each sampling station, 5 samples of wastewater have been collected separately and treated as 5 replicates. Batch experiments were configured during first week of August, September and October (2012) using the same wastewater samples collected in the same period.

Physicochemical properties of untreated wastewater from AG, HG, RPG, MG and RG have been shown in Table 1. Wastewater samples collected from RG was found most polluted with the highest concentration of pollution indicators (i.e. biochemical oxygen demand and chemical oxygen demand), nutrients (nitrate-nitrogen and phosphate-phosphorous) and heavy metals (copper, cadmium, chromium, nickel, iron, lead and zinc), which was followed by MG, RPG, HG and least for AG station (Table 1).

2.1. Experimental set up

Four biofiltration units, which consisted of a glass aquarium of 75 L (50 cm length, 50 cm width and 50 cm height) capacity fitted with 20 PVC pipes each of 30 cm length and 5 cm diameter having several pores of 27 mm diameter to enable liquid exchange, were configured (Fig. 1). During present experiment, *P. australis* and *T. latifolia* plants of 35.1 ± 2.1 cm length and 45.5 ± 0.5 g fresh weight were selected and placed individually in each PVC pipe. Experimental set 1 consisted of only *P. australis* kept at a density of 40 plants m⁻². Experimental set 2 consisted of only *T. latifolia* plants kept at a density of 40 plants m⁻². In 3rd set, each of *P. australis* and *T. latifolia* were kept at a density of 20 plants m⁻². Experimental set 4, called as reference set, was kept without any plant and was used to determine the removal of heavy metals through natural precipitation. In order to minimize the error five wastewater samples have been collected separately as replicate samples from each station i.e. AG, HG, RPG, MG and RG station and used for conducting the experiment.

2.2. Operating conditions

Plants were acclimatized for 7 days in double distilled water and washed thoroughly with distilled water before being placed

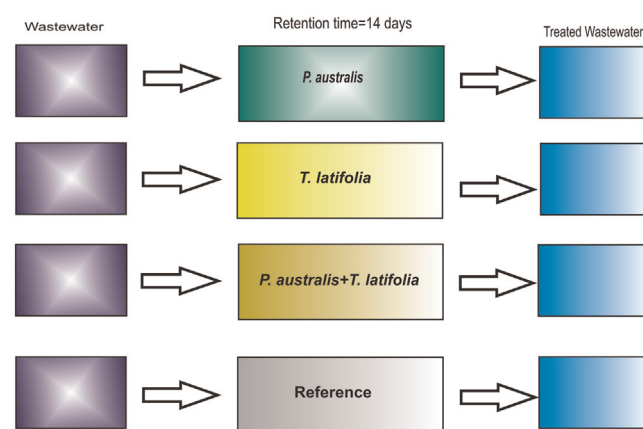


Fig. 1. Experimental layout showing *P. australis*, *T. latifolia* and their mixed culture and reference set.

individually in each PVC pipe. Fifty litres of wastewater collected from AG, HG, RPG, MG and RG stations was poured separately in each of the experimental sets and were exposed to 11 h natural sunlight. Evaporational loss was maintained by addition of an equal amount of double distilled water at regular intervals. Since very small quantity of double distilled water was added to make up the volume, it did not show any variation in the pH on scale.

2.3. Analytical procedures

From each of the four experimental sets of AG, HG, RPG, MG and RG stations, wastewater samples were collected separately on initial, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th and 14th day of treatment. The samples were analyzed for Temperature (T), pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate-N (NO₃⁻-N) and phosphate-P (PO₄³⁻-P) following procedures as prescribed in the Standard methods (APHA et al., 2005). For the analysis of copper (Cu), cadmium (Cd), chromium (Cr), nickel (Ni), iron (Fe), lead (Pb) and zinc (Zn), 100 mL of the sample was extracted using 20 mL of extraction mixture (2:1 nitric acid: perchloric acid) until a clear solution was obtained. The extracted solution was then, filtered and diluted to 25 mL with deionized water at 4 °C, after which the metals were analyzed using a flame atomic absorption spectrophotometer (FAAS Perkin Elmer model 2380, USA). The detection limits were 1.5 µg L⁻¹ for Cu, 0.8 µg L⁻¹, 3 µg L⁻¹ for Cr, 1.5 mg L⁻¹ for Ni, 5 µg L⁻¹ for Fe, 15 µg L⁻¹ for Pb and 1.5 µg L⁻¹ for Zn.

Table 1

Physicochemical properties of wastewater collected from Assi Ghat (AG), Harishchandra Ghat (HG), Rajendra Prasad Ghat (RPG), Manikarnika Ghat (MG) and Raj Ghat (RG).

Variable	AG	HG	RPG	MG	RG
Temperature (°C)	25.63 ± 0.26	25.53 ± 0.17	26.44 ± 0.24	25.36 ± 0.23	25.19 ± 0.02
pH	7.68 ± 0.01	7.67 ± 0.004	7.67 ± 0.02	7.67 ± 0.01	7.65 ± 0.01
Electrical conductivity (mS cm ⁻¹)	0.215 ± 0.001	0.216 ± 0.001	0.217 ± 0.001	0.217 ± 0.002	0.222 ± 0.002
Dissolved oxygen (mg L ⁻¹)	2.15 ± 0.04	1.48 ± 0.007	1.36 ± 0.01	1.25 ± 0.005	1.07 ± 0.008
Biochemical oxygen demand (mg L ⁻¹)	112.56 ± 0.75	122.43 ± 0.88	134.25 ± 0.71	146.48 ± 0.60	157.54 ± 0.58
Chemical oxygen demand (mg L ⁻¹)	225.54 ± 1.09	250.42 ± 1.14	273.02 ± 0.84	299.66 ± 0.90	233.55 ± 0.84
Nitrate nitrogen (mg L ⁻¹)	2.30 ± 0.01	2.38 ± 0.01	2.45 ± 0.14	2.47 ± 0.01	2.52 ± 0.02
Phosphate phosphorous (mg L ⁻¹)	5.76 ± 0.01	6.18 ± 0.01	6.54 ± 0.13	6.93 ± 0.01	7.65 ± 0.001
Copper (mg L ⁻¹)	0.088 ± 0.001	0.095 ± 0.002	0.097 ± 0.005	0.101 ± 0.003	0.110 ± 0.001
Cadmium (mg L ⁻¹)	0.057 ± 0.001	0.062 ± 0.001	0.072 ± 0.001	0.074 ± 0.001	0.079 ± 0.001
Chromium (mg L ⁻¹)	0.117 ± 0.002	0.130 ± 0.002	0.138 ± 0.005	0.141 ± 0.001	0.142 ± 0.001
Nickel (mg L ⁻¹)	0.065 ± 0.001	0.072 ± 0.001	0.080 ± 0.001	0.086 ± 0.001	0.088 ± 0.002
Iron (mg L ⁻¹)	0.132 ± 0.001	0.136 ± 0.002	0.140 ± 0.001	0.142 ± 0.002	0.145 ± 0.002
Lead (mg L ⁻¹)	0.053 ± 0.001	0.054 ± 0.001	0.056 ± 0.001	0.057 ± 0.001	0.060 ± 0.001
Zinc (mg L ⁻¹)	0.109 ± 0.001	0.108 ± 0.001	0.115 ± 0.001	0.115 ± 0.001	0.121 ± 0.002

Values are mean of five replicates ± standard error.

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