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# The use of constructed wetland for dye-rich textile wastewater treatment

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**Abstract**

The objective of the present paper was to examine the treatment efficiency of constructed wetlands (CW) for the dye-rich textile wastewater with special focus on colour reduction. Preliminary, a series of dynamic experiments was performed in the CW model packed with gravel, sand, and zeolitic tuff on three synthetically prepared wastewaters using chemically differ dyestuffs, auxiliaries and chemicals, in order to investigate the potential of low-cost materials as media for textile dye-bath wastewater treatment. The obtained results evidence that applied CW model reduces colour by up to 70%, and COD and TOC by up to 45%. Based on these results, the pilot CW with vertical (VF) and horizontal flow (HF) was constructed near textile factory mainly for cotton and cotton/PES processing with intention to treat real textile wastewater in situ. It was designed for 1 $m^3$/day, covering 80 $m^2$, packed with sand and gravel, and planted with *Phragmites australis*. The average treatment efficiency of the CW for the selected pollution parameters were: COD 84%, $BOD_5$ 66%, TOC 89%, $N_{total}$ 52%, $N_{organic}$ 87%, $NH_4$-N −331%, sulphate 88%, anion surfactant 80%, total suspended solids (TSS) 93%, and colour 90%, respectively. The results unequivocally proved that the CW could offer an optimal solution to meet the environmental legislation as well as requirements for effective and inexpensive textile wastewater treatment.


*Keywords:* Coloured textile wastewater; Constructed wetland; *Phragmites australis*

## 1. Introduction

Coloured textile effluents represent severe environmental problems as they contain mixture of chemicals, auxiliaries and dyestuffs of different classes and chemical constitutions with elevated organic parameters such as chemical oxygen demand (COD), total organic carbon (TOC), adsorbable organic halogens (AOX), inorganic parameters such as metals, chloride, sulphate, sulphide and nitrogen. A literature review regarding dye-bath wastewater treatments reveals the consideration of different approaches to handling such effluents, which include biodegradation, adsorption, advanced oxidation and membrane filtration [1–5]. Choosing the most appropriate treatment method or combination depends on the nature and the amount of effluent from textile processing plant.

In the past few years, we became aware that systems imitating the self-cleaning ability of natural wetland ecosystems by establishing optimal physical, chemical and biological conditions for in situ wastewater treatment should be considered with greater importance [6]. Constructed wetland (CW) is an example of such system that is also simple to use, environmentally friendly, with low construction and operational costs, and efficient enough to treat diverse wastewaters, although the experience in treating textile wastewaters is limited. CW's designs differ regarding to the type of flow and applied bed material [7,8]. The removal efficiencies of natural systems could be exceedingly variable, and influenced by numerous parameters such as water/bed material temperature, air temperature, sedimentation, pollutant concentration, and vegetation. These parameters cause changes in uptake or release of chemical substances, and biochemical activities of microorganisms and plants.

Methods of decolourisation of dyes, reported by a number of researchers [1–5], are often not feasible for treating dye-rich wastewater because of technology intensiveness, reliable power demand, and complexity of components, unproven long-term effectiveness and high investment and maintenance costs [9]. Promising results of CW recorded in last few years for industrial wastewater and lacking of literature on textile wastewater treatment with CW conducted us to research the viability of treating dye-rich wastewater with CW. The main objective

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of our experiment was to establish a model of CW and an integrated CW system, belonging to the generation of VHSSF (vertical–horizontal-sub-surface flow) and to evaluate its applicability in the treatment of coloured textile wastewater. The experiment was based on the selection of different bed material and mass loadings to reveal which option is more effective.

## 2. Materials and methods

### 2.1. Experimental equipment and design

A series of dynamic trials was accomplished in two stages, firstly on a CW model and secondly, on a pilot scale CW. The CW model was designed as a preliminary experiment for colour reduction of selected dyestuffs. In the model gravel and sand was used as a bed material with an addition of zeolitic tuff to reduce the risk of inefficiency. Promising results of colour removal in the CW model was encouraging to test pilot CW for real textile water, containing similar dyestuffs. The pilot CW was constructed using bed material comparable with the CW model without zeolitic tuff. The purpose was to proof the efficiency for colour removal with common material (gravel, sand) to keep low construction cost.

#### 2.1.1. CW model

It is a vertical-flow VFCW model, schematically presented in Fig. 1, made from polyethylene plates and Plexiglas, with dimensions of 0.8 m in length, 0.3 m in width, and 0.6 m in height that provides an empty volume of 144 l. The model was coated by PE-foil and filled with three different natural materials in layers from the bottom to up: washed gravel with particle size of 8 mm/12 mm, washed sand with particle size of 0 mm/4 mm, and washed zeolitic tuff with particle size of 9 mm/12 mm and chemical composition of 62.95% $SiO_2$, 15.92% $Al_2O_3$, 3.10% $Fe_2O_3$, 3.81% CaO, 1.31% MgO, 4.67% $Na_2O$, 4.67% $K_2O$ and 0.03% $SO_3$, up to 29 cm. A constant 0.2–0.24 l/min vertical wastewater flow from the vessel downwards through the porous medium packed in CW model (across the entire width) was achieved by a perforated plastic pipe, located at the top of the model. The actual retention time was 1, 2, 3, 4, 5 and 24 h. The outflow of treated effluent was located at the bottom of the model.

#### 2.1.2. Pilot scale CW

It was constructed as a VHSSF system (Fig. 2), consisting of three interconnected beds. The principal design criteria was based on a project started in 1991 in Austria [10], modified in 1997 [11] and upgraded according to the results obtained by means of laboratory scale CW experiments (optimization of retention time, flow and bed media with regard to the decolourisation efficiency of structurally different dyestuffs). The CW covered an area of 80 $m^2$ in total, which was planted with common reed (*Phragmites australis*) with 5 clumps/$m^2$, transferred from an old not-operating CW for sewage treatment. Two vertical flow (VF) beds covered 20 $m^2$ (5 m long × 4 m wide) each, with a depth of 0.6 m. The horizontal flow (HF) bed covered 40 $m^2$ (8 m × 5 m) with an average depth of 0.5 m. Bed material is composed as follows:

| | |
|---|---|
| VF beds: | Coarse sand with particle size of 4 mm/8 mm fine sand with particle size of 0 mm/4 mm ratio; 1:1 |
| HF bed: | Coarse sand with particle size of 8 mm/16 mm fine sand with particle size of 0 mm/4 mm ratio; 1:1 |
| | 0.5 m wide inlet/outlet section with gravel with size of 16 mm/32 mm |

The bottoms of both beds were fortified with a 1 mm thick LDPE foil. The real textile wastewater was transported with a 5 $m^3$ washed road tanker from the near textile factory and pumped into the retention reservoir at the pilot CW. The purified water was collected in a collective sump with outflow back to the wastewater treatment plant (WWTP).

#### 2.1.3. Mode of operation

The surface hydraulic load of VF beds was intermittent, adjusted by the aperture of the valve. The VF bed was loaded

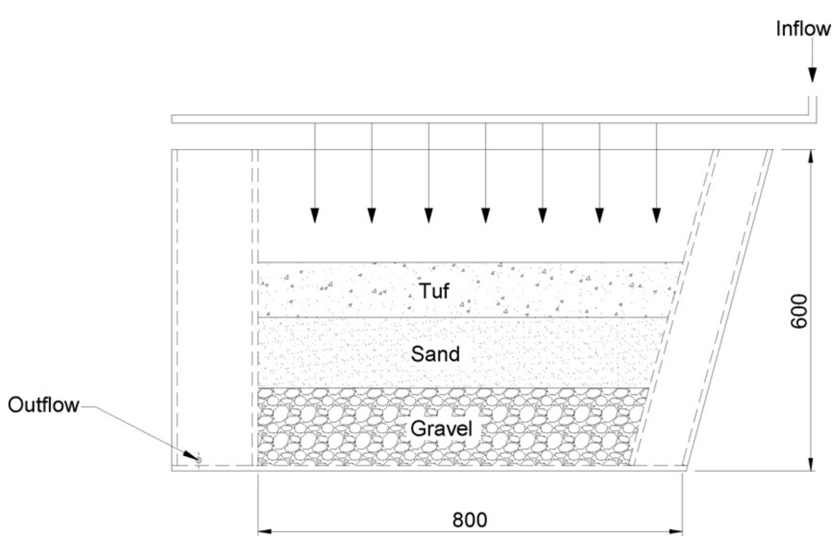

Fig. 1. Scheme of the CW model.