Science of the Total Environment 648 (2019) 144–152

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Lessons learnt from a pilot study on residual dye removal by an aerated treatment wetland

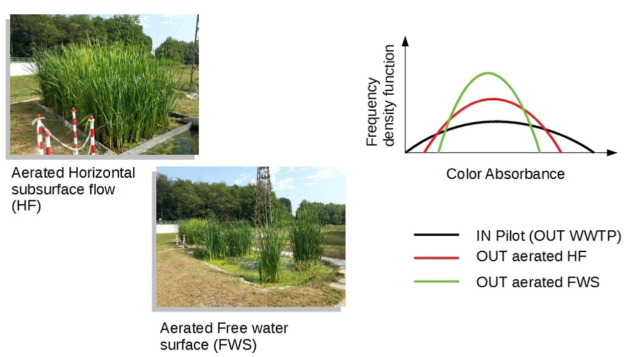
F. Masi [a,*], A. Rizzo [a], R. Bresciani [a], N. Martinuzzi [a], S.D. Wallace [b], D. Van Oirschot [c], F. Macor [d], T. Rossini [e], R. Fornaroli [e], V. Mezzanotte [e]

[a] *Iridra Srl, Via La Marmora 51, 50121 Florence, Italy*
[b] *Naturally Wallace Consulting, USA*
[c] *Rietland AGRO, Belgium*
[d] *Alto Lura Srl, Italy*
[e] *Università degli Studi di Milano-Bicocca, Department of Earth and Environmental Science, Italy*

HIGHLIGHTS

- A pilot aerated constructed wetland (CW) was tested for tertiary dye removal.
- Pilot plant had a horizontal subsurface plus free water surface aerated stages.
- Different hydraulic retention times and aeration schemes were tested.
- Aerated CW effectively removed conventional pollutant parameters.
- Only a buffer effect was observed for the removal of peak dye concentrations.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 5 March 2018
Received in revised form 6 August 2018
Accepted 8 August 2018
Available online 10 August 2018

Keywords:
Constructed wetland
Treatment wetland
Aerated wetland
Dye removal
Textile wastewater
Residual dye

ABSTRACT

Treatment wetlands (TWs) have shown good capacity in dye removal from textile wastewater. However, the high hydraulic retention times (HRTs) required by these solutions and the connected high area requirements, remain a big drawback towards the application of TWs for dye treatment at full scale. Aerated TWs are interesting intensified solutions that attempt to reduce the TW required area. Therefore, an aerated CW pilot plant, composed of a 20 m^2 horizontal subsurface flow TW (HF) and a 21 m^2 Free Water System (FWS), equipped with aeration pipelines, was built and monitored to investigate the potential reduction of required area for dye removal from the effluent wastewater of a centralized wastewater treatment plant (WWTP). During a 8 months long study, experimenting with different hydraulic retention times (HRTs – 1.2, 2.6 and 3.5 days) and aeration modes (intermittent and continuous), the pilot plant has shown a normal biological degradation for organic matter and nutrients, while the residual dye removal has been very low, as demonstrated by the absorbance measure at three wavelengths: at 426 nm (blue) the removal varies from −55% at influent absorbance of 0.010 to 41% at 0.060; at 558 nm (yellow) the removal is negative at 0.005 (−58%) and high at higher influent concentrations (72% at 0.035 of absorbance for the inlet); at 660 nm (red) −82% of removal efficiency was obtained at influent absorbance of 0.002 and 74% at 0.010. These results are a consequence of the biological oxidation processes taking place in the WWTP, so that the residual dye seems to be resistant to further aerobic degradation. Therefore, TWs enhanced by aeration can provide only a buffer effect on peak dye concentrations.

* Corresponding author.
E-mail address: fmasi@iridra.com (F. Masi).

https://doi.org/10.1016/j.scitotenv.2018.08.113

1. Introduction

The textile industries are often concentrated in specific areas located nearby water courses, because most of the production cycles are highly water demanding. Therefore the same water courses are often suffering from a high extraction rate and the consequential release of the hopefully treated effluents, still containing small amounts of persistent organic compounds. The dyeing industry is of particular concern for its environmental impacts, due to the high content in its effluents of coloured compounds that have been showed to resist any kind of degradation, such as exposure to tensides, sunlight or oxidizing agents (Demir, 2010; Vikrant et al., 2018). Even after complex biological and physical chemical treatment the residual dyes (often <1 mg L^{-1}), or their transformation products if they are still containing chromophore groups, can reduce light penetration in the receiving water bodies and therefore disturb the natural biological processes (Ikehata, 2015). Moreover, approximately 60–80% of the worldwide produced reactive dyes is based on azo-compounds (Bafana et al., 2011; Su et al., 2011). These compounds can produce toxic metabolites as aromatic amines, mutagenic or carcinogenic, and the aromatic structure of their chromophores is providing a low biodegradability for these molecules (Przystaś et al., 2012). Anyhow, it is mandatory for industries in several countries to discolour their effluents before discharging into water bodies (O'Neill et al., 1999; Croce et al., 2017). This process is presenting several difficulties for the management of wastewater treatment plants (WWTPs), due to the above mentioned environmental persistence of synthetic dyes: for instance, the Reactive Blue 19 half-life is approximately 46 years at 25 °C and pH 7 (Firmino et al., 2010).

The treatment of effluents containing dyes can be performed by biological (Demir, 2010) or traditional physico-chemical methods, as coagulation and flocculation or adsorption. Biological removal of dyes is generally based on a combination of biosorption (Guerrero-Coronilla et al., 2015) and biodegradation (Song et al., 2017) and can depend on various kinds of bacteria and fungi (Almeida and Corso, 2018). However, biological activity produces metabolites which might be toxic themselves and thus need to be monitored (Sen et al., 2016). The results obtained by in-series biological and physico-chemical processes are not completely satisfying, often leaving a residual colour in the final outlet or being too expensive (Hayat et al., 2015; Holkar et al., 2016). Consequently, more aggressive methods have been experimented, like some advanced oxidation or chemical oxidation (i.e. O_3, H_2O_2, Fenton) processes (Chanderia et al., 2017; Ertugay and Acar, 2017). These processes, if used in combination with biological treatment, especially when adopted as last stage, can produce even worst compounds in terms of environmental toxicity, in comparison to the original dyes (Punzi et al., 2015) and are still very expensive (Holkar et al., 2016).

Treatment wetlands (TWs) have shown good capacity in dye removal from textile wastewater (e.g., Davies and Cottingham, 1994; Bulc and Ojstršek, 2008; Ong et al., 2010; Khandare and Govindwar, 2015; Hussein and Scholz, 2017) and the application of this technique could efficiently reduce the treatment costs. However, the high hydraulic retention times (HRTs) required by these solutions remain a big drawback towards the application of TWs for dye treatment at full scale. Aerated TWs are an interesting intensified solution to attempt to reduce the required area, also for the particular target of residual dyes removal (Wu et al., 2014; Nivala et al., 2013). Few experiences are available in literature on the use of aerated TW system for dye removal (Ong et al., 2009, 2010; Khandare et al., 2014; Khandare and Govindwar, 2015) and all studies were performed on high inlet dye concentrations. No information is available on the use of aerated TW as tertiary stage for dye removal, i.e. receiving low dye influent concentrations. Therefore, an aerated TW pilot plant was built and monitored to investigate the potential for required area reduction for dye removal from the effluent wastewater of a centralized wastewater treatment plant (WWTP). The experimental campaign compared different operational conditions with the same aerated pilot TW and the same influent: three hydraulic retention times were tested as well as the presence/absence of aeration and different aeration modes (continuous vs. discontinuous). Furthermore, the duration of the experimental trial allowed evaluating the effect of temperature on the performance of the process. The obtained results are presented and discussed in this article.

2. Material and methods

2.1. Pilot system

The pilot plant was built to treat the effluent from the centralized WWTP of Bulgarograsso (CO - Italy). Currently, the WWTP uses a tertiary oxidation stage (ozonation) to reduce the dye content in the effluent, caused by textile industrial wastewater, discharged into the sewer network. The effluent is discharged into an effluent-dominated stream, Lura, where no dilution takes place. Therefore the quality requirements for the effluents are particularly stringent. Since the tertiary oxidation is quite expensive (Mezzanotte et al., 2013), the water utility (Alto Lura Srl) was interested in testing an alternative low-cost solution for decolourization of WWTP effluent. Therefore, the pilot plant was designed to test the possibility of implementing a full-scale tertiary treatment with TWs. Due to low land availability, when considering up-scaled implementation, an intensified approach was tested, using aerated TWs.

The pilot plant treated the effluent from the WWTP before ozonation and was designed to treat up to 9 m^3/d. The system was composed of two stages: 1st stage, aerated horizontal subsurface flow TW (HF); 2nd stage, aerated free water system TW (FWS). Both the stages were aerated with a blower (0.75 kW) injecting air at the bottom of the two beds through small pipes. The TW beds were both waterproofed with Ethylene-Propylene Diene Monomer (EPDM) liner. The plan layout of the pilot plant is shown in Fig. 1.

The HF 1st stage had a surface area of 20 m^2 (length 6.5 m and width 3 m). The HF TW bed was filled with layers of different gravel sizes, from bottom to top consisting of a layer of 10 cm of finer gravel (average diameter 4–8 mm) above the aeration pipes and 40 cm of coarser gravel (average diameter 20 mm). The bottom had a slope of 1%. A constant water table depth was maintained at 0.5 m. The effluent from the WWTP (before ozonation) was diverted to a small pumping station, from which the wastewater was pumped to feed the 1st stage HF bed. The HF feeding system was composed of an inlet manhole and T pipes placed along the whole width of the bed. Treated wastewater at the end of HF fed the FWS 2nd stage through an overflow weir, which was equipped with a small channel for wastewater sampling. Aeration pipes were placed along all the bottom surface of the HF area.

The FWS 2nd stage had a surface area of 21 m^2 (7 m length and 3 m width). The FWS was realized with a deep area (surface area 9 m^2, water depth 0.5–0.8 m) and two shallow areas in the proximity of the inlet and outlet constructions (water depth 0.1–0.3 m). The bottom of the bed had a slope of 1%. Deep and shallow areas were shaped with soil. A gravel layer (average diameter 4–8 mm) covered the aeration pipelines. The outlet area was filled with coarse gravel (average diameter 20 mm). The constant water level (0.5–0.8 m) was maintained with a regulation device placed in an external manhole and connected to the FWS drainage system. Aeration pipes were only placed at the bottom surface of the deep area.

The HF bed was planted with *Phragmites australis*. The FWS 2nd stage was planted as follows: shallow areas were planted with *Typha latifolia* while the deep area was planted with *Miriophyllum* sp. and *Potamogetum* sp. Therefore, the beds were planted with common TW and native species, with the aim to verify possible toxic effect of treated wastewater as well as favour a biologically active environment typical of TW nature-based systems.