Journal of Cleaner Production 33 (2012) 226–235

Contents lists available at SciVerse ScienceDirect

Journal of Cleaner Production

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

Coupling microfiltration and nanofiltration processes for the treatment at source of dyeing-containing effluent

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ARTICLE INFO

Article history:
Received 4 August 2011
Received in revised form
21 March 2012
Accepted 23 March 2012
Available online 14 April 2012

Keywords:
Reactive dye
Separate effluents
Treatment
Microfiltration
Nanofiltration

ABSTRACT

Dye baths of low volume compared to the volume of water used in other processing operations generate significant pollution and contaminate other wastewaters that are generally less loaded with pollutants. The aim of the present work is to treat different combination of selected dyeing cycle baths of using the combination of Microfiltration (MF) with Nanofiltration (NF) in order to reuse the treated water in the dyeing process. The characterization of the effluents coming from the different dyeing steps shows that the cotton preparation and dyeing baths are the most polluted due to the presence of dye and to high salinity content. The performances of the combination MF/NF to treat two types of effluents (Effluent 1 which is a mixture of the more polluted baths and effluent 2 which is a mixture of all baths used during the dyeing cycle) were studied. The pretreatment by MF leads to a 50% of pollutant retention except for salts which do not exceed 13%. The addition of NF leads to a high quality of treated effluent with retention of salt, color, suspended matter and COD respectively of 47–52%, 100%, 99.9% and 73–85% depending of the effluent load. The use of MF as a pretreatment prior to NF improves the treatment effectiveness by increasing the operating time and the permeate flux. NF permeate quality was satisfactory enough to be reused in reactive dyeing baths.

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1. Introduction

Increasing water demand for both industrial and public uses as well as more restrictive laws referred to water consumption and its final disposal into the main sewage network makes industrial wastewater reuse necessary, especially in those industries characterized by both high water consumptions and extremely polluted effluents. This is the particular case of textile industries, which are characterized by their high water consumption and pollution (Tang and Chen, 2002; Marcucci et al., 2002).

Textile processing industry which comprises different operations such as pretreatment, dyeing, printing and finishing, is one of the major environmental polluters. In order to process a ton of textile, one might have to use as much as 230–270 tons of water. The effluent generated by this much water would pollute the environment as it may contain a heavy load of chemicals used during textile processing. There are two main ways to limit the environmental impact of textile processing.

One is to construct sufficiently large and highly effective effluent treatment plants, and the other way is to make use of dyes and chemicals that are environment friendly (Mohammad et al., 2011).

The dyeing process is the largest part of this industry in terms of huge quantities of additives and technical complexity. The dyeing process also generates the most pollutants, accounting for more than 80% of the textile sector's total wastewater (Ibrahim et al., 2008). Dye baths, of low volume compared with other baths coming from different washing operations, generate considerable pollution and contaminate other wastewaters that are generally less loaded with pollutants. Among textile dyes, reactive dyes are more utilized owing to their technical characteristics (Allégre et al., 2006). Unfortunately, this class of dye is also the most unfavorable one from the ecological point of view, as the effluents produced are relatively heavily colored and contain high concentration of salt. Dyeing 1 kg of cotton with reactive dyes requires an average of 70–150 L water, 0.6 kg NaCl and 40 g reactive dye (Allégre et al., 2006).

Increase of water and wastewater disposal costs as well as more stringent legislations enforces the industries to find out appropriate solutions to effectively treat their effluents and eventually reuse them at the beginning of the production process. Although physico-chemical and biological treatments are typically used in textile

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doi:10.1016/j.jclepro.2012.03.025

wastewater treatment, this kind of treatment does not allow water reuse in any step of the productive process (Xujie et al., 2009). Few years ago, membrane processes gained popularity and became a promising technology to treat and reuse wastewater. Therefore, membrane technology has emerged as a feasible alternative to conventional treatment processes since it saves of operation costs and water consumption by water recycling (Tak-Hyun et al., 2005).

Membrane processes that can meet the legislative requirements are Nanofiltration (NF) and Reverse Osmosis (RO) since they are able to retain not only relatively small organic molecules but also ions from a dye wastewater. Tak-Hyun et al. (2005) studied the combined process of NF and RO membranes not only to improve the rejection efficiencies and flux recovery, but also to recycle the permeate back into the dying process. Van der Bruggen et al. (2001, 2005) studied the performances of NF treatment of textile wastewater, they concluded that the ideal membrane process for the treatment of dye wastewater was a compromise between dye retention and salt retention. Yazhen et al. (1999) had confirmed the potential of NF for the treatment of pure dye solutions as well as industrial dye solution.

However, pretreatment processes allow controlling the flux drop and hence maintain an efficient membrane separation process. The most commonly adopted pretreatment processes for textile effluents are Microfiltration (MF), Ultrafiltration (UF), Coagulation–Flocculation (CF), Sludge Process (ASP), Sand filtration (SF) and Ozonation (Bes-Pià et al., 2003; Bottino et al., 2000). These processes may be implemented individually or in combination according to the characteristics of wastewaters. Bes-Pià et al. (2009) have proposed a combination of biological treatment with UF or NF on textile wastewater treatment. Similar permeate fluxes were observed using different NF membranes (between 25 and 30 L/h m^2 at 23 °C) while salt rejection was between 20 and 70% depending on membrane nature.

Xujie et al. (2009) studied the efficiency of biological treatment and membrane filtration combination to treat printing and dyeing wastewater. The obtained permeate have an excellent quality with an important retention of COD, color and turbidity which exceed 91%. The extremely low color, low turbidity, low concentration of Fe and Mn found in their permeate was a remarkable result since it is known in the textile dying industry that such water quality is the best one to obtain an improved finish and a better quality dyeing.

Capar et al. (2006) noted that although MF, UF, Chemical Coagulation (CF), Sand filtration, and Ozonation are the most commonly adopted pretreatment processes for textile effluents, MF has been gaining a wider acceptance as it is found to be the most economic of all the pretreatment. Malack and Anderson (1997) pointed out that MF is suitable for treating dye bath containing pigment dye and it can be used as pretreatment of NF and RO.

The main objective of this study is to investigate the common effects of dye, salts and auxiliary chemicals on the separation process using a combination of MF and NF in the treatment at source of real dyeing effluent. This approach can reduce the overall flux and complexity of the effluent (Koyuncu and Topacik, 2003), thus achieving better treatment. Without any dilution, the dye concentration at the dyeing bath is higher than that at the end-pipe. Moreover, the removal of highly concentrated dye is vital for minimizing pollution (Schrader et al., 2005).

2. Materials and methods

2.1. Wastewater quality: different steps of dyeing cycle

The effluent of the current study was supplied from the discharge dyeing effluent of a textile factory specialized in the dyeing of cotton fabric and located in Ksar Hellal, Tunisia. Different dyes (reactive and direct), chemical substances such as detergents, salts, auxiliaries (e.g. surfactants, emulsifiers) and caustic soda are used in the factory dying process. Dyeing effluent is the result of several treatments steps such as, dyeing, rinsing, neutralizing, saponification and softening. A huge amount of additives and salt is usually used to fix dye. However, more than 40% of the dye is generally found in the effluents (Allégre et al., 2006). At the beginning, the cotton fabrics are prepared by non-ionic detergent. The dyeing process (Fig. 1) started by supplying the dye bath with dye, salt and additives at three stages for a period of 15–60 min. This process lasted for 105 min, followed by rinsing the cotton fabric in cold water for 15 min. Later on the saponification process follows by adding sandopan at 70 °C for 10 min. The cotton is then washed twice, for 5 min. Finally fabric is treated by the softener at 50 °C for 10 min before the drying step. Table 1 presents the different drying steps the cotton fabric undergoes.

This process lasted for 105 min, followed by rinsing of the cotton fabric in cold for 15 min. Later the saponification processes by adding sandopan at 70 °C for 10 min and the cotton are taken to be washed twice, for 5 min. Finally fabrics are treated by the softener at 50 °C for 10 min before they are fed to the centrifuge to be dried. The composition of different steps of dyeing cycle is presented in Table 1.

2.2. Membrane filtration unit

Two membrane filtration units were coupled (Fig. 2). The first one, MF bench used for pretreatment and the second one was NF bench used for final treatment. The membrane's characteristics used in this study are given in Table 2. At first experiments were carried out under total recirculation mode in order to optimize the operating parameters. Both, retentate and permeate solutions were recycled into the feed tank to keep the feed concentration approximately constant. During each experiment, the following parameters were determined: temperature (T) and transmembrane pressure (TMP) defined as: $TMP = (P_i + P_e)/2 - P_p$ where, P_i and P_e represent respectively the inlet and the outlet pressures, whereas P_p is the permeate pressure (usually $P_p = P_{atm}$, atmosphere pressure). For the increasing feed concentration, the Volume Reduction Factor ($VRF = V_i/V_r$ where V_i and V_r are respectively the initial and the retentate volumes) is then determined. After each run, the membrane was cleaned according to the manufacturer recommendations. The membrane permeability was checked using pure distilled water at room temperature. The permeability values of the NF and MF membranes were: Lp = 4 L/h m^2 bar and Lp = 1500 L/h m^2 bar, respectively.

During each experiment, permeate volumes were collected and analyzed. The retention of different parameters (R) was then determined as follows: $R\ (\%) = 100 \times (1 - C_p/C_f)$, where C_p and C_f are respectively the solute concentration in the permeate and in the feed solution, respectively.

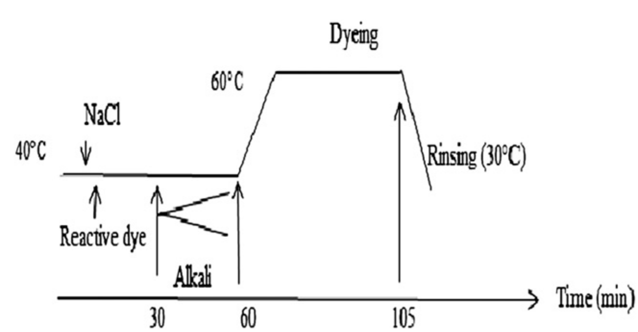

Fig. 1. Dyeing cycle using in this study.

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