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Research article

Analysis of the best available techniques for wastewaters from a denim manufacturing textile mill

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ABSTRACT

The present study was undertaken as the first plant scale application and evaluation of Best Available Techniques (BAT) within the context of the Integrated Pollution Prevention and Control/Industrial Emissions Directive to a textile mill in Turkey. A “best practice example” was developed for the textile sector; and within this context, BAT requirements for one of the World's leading denim manufacturing textile mills were determined. In order to achieve a sustainable wastewater management; firstly, a detailed wastewater characterization study was conducted and the possible candidate wastewaters to be reused within the mill were identified. A wastewater management strategy was adopted to investigate the possible reuse opportunities for the dyeing and finishing process wastewaters along with the composite mill effluent. In line with this strategy, production processes were analysed in depth in accordance with the BAT Reference Document not only to treat the generated wastewaters for their possible reuse, but also to reduce the amount of water consumed and wastewater generated. As a result, several applicable BAT options and strategies were determined such as reuse of dyeing wastewaters after treatment, recovery of caustic from alkaline finishing wastewaters, reuse of biologically treated composite mill effluent after membrane processes, minimization of wash water consumption in the water softening plant, reuse of concentrate stream from reverse osmosis plant, reducing water consumption by adoption of counter-current washing in the dyeing and finishing processes. The adoption of the selected in-process BAT options for the minimization of water use provided a 30% reduction in the total specific water consumption of the mill. The treatability studies adopted for both segregated and composite wastewaters indicated that nanofiltration is satisfactory in meeting the reuse criteria for all the wastewater streams considered.

1. Introduction

The textile industry is a water intensive sector with a great variety of process steps requiring use of large amounts of water and chemicals (GilPavas et al., 2017; Yurtsever et al., 2016b). This fact put efforts on the minimization of use of, and where applicable reuse of, raw materials and water within the production steps. Being a water intensive sector (typically 200–400 L per kg of fabric) (Dasgupta et al., 2015); in textile industry, wastewater discharges are of primary concern rather than gaseous emissions and solid wastes. Given the great variety of fibres, chemicals and other auxiliaries in use, textile manufacturing processes generate wastewaters which contain residuals of a wide variety of chemicals and auxiliaries of different nature and therefore are not adequately treated in conventional wastewater treatment plants (Dasgupta et al., 2015). The presence of dyes, metals, phenols, toxic compounds and/or phosphates of which are mostly resistant to conventional biological treatment, can pass untreated through the conventional wastewater treatment systems, and end up in the receiving streams where they may cause adverse effects. It is therefore important to minimize the use of these chemicals which result in difficult-to-treat wastewaters via chemical substitution and also excess use of water in textile plants (EU, 2003). The

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stringent environmental regulations for discharge today are forcing the dyers and finishers in the textile industry to examine the potential for recycling the water from the waste stream by new technologies (Van der Bruggen et al., 2004).

Ozturk et al. (2015a,b) indicated the importance of the implementation of in-plant control techniques for textile industries for the purposes of achieving significant reductions in water use, raw material and energy consumption, wastewater production and in some cases even reductions in wastewater load. They conducted a comprehensive plant survey including wastewater generation and characterization together with the identification of recoverable streams and the assessment of unnecessary water consumption in a textile mill employing wool and acrylic fibre production and subsequent dyeing, and indicated that significant levels of reductions in consumptions and discharges/emissions could be achieved by the application of suggested best available techniques (BAT) options. Van Veldhuisen (1991) grouped in-plant control applications under four headings: (i) water minimization (water conservation); (ii) wastewater recovery and reuse; (iii) chemical substitution, and (iv) recovery of valuable substances (material reclamation). Significant reductions in water use can be achieved by preventing the unnecessary water consumption practices in textile mills. On the other hand, one of the major in-plant control techniques is the recovery of wastewaters for reuse, directly or after being treated which might result in a stronger wastewater as dictated by the water conservation hierarchy improving environmental and economic performance of industrial facilities (Orhon et al., 2000, 2001).

The European Integrated Pollution Prevention and Control (IPPC) Bureau produces sectoral BAT reference documents, so-called BREFs to describe applied techniques, present emissions and consumption levels, techniques considered for the determination of BAT, giving special consideration to the criteria listed in Annex III of the Industrial Emission Directive (IED) (2010/75/EU) that repealed and replaced Directive 2008/1/EC on IPPC. The BREFs are the main reference documents used by the European Union (EU) Member States when issuing operating permits/licences for the activities specified in the IED. The BREFs are considered as the tools that will provide better consistency of implementation across the EU Member States. It is also likely that requirements for setting emission limits will be more consistently applied across Europe with the availability of up to date BREF documents. Thus, in assessing BATs for wastewater emissions from any IED activity, BREFs can be taken as the major reference along with other references available in the literature.

Ibáñez-Forés et al. (2013) proposed a methodology for identifying sustainable and most appropriate BAT for industrial facilities. The methodology adopted involves the use of life cycle assessment (LCA) approach to guide the selection of candidate BAT options for the control of hot spots identified in industry, and an environmental, economic, technical and social assessment. The application of the proposed approach was illustrated by a case study on ceramic tiles production. Chung et al. (2013) suggested a similar methodology addressing the environmental and economic concerns and competitiveness that are associated with the BAT for wastewater facilities in the leather tanning and finishing industry. The techniques that are applied in the leather tanning and finishing industry were compared with regard to regulatory compliance, economic feasibility, and environmental and technical aspects. Bréchet and Tulkens (2009) applied a multi-dimensional methodology to identify best combinations of these available techniques at the plant level, applied it to a plant in the lime industry; and concluded that there is in general not a single BAT, but well a best combination of BAT to be used. The tool developed consists of a decision tool based on linear programming modelling of the operations applied during production and on internalization of the external costs generated by these operations.

In a recent article, Ozturk et al. (2015b) employed multi-criteria decision-making methods to determine the most suitable BAT for a textile mill. A total of 14 BAT including good management practices, water minimization and chemical minimization/substitution were considered and a feasibility study was carried out to determine potential benefits and savings for each candidate BAT. The potential savings achievable after the implementation of BAT were indicated as 43.51% in water consumption, 16.39% in chemical consumption, and 45.52% in combined wastewater flowrate. In another recent study (Ozturk et al., 2016), it was indicated that in textile wastewater management, various wastewater streams can be segregated and directly reused without treatment in the production processes. After segregation of relatively clean wastewater streams, the remaining combined wastewater could be reused after employing advanced treatment technologies.

Due to highly polluted nature of textile wastewaters, water reuse may only be possible after proper treatment, which depends on the concentrations of pollutants and the reuse criteria. The possible treatment options include both physiochemical (coagulation-flocculation (Verma et al., 2012), adsorption (Jorfi et al., 2017), membrane filtration (Dasgupta et al., 2015), advanced oxidation (Soares et al., 2017), etc.) and biological (activated sludge (Kumar et al., 2014), anaerobic treatment (Yurtsever et al., 2016c), membrane bioreactor (Jegatheesan et al., 2016), etc.) processes. Verma et al. (2012) reported that more effective color removal is possible with novel pre-hyrolysed coagulants such as Polyaluminium chloride (PACl), Polyaluminium ferric chloride (PAFCl), Polyferrous sulfate (PFS) and Polyferric chloride (PFCl). The color removal efficiency of the process (58–100%) highly depends on the nature of wastewater, used coagulants and the aids, dosage, and pH. Although activated sludge treatment performance may be satisfactory to discharge the wastewater to sewerage, it may require additional physicochemical treatment to meet reuse criteria (Sahinkaya et al., 2008). In order to improve the biological process performance, membrane bioreactors (MBRs) are considered as a possible alternative. Yurtsever et al. (2016a, 2016c, 2015) reported that anaerobic MBR can also be effectively used in decolorization of textile wastewater and the process has high tolerance to increased salinity and sulfate concentration. In another study, Malpei et al. (2003) evaluated the feasibility of upgrading a full scale activated sludge process by a MBR and compared the performance of the processes. In the activated sludge process, although high COD removal efficiency (~90%) was observed, the effluent COD and TSS showed high fluctuations, i.e. 90–490 mg/L and 40–60 mg/L, respectively. In the MBR, the fluctuation was only 2.3% with the average effluent COD concentration of 137 $\pm$ 39 mg/L with free of TSS. Similarly, color removal efficiency of MBR was 96.5%. Hence, water may be reused after MBR treatment if high conductivity of the treated water is not a concern. Generally, reuse criteria may not be met after biological and/or chemical treatment due to remaining COD, color and especially dissolved inorganics (high conductivity) in the treated effluent. Hence, nanofiltration (Dasgupta et al., 2015) or reverse osmosis processes (Zheng et al., 2015) may be required for the remaining pollutant and conductivity removal.

This study aims to evaluate BAT for the treatment of the wastewater from a denim manufacturing mill in Turkey, within the framework of the EU's IED/IPPC philosophy. The plant produces denim textile starting from raw cotton. Textile production starts with fibre manufacturing, continues with sizing, dyeing, weaving and ends up with finishing. Among these; sizing, dyeing and finishing are the wet processes. The dyeing process of the factory is composed of pre-treatment, dyeing, rinsing and softening operations; and uses indigo, indanthrene and sulphur dyes either