GREEN PROCESSES IN THE TEXTILE DYEING AND FINISHING

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Abstract: Large amount of water is utilized in the textile dyeing and finishing processes and as a result of that, the treatment of this large amount of effluent creates cost and very important environmental problems. Therefore, the "Green Production" concept is the first key issue as far as the textile wet processes are concerned. In the last two decades, new technologies have been utilized in order to minimize the processing time, energy consumption, water consumption and the amount of effluent. "Green production" is a preventive business strategy in textile dyeing and finishing industry and may include the following emerging technologies:

- use of ultrasonic energy in textile dyeing and finishing,
- use of microwave energy in textile dyeing, drying, and dye fixing,
- use of plasma technology in textile dyeing and finishing,
- use of supercritical fluids in textile dyeing and cleaning,
- use of ozone in bleaching of textiles and also in the treatment of dyeing effluents,
- use of combined enzymatic processes in the pre-treatment of textiles,
- use of the "Direct Dyebath Reuse" technology to minimize the amount of water to be used,
- reuse of recovered chemicals and dyes from processes and
- reuse of decolorized effluent in dyeing and finishing.

This current work will review the recent technology used in the textile wet processes with a particular emphasis on the work carried out in the Turkish textile industry.

Keywords: Green chemistry, Dyeing, Microwave, Ultrasound, Supercritical carbon dioxide

Introduction

Water has been an essential medium in many textile wet processes including pre-treatment, dyeing, finishing and printing. These processes use large amount of water and the effluents of these processes create very big environmental problems and cost in the textile industry as far as the treatment of the polluted water is concerned (Christie, 2007). The Water Stress Index is defined as the ratio of a country's total water withdrawal to its total renewable freshwater resources and it is a measure of the pressure exerted on water resources (Bixio, 2006). A recently published OECD (Organisation for Economic Co-operation and Development) document draws attention to the fresh water availability with a projection to the year 2050 (OECD, 2012). Therefore, in the last two decades, new strategies were put in use and the research has been done to minimize the amount of process water, the amount of chemicals used, the process time and the energy consumed for each process (EC, 2003). In order to that, the following strategies, under the name of "Green Production", are employed:

- use of ultrasonic energy in textile dyeing and finishing,
- use of microwave energy in textile dyeing, drying, and dye fixing,
- use of plasma technology in textile dyeing and finishing,
- use of supercritical fluids in textile dyeing and cleaning,
- use of ozone in bleaching of textiles and also in the treatment of dyeing effluents,
- use of combined enzymatic processes in the pre-treatment of textiles,
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- reuse of recovered chemicals and dyes from processes and
- reuse of decolorized effluent in dyeing and finishing.

"Green production" is a preventive business strategy in textile dyeing and finishing industry and nowadays, more research is carried out on these topics.

Use of Ultrasonic Energy in Textile Dyeing and Finishing

Ultrasonic waves lie between 20 kHz and 500 MHz frequencies. The chemical power of ultrasound comes from the *cavitation* phenomena and the cavitation occurs as the micro bubbles in water when a negative pressure applies to it. In the collusion of these bubbles, a large amount of energy exists. The use of ultrasonic energy decreases the process time and the required energy for the process. Ultrasonic energy is used in textile processes for pre-treatment (desizing, bleaching and scouring), dyeing and textile finishing processes (Öner, 2009; Yachmenev

(2007); Basto, 2007). In the textile sector, a pilot size dyeing machine which was equipped with ultrasonic transducers was constructed and used in dyeing of textile materials (Perincek, 2009); however, no commercial size dyeing machine is yet available.

Use of Microwave Energy in Textile Dyeing, Drying and Dye Fixing

In the electromagnetic spectrum, the microwaves (MW) are in the range between radio and infrared waves. The microwave region of the electromagnetic spectrum corresponds to wavelengths of 1 cm to 1m (30 GHz to 300 MHz) and only the frequencies 2.45 GHz (12.2 cm) and 900 MHz (33.3 cm) are available for dielectric heating. The microwave applicators used for chemical purposes generally operate at 2.45 GHz (12.2 cm) (Tierney, 2005). It has been reported that the dyeing processes have been enhanced by MW heating and the dyeing rates have been increased (Öner, 2013; Haggag, 1995; Berns, 1979; Kim, 2003; Haghi, 2004; Buyukakinci, 2005; Nourmohammadian, 2008; Yoshimura, 2009; Ohe, 2009; Montazer, 2007). Microwave energy improves the dyeability of flax fibre with reactive dyes (Sun, 2005). Microwave energy is also used for dye fixing and drying in textile processes. More research goes on the construction of commercial size microwave treatment machine to be used in textile processes.

Use of Plasma Technology in Textile Dyeing and Finishing

Plasma technology is one of the environmentally friendly techniques. The enormous advantage of plasma processes concerns the drastic reduction in pollutants and a corresponding cost reduction for effluent treatment (Morent, 2008). Atmospheric pressure plasmas (typically corona plasmas) are used for the ease of generation of gas-phase radicals which react with and modify the polymer surface (Shishoo, 2007). Particularly, the plasma treatment is useful for the polymers which cannot be dyed easily by the conventional methods, e.g. exhaustion or impregnation (Park, 2001; Shahidi, 2007).

Use of Supercritical Fluids in Textile Dyeing and Cleaning

Carbon dioxide has a low critical point (74 bar and 31°C) and it can be used in many applications in industry. As a super critical fluid, it is a very good solvent for hydrophobic materials. Carbon dioxide is a cheap, inert, non-combustible, non-toxic and easily available chemical. There are several reviews in the literature to summarize the use of super critical carbon dioxide in textile processes (Derbent, 2015; Banchero, 2013; Banchero, 2008; Liao, 2012;). Textile fibres containing polyester (Cardozo-Filho, 2015; Giorgi, 2000; Van Der Kraan, 2007; Zheng, 2015), acrylic (Jun, 2005; Zheng, 2017), polyamide (Elmaaty, 2015; Liao, 2000;), wool (Güzel, 2000), Nomex (Kim, 2006), ramie (Liu, 2000), cotton (Fernandez Cid, 2007; Schmidt, 2003) and the blend of polyester/cotton (Maeda, 2004) can be successfully dyed by the supercritical carbon dioxide. It can also be used in the textile cleaning and the finishing processes (Rombaldoni, 2009). A very recently, a Dutch company, DyeCoo has introduced a beam dyeing machine which uses the super critical carbon dioxide technology (DyeCoo, 2017).

Use of Combined Enzymatic Processes in the Pre-Treatment of Textiles

The possibilities of enzymatic processes have been discussed in detail in the literature (Cavaco-Paulo, 2003). It has been suggested that using various types of enzymes, namely amylase, protease, lipase, pectinase, laccase, glucose oxidase, catalase and cellulase, from the beginning to the end of the preparatory processes of textile substrates could be achieved (Quandt, 2000). The combined enzymatic processes of textile materials were also achieved by several researchers (Öner, 2011; Aly, 2010; Hebeish, 2009; Kokol, 2004; Tanapongpipat, 2008; Tzanov, 2001). The use of enzymes enhances the process efficiency, shortens the process time and requires the use of less energy, compared to the conventional methods which are carried out separately. In the Turkish textile companies, the enzymes, namely amylase, pectinase and catalase are widely used in the preparatory processes.

Reuse of Recovered Chemicals and Dyes from Processes

Dyes and various chemicals can be recovered from the effluents of the processes and these are very valuable. For example, there are several techniques which are used to separate the caustic soda from industrial wastewater, namely neutralization, filtration process, leaching, evaporation, and electrodialysis (ED). In one recent sturdy, caustic soda was recovered from industrial wastewater by two-stage diffusion dialysis (DD) and electrodialysis (ED) processes (Imran, 2017). Also, the recovering and reuse of sodium hydroxide by evaporation is very beneficial as reported in a recent work (Topgül, 2017). A 4-stage evaporator was used to recover NaOH from the mercerization effluent containing 11.8°Bé weak caustic. The total benefit of the system was almost 178 USD/h per 1 ton of fabric (Topgül, 2017). Textile dyes, particularly indigo dye from the denim plant' effluents are successfully recovered and reused for the next process (Wambuguh, 2008; Amaral, 2014).

Use of Ozone in Bleaching of Textiles and also in the Treatment of Dyeing Effluents
Ozone is a very powerful oxidant and the bleaching of cellulosic fabrics by a process containing ozone efficiently is possible (Prabaharan 2001; Arooj 2013). Ozone is also used to decolorize the dyeing effluents. Around 90% reduction of the incoming COD and BOD was reduced effectively (Carriere, 1993; Colindres, 2010; Constapel, 2009; Günes, 2012; Takahashi) .

Conclusion

Water is an essential chemical for the dyeing and finishing industry. However, the prevention at source can be achieved by the use of new technologies, the reuse and the recycling of water. The minimization of water usage in the textile wet processes can be accomplished by putting one or more technologies mentioned above. From the most desirable to less desirable, the hierarchy of pollution control measures are listed below (Christie, 2007):

- Prevention
- Reduction
- Reuse
- Recovery
- Recycling
- Energy recovery
- Disposal

No doubt that the super critical carbon dioxide as a solvent in textile dyeing and finishing will substitute water in near future, since there is no effluent discharged to the environment after the process and more research on this technology is going on. Also, the reuse of spent dyebath, particularly in disperse dyeing of polyester is widely practised in the industry. Prevention is always better than cure and the right strategy can save money, reduce pollution, reduce waste disposal and effluent discharge, and improve product quality.

Acknowledgements

The author gratefully acknowledges the grant FEN-D-110717-0438 by Marmara University Scientific Research Projects Coordination Unit (BAPKO).

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