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Sustainable textile production: a case study from a woven fabric manufacturing mill in Turkey

Emrah Alkaya [a], Göksel N. Demirer [b,*]

[a] Technology Development Foundation of Turkey, Cyberpark Cyberplaza B-Blok Kat: 5-6, 06800 Bilkent, Ankara, Turkey
[b] Department of Environmental Engineering, Middle East Technical University, Dumlupinar Bulvari, 06800 Ankara, Turkey

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ABSTRACT

The aim of this research was to investigate the applicability of different sustainable production measures and demonstrate environmental and economical benefits in a woven fabric manufacturing mill in Bursa, Turkey. As a result of an Environmental Performance Evaluation (EPE) evaluation, five sustainable production applications were proposed and implemented to decrease water consumption, wastewater generation, energy consumption, greenhouse gas emissions and salt (NaCl) consumption in the company. As a result, the total water consumption of the company was decreased 40.2% while wastewater generation was reduced by 43.4%. Total energy consumption and associated CO_2 emissions of the company were decreased 17.1 and 13.5%, respectively. While total salt (NaCl) consumption was decreased by 46.0%. The payback period was calculated as approximately 1.5 months. This study can be regarded as a successful example of adoption of "Communiqué of Integrated Pollution Prevention and Control in Textile Sector" with tangible economical and environmental achievements in the Turkish textile industry. The results of the study show that the wide-spread uptake of proposed sustainable production measures would generate a tremendous change in the Turkish textile industry without a need for heavy investments in technology. Moreover the economic returns would help Turkish textile industry to sustain its competitive position in the global textile market which faces a pressing challenge of low cost, high quality and environmentally benign production.

1. Introduction

Turkey is a leading country in textile/garment manufacturing and export with a share of 3.6% (8th rank in the world). Moreover, Turkey has the 3rd rank in the textile and garment export to European Union (EU) countries, 7th rank in cotton production, 4th rank in cotton consumption, 5th rank in fiber yarn production, and 4th rank in open-end yarn production in the world. Moreover Turkey has the 2nd rank in organic cotton production. According to the Ministry of Labor and Social Security records of 2010, 746,617 people are employed in 43,035 registered workplaces operating in textile, garment and leather industries in Turkey (MOIT, 2012).

In Turkey, textile industry has quite fragmented and complex production system among the processes such as the production of simple fiber, yarn, fabric production for apparel, industrial goods, and home furnishing. Through the various production processes, high amount and various kinds of chemicals, raw materials, energy, and water are used. Consequently, relatively high amount of waste emissions to different receiving environments take place leading to significant risks on the environment as well as human health. Among all industrial sectors, textile industry is rated as one of the most polluting, considering both the volume discharged and effluent composition of the wastewater (Gümüş and Akbal, 2010).

One of the main environmental concerns is about the amount of water discharged and the chemical load it carries (Ozturk et al., 2009). According to Turkish Statistical Institute, textile and garment industry is responsible for 15% of industrial water consumption (191.5 million m^3), which makes it 2nd largest industrial water consumer within the whole Turkish manufacturing sector (Turkish Statistical Institute - TSI, 2008). Water pollution due to textile industry has become a major problem in Turkey. As an example, textile industry in Ergene Basin resulted in drastic changes in water quality and increasing territorial reduction of groundwater level in aquifer fields. (Kaykıoğlu and Ekmekyapar, 2005). Another important environmental issue associated with the textile industry is high energy consumption and related CO_2 emissions. In Turkey, the textile industry has been reported as the

* Corresponding author. Tel.: +90 312 210 58 67; fax: +90 312 210 26 46.
E-mail addresses: ealkaya@ttgv.org.tr (E. Alkaya), goksel@metu.edu.tr (G.N. Demirer).

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3rd most energy intensive sector after iron/steel and cement industries (Ozturk, 2005).

As it is the case for most of the manufacturing plants, sustainable production approach can help reduce resource consumption, waste generation and associated costs in textile mills (Alkaya et al., 2011). The economic advantages gained by implementing sustainable production in textile industry are twofolds: it will reduce both the costs of production and the need for costly end-of-pipe pollution control facilities. At the same time, health and environmental impacts on plant workers and the surrounding community are reduced. As remarkable examples of achievements through sustainable production approaches, various studies indicated that it is possible to achieve water savings between 15 and 79% (European Commission, 2003; NCDENR, 2009; Shaikh, 2009). Moreover wastewater volume reductions up to 70% were reported as a result of sustainable production applications in textile factories (NCDENR, 2009).

It is underlined in various studies and national policy/strategy documents that sustainable production approaches should be adopted in Textile industry as being one of the important sectors in terms of both economic and environmental indicators (MOEF, 2010; MOIT, 2010; Ulutas et al., 2011). In December 2011, "Communiqué of Integrated Pollution Prevention and Control in Textile Sector" has been put into effect by Ministry of Environment and Urbanization as part of the EU Harmonization Acquisition Programme of Turkey (TTGV, 2012). The major purposes of the communiqué are setting the procedures and principles in relation to minimizing the negative environmental impacts of textile industry activities, achieving an environmentally friendly management through the control of all industrial emissions, efficiently use of raw materials and energy as well as sustainable production technologies.

The major objective of this study was to demonstrate that sustainable production measures can help Turkish textile producers to achieve solid benefits in terms of environmental and economic performance. The research was based on the environmental performance evaluation (EPE) followed by the sustainable production applications in a woven fabric manufacturing facility in Bursa, Turkey. The study was carried out as part of "National Eco-efficiency (Cleaner Production) Programme" coordinated by United Nations Industrial Development Organisation (UNIDO) as a subprogramme of a joint United Nations programme "MDG-F 1680: Enhancing the Capacity of Turkey to Adapt to Climate Change". Please note that further information about the project can be retrieved from its web page (http://www.ecoefficiency-tr.org/).

This paper is organized as follows: Section 2 presents a review of the literature and develops a theoretical background for sustainable production applications in textile industry. Section 3 was devoted to the research design and methodology which gives the general information about the company and presents the methods followed for stepwise evaluations/applications. Section 4 provides results of the evaluations/applications and discusses the results by referring to the relevant literature. Section 5 concludes the study by wrapping up the achievements and discussing the implications as well as the limitations of the research. The paper ends with recommendations for future research.

2. Literature review

Sustainable production approach was successfully realized in many textile mills all around the world. In these full-scale applications various techniques/technologies were investigated in order to decrease chemical, water and energy demand of companies. According to Hoque and Clarke (2013) chemical consumption and associated pollutant load of wastewater can be reduced in each process in textile companies by; (i) replacing sizing agents with low Biochemical Oxygen Demand (BOD) synthetic sizes in sizing, (ii) replacing enzymes with mineral acids in de-sizing, (iii) employing solvent-aided processes in scouring, (iv) using ammonium salts or hydrogen peroxide instead of chlorine in bleaching, (v) recovering caustic soda in mercerizing, (vi) implementing pad-batch systems in dyeing and (vii) avoiding the use of preservation compounds in finishing. Ozturk et al. (2009) carried out a chemical substitution study for a textile mill with a capacity of 20,000 tons of denim fabric per year. The research group identified 8 environmentally problematic chemicals out of 128 chemicals. In the scope of the study, sulfur dyestuff was replaced with low sulphide content which led to 76% decrease in the amount of sulphide in the wastewater. In addition the biodegradability of the wastewater was increased from 38 to 64%. Another chemical substitution study conducted by Ferrero et al. (2011) shows that some auxiliary materials can be substituted with ethanol at low concentrations (1–3% v/v) in dyeing processes of certain yarns in order to increase the biodegradability of the wastewater.

Oner and Sahinbaskan (2011) developed a new process for combined pre-treatment and dyeing of starch-sized 100% woven cotton fabric so as to decrease process time and increase water use efficiency. The novel process namely, rapid enzymatic single-bath treatment (REST) allows various enzymatic processes and dyeing to proceed in the same tank. Results indicated that REST saves up to 50% of process time when compared to the conventional processes. Besides, water consumption was reduced by 66% which decreased associated wastewater amount. Another process modification example was demonstrated by Tanapongpipat et al. (2008) for scouring process. Tanapongpipat et al. (2008) optimized scouring process by investigating the effect of operational parameters (concentration of de-sizing agent, temperature and dipping time) on the scouring efficiency. The optimum conditions in the scouring process were determined as follows: (i) de-sizing agent to fabric ratio of 20 g/g fabric, (ii) 80 °C temperature of the first de-sizing agent tank and 90 °C temperature for the second de-sizing agent tank and (iii) dipping time of 7 s. Applying these conditions more than 89% of the sizing agent was eliminated from production processes.

Ulson de Souza et al. (2010) applied water source diagram method for investigating the reuse potential of effluent generated in the washing process (continuous) of textile mills. For this purpose, a computer software was developed in the Matlab environment called MATrix Laboratory. The software enables the optimization of water consumption by analyzing the process topology, number of units/streams and weight/velocity/width of the fabric as well as chemical oxygen demand (COD) of the wastewater. Application of the proposed methodology increased the water use efficiency by 64% in a real textile washing process. Jiang et al. (2010) claimed that it is possible to reduce production time, water consumption and wastewater generation by optimizing production schedules in textile industry. The research group developed a genetic algorithm and implemented in a textile mill for the optimization of the orders according to color. The results indicated that the optimized scheme reduced water consumption by 20–30%, wastewater amount by about 20% and production time by 10–15%. Moreover, Faria and Bagajewicz (2011) developed a novel bound contraction procedure to solve water management/allocation problems using mixed-integer nonlinear programming (MINLP) which can be applied to various industries including textile industry. Using mathematical programming water consumption could be decreased 72% by global optimization of a bilinear MINLP water management/allocation problem (Bagajewicz and Faria, 2009).

Apart from chemical and water use efficiency, energy efficiency in textile industry receives much attention from a number of environmental/energy management scholars. Palamutcu (2010) advocated

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