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Minimization of water and chemical use in a cotton/polyester fabric dyeing textile mill

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ABSTRACT

Water, wastewater and chemical minimization studies were carried out in a textile mill employing cotton–polyester weaving–knitting and subsequently dyeing–finishing. Detailed on-site investigations and analysis on production processes were performed according to Integrated Pollution Prevention and Control principles. Specific consumptions in wet processes were calculated by mass balance analyses. Water/wastewater samples were collected and various parameters were analyzed. Specific wastewater generations and pollutant loads were determined. Wastewater reuse (with or without treatment), potential chemical recovery and reuse options were evaluated. A company-wide chemical inventory study was conducted and material safety data sheets of 291 chemicals were evaluated in terms of their biodegradability and toxicological effects. It was found that 74 chemicals may be replaced with less toxic and more biodegradable counterparts. Best available techniques were determined on the basis of Integrated Pollution Prevention and Control and Turkish Textile BREFs. The multi-criteria decision-making methods were employed to determine suitable best available techniques. Feasibility analysis was performed and potential benefits and savings were determined for each suggested best available technique. A total of 14 best available techniques including good management practices, water minimization and chemical minimization/substitution were suggested to the mill. After the implementation of best available techniques, the following reductions can be potentially achieved; 43–51% in water consumption, 16–39% in chemical consumption, 45–52% in combined wastewater flowrate, and 26–48% in specific chemical oxygen demand load. By the implementation of 14 BATs in the mill, operational costs for water/wastewater and chemicals may be reduced 49% and 28% (annual average), respectively. The cost analysis indicated that the estimated payback periods of BATs may range from 1 to 26 months. It was found that 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.

1. Introduction

Limited natural resources have been polluted by industrial activities. According to average economic growth scenario, the global water demand is expected to be 1500 billion m^3 in 2030 (Vajnhandl and Valh, 2014). Therefore, sustainability of water resources and protection against contamination are important issues all over the world on behalf of avoiding global fresh water crisis in the future (Mughess and Al-Ahmad, 2015).

Various approaches that support the sustainable use of natural resources and sustainable production processes have been developed in the last 20–30 years (Bevilacqua et al., 2014). One of these approaches is pollution prevention, or generally speaking cleaner production, which means protection of resources and environment as a whole with an integrated approach (UNIDO, 2002). Cleaner production approach aims to prevent high amounts of resource consumption and pollutant generation as a result of inefficiency in the production processes. Cleaner production and

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pollution prevention/minimization approaches try to optimize the production processes in terms of environmental considerations. Cleaner production is also referred as a proactive environmental protection strategy (Gavrilescu, 2005). Besides, cleaner production in the industrial enterprises may provide reduced production costs, improved competitiveness to meet the requirements of existing and future regulation or standards (UNEP, 2013). Cleaner production approach began to take place rapidly in environmental protection policies and regulations of the countries. The first European framework for pollution prevention at industrial level was Integrated Pollution Prevention and Control (IPPC) Directive (2008/1/EC) published in 1996, which is one of the key instruments of the European Union's (EU) environmental legislation (Kocabas et al., 2009). It covers legal arrangements and requires the inspecting authorities to give permits to the industrial facilities and to monitor their environmental performances within this general approach (Kocabas, 2008). The Directive covers the application of "best available techniques-BAT". The selection of BAT consists finding the appropriate balance between environmental performance and technical/economical availability (EC, 2003). On November 24, 2010, the European Parliament adopted the Industrial Emissions Directive 2010/75/UE (IED). IED consists six previous directives, including IPPC Directive (Banchmann and Van Der Kamp, 2014). General principles of the IPPC-IED are integrated approaches, flexibility principle, participative principle, and usage of BAT (EU, 2010).

Within the Turkey's efforts for the on-going EU accession process, harmonization of current legal infrastructure with EU standards is underway. In this context, IED is one of the main directives which have been evaluated during harmonization process. IED has not yet been introduced to the Turkish legislation but the first step has been taken with the publication of a Communique entitled "Integrated Pollution Prevention and Control in the Textile Sector" (Turkish BREF) in 2011 (TMEU, 2011). Regulation of procedures and principles that minimize negative effects of textile sector activities, control of discharges to water, air and soil environments, efficient usage of raw materials/energy, and usage of cleaner production technologies can be listed as the general aims of Turkish BREF. Textile plants with production capacities over 10 tons/day are subject to the provisions of the communique. They have to meet Turkish BREF related requirements and employ their cleaner production plans. According to harmonization calendar, it is planned that the integrated permission process will be completed in 2015 and entire harmonization process will be completed in 2018.

Configuration of the cleaner production approach in industrial enterprises is a challenging process that requires substantial know-how (Price and Hasanbeigi, 2012). In this study, on-site cleaner production assessment study was carried out according to IPPC-IED in a textile mill, employing cotton and polyester fabric finishing–dyeing. The study followed a systematic approach consisting of three basic steps including pre-assessment, assessment and feasibility analysis. After the technical evaluations with the mill management the priority issues requiring detailed further investigations were decided to be water and chemical consumptions, wastewater generation and pollutant loads. Therefore, the main focus of this study was the minimization of water and chemical consumptions and wastewater generations in the mill. Multi-criteria decision-making methods employed together with the mill management were used for the first time to evaluate and finalize BAT options. We believe that the employed unique methodology and the findings of this study (i.e., potential reductions in water and chemical usages and potential savings after BAT implementations) will be useful to similar textile mills, stakeholders and regulators. The structure of this study may provide a road map to textile industry for their cleaner production applications.

1.1. Turkish textile industry

Textile industry has a significant role in the economic development of the countries in terms of export income and employment (Heymann, 2011). Today, there are more than 150 countries supplying textile all over the world and it is a global industry in this respect (WTO, 2007). Turkey is one of the leading textile suppliers with 3.6% share in the world textile trade (RTPM, 2014). Turkey is the second largest textile supplier of Europe. Textile industry creates 16% of added values (Cukul, 2008) and it provides 27% of all employment in Turkish manufacturing industry (RTMIT, 2010). Turkish textile industry is dominated by small and medium enterprises (SMEs). It consists of large number of sub-sectors and has complex manufacturing processes. According to Turkish Statistical Institute, textile industry is responsible from 15% of overall industrial water consumption (191.5 million m^3 per year) and it is the second largest industrial water consumer in the manufacturing sector (TSI, 2010). Therefore, reduction of water consumption and prevention of contamination of water resources are important concerns for the Turkish textile industry. The stringent discharge limits and requirements of regulatory-standards are forcing Turkish textile industry for more efficient usage of water and chemicals. Therefore, Turkish textile industry has already prepared cleaner productions plans based on the Communique recently published. Some mills already applied some parts of these plans by making investments, considering Turkish BREF and IPPC-IED directive. Majority of these investments are process and machinery/equipment modifications with an effort to reduce water and chemical consumptions.

1.2. Water consumption in textile industry

Water is one of the most significant inputs of wet processes (pre-treatment, dyeing and finishing) in textile industry. The specific water consumption is reported to range 3–932 L/kg product depending on fiber type, applied techniques and technologies (Brik et al., 2006; Kocabas, 2008). IPPC Textile BAT Reference (BREF) document indicates that specific water consumption ranges from 10 to 645 L/kg product (average 22–184) in the textile industry and such values are 21–645 L/kg product (average 92–162) in mills employing cotton and polyester fabric finishing–dyeing (EC, 2003). In other studies performed for the Turkish textile industry, specific water consumption was found 20–350 L/kg product (Alaton et al., 2006; Ozturk et al., 2009). For the cotton and polyester fabric finishing–dyeing mills in Turkey, specific water consumptions are expected to be 70–250 L/kg product. The Textile and Apparel Specialist Commission Report of the 8th Five Year Development Plan of the State Planning Organization stated that the current specific water consumption in textile industry should be reduced to <80 L/kg product using water saving technologies (Kocabas et al., 2009). Such water saving technologies and BATs are available and can easily be implemented by the textile industry. For example, it was reported that water consumption in the textile industry can be potentially reduced about 15–79% with the implementation of various cleaner production measures (Alkaya and Demirer, 2014).

1.3. Chemical consumption in textile industry

Textile production processes are characterized by their comparatively high specific chemical consumption. Chemical consumption is about 10–100% in proportion to total fiber weight in textile processing (Ozturk et al., 2009). A large number of chemicals are needed to impart the desired properties to textile fibers such as acids, bases, surfactants, enzymes, stabilizers, dispersing agents, retarders, salts, dyes, solvents, emulsifiers, fixing and complexing