DIFFUSION OF SUSTAINABLE PRODUCTION APPROACH INTO TURKISH MANUFACTURING INDUSTRY: PILOT APPLICATIONS AND SECTORAL ASSESSMENTS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

EMRAH ALKAYA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
ENVIRONMENTAL ENGINEERING

DECEMBER 2013

Approval of the thesis:

DIFFUSION OF SUSTAINABLE PRODUCTION APPROACH INTO TURKISH MANUFACTURING INDUSTRY: PILOT APPLICATIONS AND SECTORAL ASSESSMENTS

submitted by **EMRAH ALKAYA** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Environmental Engineering Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen
Dean, Graduate School of **Natural and Applied Sciences** _____________________

Prof. Dr. F. Dilek Sanin
Head of Department, **Environmental Engineering** _____________________

Prof. Dr. Göksel N. Demirer
Supervisor, **Environmental Engineering Dept., METU** _____________________

Examining Committee Members:

Prof. Dr. Ülkü Yetiş
Environmental Engineering Dept., METU _____________________

Prof. Dr. Göksel N. Demirer
Environmental Engineering Dept., METU _____________________

Assoc. Prof. Dr. İpek İmamoğlu
Environmental Engineering Dept., METU _____________________

Assoc. Prof. Dr. Nihal Bektaş
Environmental Engineering Dept., GYTE _____________________

Assist. Prof. Dr. Emre Alp
Environmental Engineering Dept., METU _____________________

Date: 06.12.2013

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Emrah Alkaya

Signature :

ABSTRACT

DIFFUSION OF SUSTAINABLE PRODUCTION APPROACH
INTO TURKISH MANUFACTURING INDUSTRY:
PILOT APPLICATIONS AND SECTORAL ASSESSMENTS

Alkaya, Emrah

Ph.D., Department of Environmental Engineering
Supervisor: Prof. Dr. Göksel N. Demirer

December 2013, 333 pages

The main aim of this study was (i) to investigate the applicability of various sustainable production measures in different industrial sectors and (ii) to conduct a sectoral assessment study for a selected sector in order to contribute to the diffusion of sustainable production approach into Turkish manufacturing industry.

As a result of the environmental performance evaluations, objectives were set for six companies from six different sectors in order to decrease the negative environmental impacts and production costs associated with the high impact processes/practices. To achieve these objectives, 77 options were developed and 19 options were selected/implemented in the companies. In the companies, significant water saving (849,668 m^3/year) was achieved. In addition to water, 3,607 MWh of total energy was saved. Due to energy saving, CO_2 emissions of companies were reduced considerably by 904.1 tons/year. Chemical saving (e.g. NaCl, CdO, NaCN) of 278.4 tons/year was achieved by process and technology changes. By this way pollutant load in generated wastewaters were decreased substantially.

Within the scope of the sectoral assessment of Turkish textile industry, a three scale analysis (micro, meso and macro) was conducted by means of survey studies taking into account (i) the textile producer firms’ capacities and awareness, (ii) standards and demands of retailer companies as well as (iii) the existing institutional framework, strategies, supports and incentives. Survey study covered 76 textile producer firms, 10 retailer companies (e.g. multinational corporations) and 17 institutions. As a result of the analysis, recommendations were developed for the diffusion of sustainable production into 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 manufacturing industry even without heavy investments for technology changes. It is expected that the methodologies developed/followed throughout this study will shed light on future sustainable production applications and policies for the widespread adoption of this approach within Turkish manufacturing industry.

Keywords: Sustainable production, resource efficiency, manufacturing industry, pilot applications, sectoral assessments

ÖZ

SÜRDÜRÜLEBİLİR ÜRETİM YAKLAŞIMININ TÜRKİYE İMALAT SANAYİİNE ENTEGRASYONU:
PİLOT UYGULAMALAR VE SEKTÖREL DEĞERLENDİRMELER

Alkaya, Emrah

Doktora, Çevre Mühendisligi Bölümü
Tez Yöneticisi: Prof. Dr. Göksel N. Demirer

Aralık 2013, 333 sayfa

Bu çalışmanın temel amacı sürdürülebilir üretim yaklaşımının Türkiye imalat sanayiine entegrasyonuna katkıda bulunmak için (i) çeşitli sürdürülebilir üretim önlemlerinin farklı endüstriyel sektörlerde uygulanmasının araştırılması ve (ii) seçilen bir sektörde sektörel değerlendirme çalışmasının gerçekleştirilmesidir.

Çevresel performans değerlendirmeleri sonucunda altı farklı sektörde faaliyet gösteren altı firmanın yüksek etkili prosesleri/hatları nedeniyle yarattıkları çevresel etkilerini ve üretim maliyetlerini düşürmeye yönelik olarak hedefler belirlenmiştir. Bu hedeflere ulaşabilmek amacıyla 77 uygulama seçeneği belirlenmiş ve bu seçeneklerden 19 tanesi firmalarda uygulamaya konmuştur. Uygulamalar neticesinde firmalarda yüksek miktarlarda su tasarrufu (849.668 m^3/yıl) gerçekleşmiştir. Suya ek olarak 3.607 MWh toplam enerji tasarrufu sağlanmıştır. Enerji tasarrufu kaynaklı olarak ise CO_2 emisyonları 904,1 ton/yıl gibi önemli

oranda düşürülmüştür. Proses ve teknoloji değişiklikleri sayesinde 278,4 ton/yıl mertebelerinde kimyasal tasarrufu (NaCl, CdO, NaCN vd.) sağlanmıştır. Bu sayede firmaların atıksularının kirlilik yükleri ciddi şekilde azaltılmıştır.

Türkiye tekstil endüstrisinin sektörel değerlendirmesi kapsamında yürütülen anket destekli araştırmada üç aşamalı bir analiz (mikro, mezo and makro) gerçekleştirilerek (i) tekstil üretici firmalarının kapasite ve farkındalıkları, (ii) perakendeci firmaların standartları ve taleplerinin yanı sıra (iii) mevcut kurumsal çerçeve, stratejiler, destekler ve teşvikler değerlendirilmiştir. Anket destekli araştırma 76 tekstil üreticisi firma, 10 perakendeci firma (uluslararası markalar vd.) ve 17 kurumu kapsamaktadır. Analizler sonucunda temiz üretimin Türkiye tekstil sektörüne entegrasyonu için öneriler getirilmiştir.

Bu çalışmanın sonuçları göstermektedir ki geniş ölçekte yaygınlaştığı taktirde önerilen sürdürülebilir üretim önlemleri/yaklaşımları yüksek yatırım maliyetlerine ihtiyaç duymaksızın Türkiye imalat sanayiinde önemli değişikliliklere olanak tanıyacaktır. Bu çalışma ile geliştirilen/takip edilen yöntemlerin sürdürülebilir üretim yaklaşımının Türkiye imalat sanayiinde geniş çerçevede kabul görmesi için önümüzdeki dönemde gündeme gelecek uygulamalara ve politikalara ışık tutması beklenmektedir.

Anahtar Kelimeler: Sürdürülebilir üretim, kaynak verimliliği, imalat sanayii, pilot uygulamalar, sektörel değerlendirmeler

To ece…

ACKNOWLEDGEMENTS

Well, now it is time to express my feelings and gratitude to the people who helped me gain this invaluable experience which took "our" more than just five years!! I should confess that after some time (let's say ten years from now) this part of my thesis will be the most attractive one for me since it is full of good memories and smiling faces rather than boring figures or tables:))

This thesis would not have been possible without the guidance and encouragement of my supervisor, Prof. Dr. Göksel N. Demirer. It has been a privilege to be supervised by him. He keeps using the analogy of "running a marathon" when facing challenges like a doctoral research. I am very fond of his philosophy that patience and determination are all you need to finish most of the marathons in your lifetime. By the way, I hope he knows that I will challenge him in other areas of sport after this mess is over…

I am grateful to the supervising committee members, namely Assoc. Prof. Dr. İpek İmamoğlu and Assoc. Prof. Dr. Nihal Bektaş. I tried to capture all their constructive comments and critical advices to shape this thesis. They were so kind to share their pens with me to do that. In addition, I would like to thank to the dissertation committee members Prof. Dr. Ülkü Yetiş and Assist. Prof. Dr. Emre Alp.

Before coming to the individuals outside the academic world, I want to take this opportunity to appreciate the financial supports provided by the Millennium Development Goals Fund (MDGF) within the scope of United Nations Joint Programmes entitled "MDG-F 1680: Enhancing the Capacity of Turkey to Adapt to Climate Change" and "MDG-F 2067: Harnessing Sustainable Linkages for Small and Medium Sized Enterprises (SMEs) in Turkish Textile Sector".

I am deeply indebted to my colleagues in TTGV for their endless support and understanding during hard times. I feel so lucky that I have managers like Ms. Ferda Ulutaş and Dr. A. Mete Çakmakcı who are so inspiring for me from different angles. They made me curious and excited about the results of this journey which would in a way affect my professional career.

Special thanks go to my parents whose only child is a "student" since 1989. They certainly deserve to spend quality time with their child which was not possible during the course of this study. Moreover Alkaya, Dogruel, Gürakar, Özkara, Yakar, Dağıstan and Koçer families were so supportive that I don't know how to express my gratitude to them. One of the major motivations to finish this study was to be again a part of the enjoyable and memorable moments with them.

Hmmmm... I don't know what to say about my dear friends who interfered with my thesis studies. Okan Şenyurt made me cheer all the time and made me drink even if I had to study afterwards. Ahmet Tamay convinced me to watch the exciting games of Beşiktaş and prevented me from sending the articles to my supervisor on time. Dr. Turgay Baş (really a doctor) took me to these beautiful caves when I should do some literature survey instead. Kemal Işıtan dared to offer me always tempting outdoor activities (e.g. a bicycle tour at night). I will never forgive you guys!! Thanks god that Volkan Emre, Mehmet Yıldırım and Onur Güven Apul are far from here. Otherwise they would do the same to me:)) I really miss you guys:((Furthermore I want thank to all of my other close friends who enrich my life: Merve Böğürcü, Dr. Özge Yılmaz, Şahap Aşçı, Müge Erkan, Ekrem Aydar, Hülya Güneri Tamay, Evren Eser, Emrah Dirmit, Beril Büyüker Şenyurt, Kezban Akyol Eser, Amelia Amstutz, Dr. Akif Kutlu, Diana Meschter and Yasemin Dilşad Yılmazel. All jokes aside, these precious people owe more than just a paragraph stating how great they are.

It is not over yet… I would like to express my sincerest appreciation to my laptop computer (a.k.a. Casper "the Veteran"). I think after 8 years of excellent academic service he is now able to write scientific papers and theses by itself. Even the computer mechanic amazed his performance after all these years. But I know he wants to enjoy his retirement after these busy years. Further thanks go to my favorite online radio stations Radioparadise, Radiobabylon and Eldoradio Chill. They were like my life support units during intensive working hours.

Finally, this dissertation (and all the other things) is lovingly dedicated to Ece (Gürakar) Alkaya. Now I am sure that I will never be able to find exact words to express my feelings for her…

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

ABBREVIATIONS

ADA	: Ankara Development Agency
AFGC	: Australian Food and Grocery Council
AISI	: American Iron and Steel Institute
BAT	: Best Available Technique
BMP	: Best Management Practice
BOD	: Biochemical Oxygen Demand
BPU	: Batch Polycondensation Unit
BRC	: British Retail Consortium
BTYK	: Supreme Council for Science and Technology
CIRAS	: Center for Industrial Research and Service
COD	: Chemical Oxygen Demand
CR	: Cycles of Concentration
CSR	: Corporate Social Responsibility
CSTR	: Continuous Stirred Tank Reactor
DEMEA	: German Material Efficiency Agency
DMC	: Domestic Material Consumption
DMT	: Dimethyl Terephthalic Acid
EEA	: European Environment Agency
EPA	: Australian Environment Protection Agency
EPE	: Environmental Performance Evaluation
EPI	: Environmental Performance Indicator
EPS	: Expandable Polystyrene
ETBPP	: Environmental Technology Best Practice Programme
EU	: European Union
FAO	: The Food and Agriculture Organization of the United Nations
GPPS	: General Purpose Polystyrene

GDP : Gross Domestic Product
GVA : Gross Value Added
HACCP : Hazard Analysis and Critical Control Points
HDPE : High Density Polyethylene
HIPS : High Impact Polystyrene
IDA : İzmir Development Agency
IFC : International Finance Corporation
ILO : International Labour Organization
ISDA : İstanbul Development Agency
ISO : International Organization for Standardization
KOSGEB : Small and Medium Enterprises Development Organization
LDPE : Low Density Polyethylene
LLDPE : Linear Low Density Polyethylene
LPG : Liquefied Petroleum Gas
MDG-F : Millennium Development Goals Fund
MINLP : Mixed-Integer Nonlinear Programming
MOE : Ministry of Economy
MOEF : Ministry of Environment and Forestry
MOEU : Ministry of Environment and Urbanization
MOIT : Ministry of Industry and Trade
MOSIT : Ministry of Science Industry and Technology
MPM : National Productivity Center
MRC : Marmara Research Center
MSDS : Material Safety Data Sheet
NCDENR : North Carolina Division of Pollution Prevention and Assistance
NGO : Non Governmental Organization
OECD : Organisation for Economic Co-operation and Development
PET : Polyethylene Terephthalate
PFR : Plug Flow Reactor
PPP : Purchasing Power Parity

PVC	: Polyvinyl Chloride
QA/QC	: Quality Assurance and Quality Control
RAC/CP	: Regional Activity Centre for Cleaner Production
REST	: Rapid Enzymatic Single-Bath Treatment
RO	: Reverse Osmosis
SEM	: Structure Equation Model
SME	: Small and Medium-Sized Enterprise
SPO	: State Planning Organization
SUSCHEM	: European Technology Platform for Sustainable Chemistry
TGDF	: Federation of Food and Drink Industry Associations of Turkey
TOC	: Total Organic Carbon
TPA	: Terephthalic Acid
TPE	: Thermoplastic Polyester Elastomers
TSI	: Turkish Statistical Institute
TTGV	: Technology Development Foundation of Turkey
TUBITAK	: The Scientific and Technological Research Council of Turkey
UNDP	: United Nations Development Programme
UNEP	: United Nations Environment Programme
UNFCCC	: United Nations Framework Convention on Climate Change
UNIDO	: United Nations Industrial Development Organization
UP	: Unsaturated Polyester
USAID	: United States Agency for International Development
UV	: Ultraviolet
VOC	: Volatile Organic Carbon
WRAP	: Waste and Resources Action Programme

CHAPTER 1

BACKGROUND INFORMATION

Several macroeconomic indicators show that, over the last decade, Turkey experienced a remarkable economic growth along with a rapid transition from an agricultural to an industrial economy. During 2002–2011 period, average annual growth rate of the country was realized as 6% while Gross Domestic Product (GDP) per capita has tripled from 3,492 $ to 10,444 $ (MOE, 2013a). Turkey had an estimated GDP of 789.7 billion $ in 2011 (Goldblatt et al., 2012) and it is currently the 16th highest ranked country by GDP (Undersecretariat of Treasury, 2013). According to Ernst & Young (2013), the country still has a considerable untapped potential, with its economy set to grow at least 5% each year in the medium term and it set ambitious targets which are 500 billion $ of export, 2 trillion $ of GDP and 25,000 $ of GDP per capita to be achieved until the year 2023.

Although the recent economic performance indicators of Turkey clearly show that it is witnessing a certain "growth" trend, there is still an important question to be answered whether the country is "developing" or not. If the answer is "yes", one should look for the environmental performance indicators whether this development is "sustainable" or not:

- According to Environmental Performance Index published by the Yale University, Turkey, one of the "weaker performer countries", is ranked in the 109th place among 132 countries (Yale University, 2012).

- The results of the "Better Life Index" study carried out by the Organisation for Economic Co-operation and Development (OECD) show that under the "environment" topic, Turkey is currently in the 35th rank among total 36 OECD countries (OECD, 2013a).
- Among 30 countries in Europe, Turkey is placed in the 26th position in terms of "resource efficiency (material productivity)" as $ purchasing power parity (PPP) per ton domestic material consumption (DMC) (EEA, 2011).
- In terms of "industrial environmental protection expenditure by GDP" Turkey is placed in the last position among all of the European Union (EU) countries (Eurostat, 2012).

Abovementioned metrics are only some of the examples which indicate that although it is a growing/emerging economy, Turkey performs way below most of the developed and developing nations in terms of one of the integral pillars of "development", namely environmental sustainability.

One of the major approaches which stimulate industrial development while ensuring environmental sustainability is "sustainable (cleaner) production". Sustainable production is defined as "*the continuous use of industrial processes and products to prevent the pollution of air, water and land, reduce wastes at source, and minimize risks to the human population and the environment*" (UNEP, 1994). This approach assumes that environmental degradation is a result of the "ineffective" use of raw materials, processes or products (Van Hoof and Lyon, 2013). In contrast to the "pollution control" approaches which try to overcome the environmental problems after they arise, "sustainable production" approach accepts the pollution as a result of deficiencies and inefficiencies during design, raw material utilization and production processes; and aim to find solution by providing necessary developments during these processes (Ulutaş et. al, 2012a). In essence, sustainable production is about (Alkaya et al., 2011):

- Preventing waste and pollution at source
- Minimizing the use of hazardous raw materials
- Improving water and energy efficiency
- Reducing risks to human health
- Reducing operational costs
- Improving efficient management practices
- Promoting sustainable development

"Sustainable Production" concept has been firstly brought to the agenda of Turkey in 1999 by The Scientific and Technological Research Council of Turkey (TUBITAK) and Technology Development Foundation of Turkey (TTGV) (Böğürcü, 2012). They emphasized that "meeting environmental liabilities and assuming an active role in the 21st century world trade are possible through determining and adopting a national sustainable (cleaner) production policy". Sustainable Production concept is placed in the priority areas of the Supreme Council for Science and Technology (BTYK) which determines the national science and technology policies. This concept has also been emphasized in the Vision and Prediction Report of Environment and Sustainable Development subjected Panel prepared in the scope of the TUBITAK's Vision 2023 Project (TUBITAK, 2003a). In addition to this, "raising manufacturing industry awareness on the subject and inducing Cleaner Production by giving priority to environmental friendly technologies during determination of the industrial policies" are the main policies which are stated in 8th Five Year and 9th Seven Year Development Plans and documents prepared for the EU accession efforts (SPO, 2000 and 2006; MOEF, 2006a).

Moreover, the priority research and development areas for the next 10 years were determined by the Supreme Council for Science and Technology in 10 March, 2005 and the "Environment and Forestry Research Program" prepared by the Ministry of Environment and Forestry (MOEF) and TUBITAK (MOEF, 2006b). Cleaner production technologies, waste minimization, minimization at source (human factor and environmentally friendly products), reuse, recovery and recycle have been placed in these areas. The Cleaner Production, Clean Products and Environmentally Friendly Technologies Working Group Industrial Sector Report recommended that a national scale Cleaner Production Centre should be established under the TUBITAK Marmara Research Center (TUBITAK-MRC) (TUBITAK-TTGV, 1999).

In 2009 MOEF initiated a project namely "Determination of the Framework Conditions and Research-Development Needs for the Dissemination of Cleaner Production Applications in Turkey" which was carried out by TTGV and Department of Environmental Engineering of Middle East Technical University between 2009 and 2010. As the major output of the project, a draft report was prepared by the project team. Then, a workshop was organized to present the major findings and receive the feedback of all the stakeholders. A total of 125 participants represented 62 different institutions (public, private, NGOs, universities, sectoral and financial institutions, etc.) in the workshop. Some of the major conclusions, drawn as a result of the project, which was one of the milestones for the diffusion of sustainable production policies and approaches into national agenda, were provided below (TTGV, 2010):

- Due to limited resources, priority should be given to the below sectors which are determined to be priority sectors for cleaner production in Turkey: (i) basic metals, (ii) food products and beverages, (iii) chemicals and chemical products, (iv) other nonmetallic mineral products and (v) textile products.
- Demonstration and eco-innovation projects with different tools and strategies of cleaner production in companies from high priority sectors to form examples of efficient resource utilization and pollution prevention should be implemented.

- The developed/adopted cleaner production practices and experience should be published.
- The demonstration projects should be used as dissemination and training tools.
- Capacity assessment should be conducted at sectoral levels as well; sectoral roadmaps and action plans must be prepared for the industry, accordingly.

Between 2008-2011 "UNIDO Eco-efficiency (Cleaner Production) Program" the only national program on cleaner production, was implemented by TTGV with the consultancy of Department of Environmental Engineering of Middle East Technical University (Prof. Dr. Göksel N. Demirer) under the responsibility of The United Nations Industrial Development Organisation (UNIDO). It was executed as a subproject of "MDG-F 1680: Enhancing the Capacity of Turkey to Adapt to Climate Change" a Joint United Nations Programme (TTGV, 2011).

In 2011, National Productivity Center (MPM) was closed and restructured as the "Directorate General for Productivity" under Ministry of Science Industry and Technology (MOSIT) which assumed the responsibility of coordinating Cleaner Production activities in Turkey. In 2012 MOSIT published the "Strategic Plan 2013-2017" which sets "the efficient use of resources and adoption of cleaner production (eco-efficiency) programs in industry as well as establishing a national cleaner production (eco-efficiency) center" as one of the targets (MOSIT, 2012a). Based on these developments, in April 2013, "TUBITAK-MRC Environment Institute" was restructured as "TUBITAK-MRC Environment and Cleaner Production Institute" and become the national cleaner production center of Turkey.

"10th Development Plan: 2014–2018" prepared by the Ministry of Development (MOD) states that "the activities will be supported for the development of products/services in the areas of renewable energy, eco-efficiency and cleaner production" (MOD, 2013). Supporting this policy objective, regional development agencies incorporated cleaner production approach into their regional plans as one of the areas to be supported and disseminated between 2014-2023 (ADA, 2013; IDA, 2013a; ISDA, 2013).

As presented above the term sustainable (cleaner) production has been cited for about 15 years in several policy and strategy documents of the top level agency/institutions on science, technology, development, etc. in Turkey. However sustainable production is still not sufficiently known and applied except its energy efficiency aspect in our country. There is very limited number of demonstration projects (case studies) and there is a lack of methodologies, models, case studies and tools which can be followed for the diffusion of sustainable production approach into Turkish manufacturing industry.

According to various studies from around the world, sector specific actions need to be taken in order to successfully diffuse sustainable production approach into manufacturing industries within a country (Asipjanov, 2004; Rogers and Banoo, 2004; TTGV, 2010; Sellahewa, 2011). United States Environmental Protection Agency - USEPA (2010) states that sector specific policies and recommendations need to be developed by means of detailed sectoral assessment studies. This approach is also in line with the policy development cycle (Figure1.1) proposed by UNIDO and The United Nations Environment Programme (UNEP) which advocate that awareness creation and capacity building activities (from bottom to top) need to be supported by sectoral and macro level interventions (from top to bottom) (UNEP, 2002; UNIDO, 2002). Supporting above arguments, the developed and industrialized countries analyze individual sectors so as to set up tailored sustainable production programmes for relevant sectors.

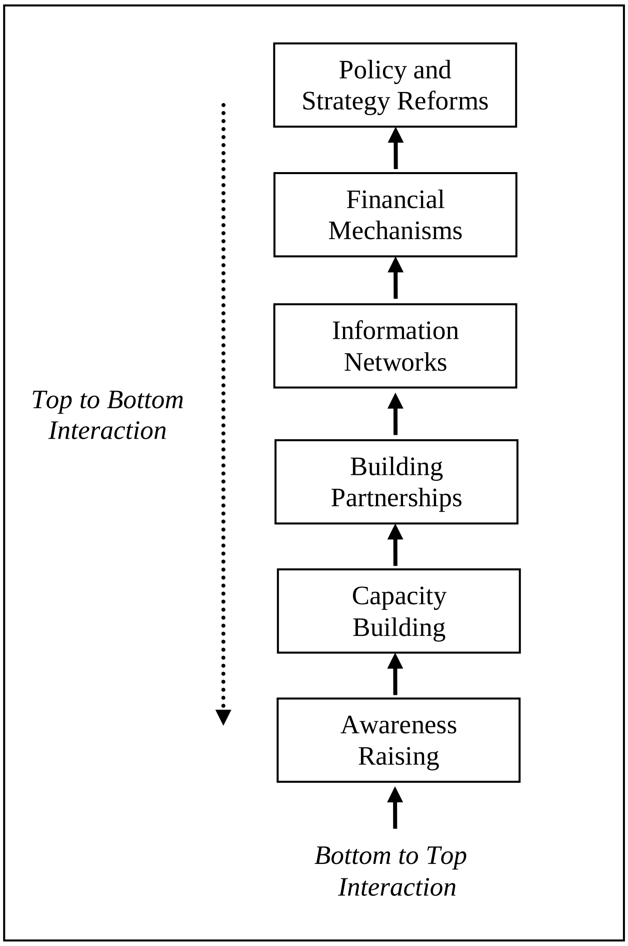


Figure 1.1. Typical development process of sustainable production concept in a country (UNEP, 2002)

CHAPTER 2

AIM AND SCOPE

The main aim of this study was (i) to investigate the applicability of various sustainable production measures in different industrial sectors and (ii) to conduct a sectoral assessment study for a selected sector in order to contribute to the diffusion of sustainable production approach into Turkish manufacturing industry. This study undertakes some of the recommendations developed by TTGV (2010) within the scope of “Determination of the Framework Conditions and Research-Development Needs for the Dissemination of Cleaner Production Applications in Turkey” (provided in Chapter 1).

Sustainable production pilot applications were investigated and realized in six companies from six industrial sectors listed below:

- Metal Processing Industry
- Chemical Industry
- Food Industry
- Textile Industry
- Surface Coating/Painting Industry
- Soft Drink Industry

In each of the company, comprehensive sustainable production audits were carried out in order to determine processes/practices with high potential for the improvement of environmental and economic performance of the company. During and beyond the audits, monthly resource consumption, waste/emission generation data and associated expenditures were compiled from the companies. Environmental Performance Evaluation (EPE) was carried out by using the data collected before sustainable production applications. Environmental benchmarking was carried out by using Environmental Performance Indicators (EPIs). Then, the specific resource consumption and waste/emission generation data was used for environmental benchmarking with relevant literature. As a result of environmental performance evaluation, the objectives were set for each company. To achieve these objectives, 77 options were developed for six companies in total. In order to find the most feasible solutions among the 77 options, an opportunity assessment phase was carried out together with company officials. As a result of the opportunity assessment, 19 options were selected and implemented full-scale as demonstration projects. The results of the implementations were monitored up to 16 months. Achieved gains were presented in relevant chapters (results and discussions sections) from both environmental and economic point of views.

Sustainable production pilot applications were carried out within the framework of “UNIDO Eco-efficiency (Cleaner Production) Programme” the subproject of “MDG-F 1680: Enhancing the Capacity of Turkey to Adapt to Climate Change” a Joint United Nations Programme. The “UNIDO Eco-efficiency (Cleaner Production) Programme” was implemented by TTGV with the consultancy of Prof. Dr. Göksel N. Demirer under the responsibility of UNIDO. The aim of the UNIDO Programme was to investigate cleaner production applications with a priority of improved “water efficiency” in order to demonstrate that industrial companies can adapt to climate change by adopting cleaner processes/technologies (TTGV, 2011). Based on this objective priority was given to the processes and applications where significant water saving potential is present. Since almost in all of the companies water use is associated with other resources (energy, chemicals etc.) this approach was expected to bring additional benefits in addition to increased water efficiency.

“UNIDO Eco-efficiency (Cleaner Production) Programme” included more than just six pilot applications. Since it was the first ever national programme on sustainable production in Turkey, pilot applications were supported by awareness raising activities and training programmes. Since a scientific and comprehensive approach was not the priority in the UNIDO programme, developed/implemented methodologies (evaluation of processes, environmental performance evaluation, benchmarking etc.) during sustainable production applications were differentiated considerably between this thesis and the UNIDO programme. So this thesis presents a methodological approach with comprehensive data analysis beyond technical specifications of equipments, work plan development and project financing which constitute the backbone of the UNIDO programme.

Textile industry was selected for the sectoral assessment study since it was referred as one of the priority sectors in various studies (TTGV, 2010; MOIT, 2010; Ulutaş et al., 2011, IDA, 2012). Moreover the “Communiqué of Integrated Pollution Prevention and Control in Textile Sector” is the first and only legal regulation on sustainable production in Turkey. This situation shows that textile industry has a big potential to act as a pioneering and a model sector for others for the dissemination of sustainable production applications in the future.

In this study textile industry was subjected to a three scale analysis (micro, meso and macro). Namely, (i) micro scale analysis: the textile producer firms’ capacities and awareness, (ii) meso scale analysis: perceptions of retailer companies and (iii) macro scale analysis: the existing institutional framework, strategies, supports and incentives. The backbone of the study was the “Current Situation Analysis” on environmental management and sustainable production in textile industry. “Current Situation Analysis” was based on survey studies on producer firms (76 firms), retailer companies (10 companies) and institutions (17 institutions). The outcomes of the survey were also evaluated based on a literature review of the relevant research studies and reports prepared for Turkish textile industry. After the analysis, results were discussed and recommendations were developed.

Sectoral assessment study was carried out parallel to the project “MDG-F 2067: Harnessing Sustainable Linkages for Small and Medium Sized Enterprises (SMEs) in Turkish Textile Sector” a joint project between United Nations Development Programme (UNDP), International Labour Organization (ILO) and UNIDO. TTGV was the implementing agency of the subproject “Services in the Field of Environmental Management and Cleaner Production in Textile Industry” (TTGV, 2012).

It is expected that the methodologies developed/followed throughout this study will shed light on future sustainable production applications and policies for the widespread adoption of this approach within Turkish manufacturing industry.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1. Sustainable Production Pilot Applications in Six Industrial Sectors

3.1.1. Data Collection and Environmental Performance Evaluation

In each company an initial walk-through audit was carried out together with company officials before gathering detailed process-based numerical data. As a result of these half-day walk-through audits, the process flow diagrams of companies were developed by getting information on inputs and outputs of major processes. Since the objective of the study was to increase environmental performance in each company as well as decreasing manufacturing cost, resource intensive and polluting processes/practices were investigated in the companies. Thus, monthly resource consumption, waste/emission generation data and associated expenditures were compiled from different sources provided by the staff of the companies (Appendix A). For this purpose, information sources like process-based record sheets as well as water/energy/chemical bills were analyzed. Moreover, informative catalogs of equipment and material safety data sheets (MSDS) of chemicals were also used for data collection.

Since each company has different policies, procedures and methods for monitoring and management of their resources/wastes data collection was different from one company to the other. For example, some of the companies were recording process based water consumption but some of them were not. Some of the companies were monitoring resource consumption but some of them were not. Due to time and budget constraints it was not possible to carry out dedicated monitoring periods for specific processes/practices. So, all the evaluations and analyses were only based on the data provided by the companies. All the data provided by the company representatives were processed as it is without making any assumptions or forecasts.

Environmental Performance Evaluation (EPE) was carried out by using the data collected before sustainable production applications. As described by the International Organization for Standardization (ISO) “environmental performance evaluation is a process to facilitate management decisions regarding an organization’s environmental performance by selecting indicators, collecting and analyzing data and assessing information against environmental performance criteria” (Dias-Sardinha and Reijnders, 2001). So, in order to identify the processes/practices which need to be improved in manufacturing enterprises environmental performance evaluation methodologies are being developed and widely used in various sectors (Jiang et al., 2012a).

Environmental benchmarking was carried out by using Environmental Performance Indicators (EPIs) that are specific resource consumption and waste/emission generation data. According to Thoresen (1999), EPIs can be used by industrial enterprises to control performance of processes and set goals as well as benchmark with competitors’ performance. In this study EPIs were calculated by dividing resource consumption or waste/emission generation data by manufactured products or processed raw materials depending on the data provided by the associated companies. Then, the specific resource consumption and waste/emission generation data was used for environmental benchmarking with relevant literature. It was not possible to evaluate the performance of the companies within Turkish manufacturing industry as a benchmarking study since no sector specific environmental performance indicators are published in Turkey.

3.1.2. Site Specific Analyses and Evaluations

3.1.2.1. Greening of Production in Metal Processing Industry through Process Modifications and Improved Management Practices

Since the major objective of the study was to decrease water consumption in the metal processing company water intensive processes were determined based on the water consumption data provided by the company. Since company was recording monthly water consumption in each of the processes it was possible to conduct a water balance analysis in the company. In other words, water inputs and outputs were calculated for all water consuming processes which were listed below:

- Heat treatment
- Surface finishing: Zinc phosphating
- Dyeing
- Induction heating/hardening
- Surface finishing: Galvanization
- Parts cleaning
- Vulcanization

As a result of water balance analysis heat treatment and surface finishing: zinc phosphating processes were determined to be among the most water intensive processes. In addition zinc phosphating processes was among the most chemical intensive process. Based on this initial analysis more information was requested from the company on inputs and outputs of this process to get into details of the surface finishing process. So environmental benchmarking was performed by generating belowlisted performance indicators in surface finishing process:

- Total specific water consumption (L/m^2 finished surface)
- Specific rinsing water consumption (L/m^2 finished surface)

- Rinsing ratio drip time (seconds)
- Specific degreasing chemical consumption (L/m^2 finished surface)
- Specific pickling chemical consumption (L/m^2 finished surface)

3.1.2.2. Reducing Water and Energy Consumption in Chemical Industry by Sustainable Production Approach: A Pilot Study for Polyethylene Terephthalate (PET) Production

The company provided annual water consumption data for belowlisted processes which were averaged for determining monthly usage. The company representatives stated that the company was operating quite stable throughout a year. So averaging the water consumption data was not expected to contribute to an important error.

- DMT production
- Polymerization (batch)
- Polymerization (continuous)
- Fiber production
- Filament production
- Cooling

One of the major problems encountered during data collection was the fact that the company was so big in scale (approximately 1,200 employees) that the data acquisition required quite an effort. Based on the data provided by the company, belowlisted performance indicators were developed and used for benchmarking purposes:

- Total and cooling water consumption (m^3/ton product)
- Energy consumption (GJ/ton product)
- Wastewater generation (m^3/ton product)
- Wastewater organic load (kg COD/ton product)

The initial evaluations, environmental benchmarking and water consumption analyses indicated that cooling process was responsible for the majority of water use in the company. So a more comprehensive water balance study was performed for cooling systems. Water balance was developed for two cooling towers (Tower A and B) which receive process cooling water and soft cooling water from heat transfer systems. In other words, more data was requested from the company concerning the water recirculation in the cooling towers. So inputs and outputs as well as quality parameters were analyzed and benchmarked for determining possible improvement potential.

3.1.2.3. Minimization and Valorization of Seafood Processing Wastes by Onsite Recycling and Reuse

Since high water consumption is very common in seafood processing industry, the company was using water considerably in almost every process. However the company officials determined thawing and gutting processes as the priority processes before any analysis or benchmarking study since in these processes water consumption was very much associated with the product quality. Based on this decision no additional effort was made on collecting information on water consumption in other processes. Indeed, thawing and gutting processes were the major water consuming processes in the company. Therefore, belowlisted environmental performance indicators were selected and compared with the literature in order to determine water saving potential in thawing and gutting processes:

- Total specific water use (m^3/ton raw fish)
- Specific water use in thawing (m^3/ton raw fish)
- Specific water use in gutting (m^3/ton raw fish)
- Specific energy use (kWh/ton raw fish)
- Specific solid waste generation (tons/ton raw fish)

3.1.2.4. Sustainable Textile Production: A Case Study From A Woven Fabric Manufacturing Mill in Turkey

As a different approach from other companies an initial water monitoring period was realized in the textile company by implementing water meters in seven different locations within production processes. By this way daily water consumption was recorded for 8 months (the baseline situation) for below listed processes.

- Fabric preparation, dyeing and finishing
- Cooling processes
- Utility operations
- Unaccounted losses

Since water consumption was associated with energy and chemical consumption as well as wastewater generation in textile mills belowlisted environmental performance indicators were determined and compared with relevant literature:

- Specific water consumption (L/kg product)
- Electrical conductivity (µs/cm)
- COD concentration (mg/L)
- Specific COD (kg/ton product)
- Thermal energy consumption (kWh/ton product)
- Electricity consumption (kWh/ton product)

The textile industry is under increasing pressure of wastewater regulations on organic pollutants, color and electrical conductivity due to excessive salt consumption. Because of this situation the company representatives set the priority of decreased salt consumption in addition to water and energy saving as a result of applications. Accordingly the processes/practices where high amounts of salt consumption was observed were analyzed in detail. For example, existing ion-exchanger system was compared with the state-of-art ion-exchanger systems by the help of several technology vendor firms which are in close contact with the company of concern.

3.1.2.5. Improving Resource Efficiency in Surface Coating/Painting Industry: Practical Experiences from a Small-sized Enterprise

As a different approach from rest of the companies, surface coating/painting company was subjected to comprehensive chemical use analyses rather than a water use analyses. Because the company was associated with high chemical consumption rather than water consumption. Since the company was a small-sized enterprise with only 12 employees it is operational procedures/practices are well-defined and easily accessible for external audits and evaluations. Therefore every process of the company was evaluated one by one in terms of chemical usage. As presented below five processes were analyzed for potential chemical saving opportunities:

- Chromium coating line
- Cadmium plating line
- Undercoating
- Wet painting
- Powder painting

As a result of initial analyses/evaluations, cadmium plating process and painting operations were determined for environmental benchmarking. Belowlisted environmental performance indicators were calculated and used for benchmarking purposes:

- Total specific water consumption (L/m^2 coated surface)
- Specific rinsing water consumption (L/m^2 coated surface)

- Specific NaCN consumption (g/m^2 coated surface)
- Specific degreasing chemical consumption (g/m^2 coated surface)
- Specific energy consumption (kWh/ m^2 coated surface)

In addition to the abovelisted performance indicators, type of painting systems were comparatively evaluated in terms of paint use efficiency of each technology. By this way, wasted paint amount was aimed to be decreased. However, company officials were against changing the painting technology. Therefore a comprehensive analysis was not conducted further to provide quantitative information on painting systems.

3.1.2.6. Water Recycling and Reuse In Soft Drink/Beverage Industry: A Case Study for Sustainable Industrial Water Management in Turkey

Among all of the companies soft drink producer was the second highest water consumer after chemical company. However the monitoring of water consumption was not well-established in the company. The company was only able to provide monthly water consumption for belowlisted processes as aggregated values:

- Cooling
- Bottle preparation/filling
- Facility cleaning
- Utility operations
- Fruit washing

Based on the initial analyses and simple environmental performance consisting of only water consumption, cooling water consumption was determined as the “hot spot” for this company. So, alterative cooling practices were gathered from technology vendors for comparative evaluation of technologies in addition to a literature survey.

3.1.3. Opportunity Assessment for Sustainable Production

As a result of environmental performance evaluation, the objectives were set for each company to decrease the negative environmental impacts and production costs associated with the high impact processes/practices. To achieve these objectives, 77 options were developed for six companies in total.

In order to find best possible and applicable solutions among the 77 options, an opportunity assessment phase was carried out together with company officials. The first step of this phase was the determination of "assessment criteria". Assessment criteria were determined by referring to 5 studies in the literature (Barros et al., 2008; European commission, 2006a; Klipova and Bagdonas, 2003; Pandey, 2007; UNEP, 2004). In these studies, when sustainable production options are to be evaluated, it is recommended to consider the following criteria:

- Environmental requirements, adaptability to employed processes, quality requirements, occupation, health and safety requirements, (Klipova and Bagdonas, 2003)
- Applicability of the technology, economical feasibility, examples of successful applications, level of technology (UNEP, 2004)
- Environmental benefit, complexity of the application, cost saving, scale of innovation, effect on processes/products, (Pandey, 2007)
- Achieved environmental benefits, economics, operational data, applicability, examples of successful applications, cross-media effects (European commission, 2006a)
- Environmental aspects, applicability and characterization, economic aspects, plants where the technique is already implemented, secondary effects (Barros et al., 2008).

Referring to above listed studies, 7 assessment criteria were determined as follows:

- Environmental benefits
- Technical applicability
- Economic viability
- Easiness of implementation
- Long-term sustainability
- Operational and maintenance requirements
- Cross-media effects

Although a structured and step-wise assessment tried to be carried out in each company different approaches needed to be followed due to the nature (management policies, technical capacities etc.) of the companies. In other words, in some of the companies above-listed criteria are discussed with the company officials in detail to select best possible and applicable solutions. However in some of the companies company managements decided on which applications to be realized.

As a result of the opportunity assessment, below listed 19 options were selected and implemented in the companies (Table 3.1). Implementations were monitored by using the data collection forms presented as Appendix B. In the conclusions section in each of the pilot applications aggregated results (e.g. water saving) were presented as percent reductions. These percentages were calculated by averaging the last 3-4 months where water/energy/chemical consumption of the companies achieved a steady-state value.

Table 3.1. Sustainable production applications realized in the companies

Industrial Sectors	Sustainable Production Applications
Metal Processing	1. Recycle the spent cooling water generated in heat treatment process to main water supply tank of the company (Van Berkel, 2007)
	2. Increase the drip (drainage) time above process baths to decrease drag-outs (Hunt, 1988; FDOEP, 2006)
	3. Place drain boards between process tanks to prevent drips from workpieces to the floor and recover drag-outs (Dahab and Lund, 1994; Barros et. al., 2008; NCDENRb, 2009; RAC/CP, 2002)
	4. Divide rinsing tanks into two stages and apply counter current rinsing using two consecutive rinsing stages (RAC/CP, 2002; European Commission, 2006a; Reeve, 2007; Barros et. al., 2008)
	5. Install covers on top of tanks to prevent evaporation losses of chemicals, water and energy (USAID, 2009)
Chemical	6. Substitute water-cooled heat transfer pumps with air-cooled centrifugal pumps (Arneth and Dötsch, 2006; CIRAS, 2005; Environment Agency, 2003; Werner, 2006)
	7. Substitute “EFF-3 Standard Efficiency” class motor mounted heat transfer pumps with “EFF-1 High Efficiency” class motor mounted pumps (European Commission, 2001)
Food	8. Recycle the thawing water through a closed-circuit water recirculation system (Archer et al., 2008; European Commission, 2006a)
	9. Treat and reuse the wastewater generated in the gutting process (Bugallo et al., 2013; Cappell et al., 2007; European Commission, 2006a; Hall, 2010; UNEP, 2004)
	10. Separate/segregate solids, fats and oils from waste streams for valorization of by-products and reduction of pollutant load (Barros et al., 2009; ETBPP, 1999; Hall, 2010; Thrane et al., 2009)
Textile	11. Use drop-fill washing instead of overflow (ETBPP, 1997; European Commission, 2003; NCDENR, 2009c; Shaikh, 2009)
	12. Reuse stenter cooling water (European Commission, 2003; NCDENR, 2009c; Shaikh, 2009; Greer et.al., 2010; Chougule and Sonaje, 2012)

Table 3.1. Sustainable production applications realized in the companies (Continued)

	13. Reuse singeing cooling water (European Commission, 2003; NCDENR, 2009c; Shaikh, 2009; Greer et.al., 2010; Chougule and Sonaje, 2012)
	14. Renovate water softening system (ETBPP, 1997; Kalliala and Talvenmaa, 2000; European Commission, 2003)
	15. Renovate various valves and fittings in water transmission system (European Commission, 2003; NCDENR, 2009c; Greer et.al., 2010)
Surface Coating/Painting	16. Replace chemical/labor intensive solvent based degreasing (hand wiping) process with alternative degreasing practices (Envirowise, 2003; European Commission, 2006a)
	17. Substitute cadmium plating process with a less toxic and more environmentally friendly alternative coating process (European Commission, 2006a; Heimann and Simpson, 2005; RAC/CP, 2002; USAID, 2009)
Soft Drink/Beverage	18. Replace once-through cooling system with closed-circuit cooling system in fruit concentrate and fruit juice production lines (Casani and Knochel, 2002; European Commission, 2006b; WRAP, 2013).
	19. Reuse cooling water blow-down in fruit washing process (Envirowise, 2002; European Commission, 2001; NCDENR, 2009a).

3.2. Sectoral Assessment of the Turkish Textile Industry for the Diffusion of Sustainable Production Approach

The sectoral assessment framework developed consists of a three scale analyses (micro, meso and macro). Namely, (i) the textile producer firms' capacities and awareness, (ii) standards and demands of retailer companies and (iii) the existing institutional framework, strategies, supports and incentives. The assessment was conducted in a step-wise manner as depicted in Figure 3.1. The backbone of the study was the "Current Situation Analysis" on environmental management and sustainable production in textile industry. "Current Situation Analysis" was based on survey studies on producer firms, retailer companies and institutions. The survey studies were also supported by a literature survey which includes the review of relevant research studies and reports prepared for Turkish textile industry. After the analysis, results were discussed and recommendations were developed.

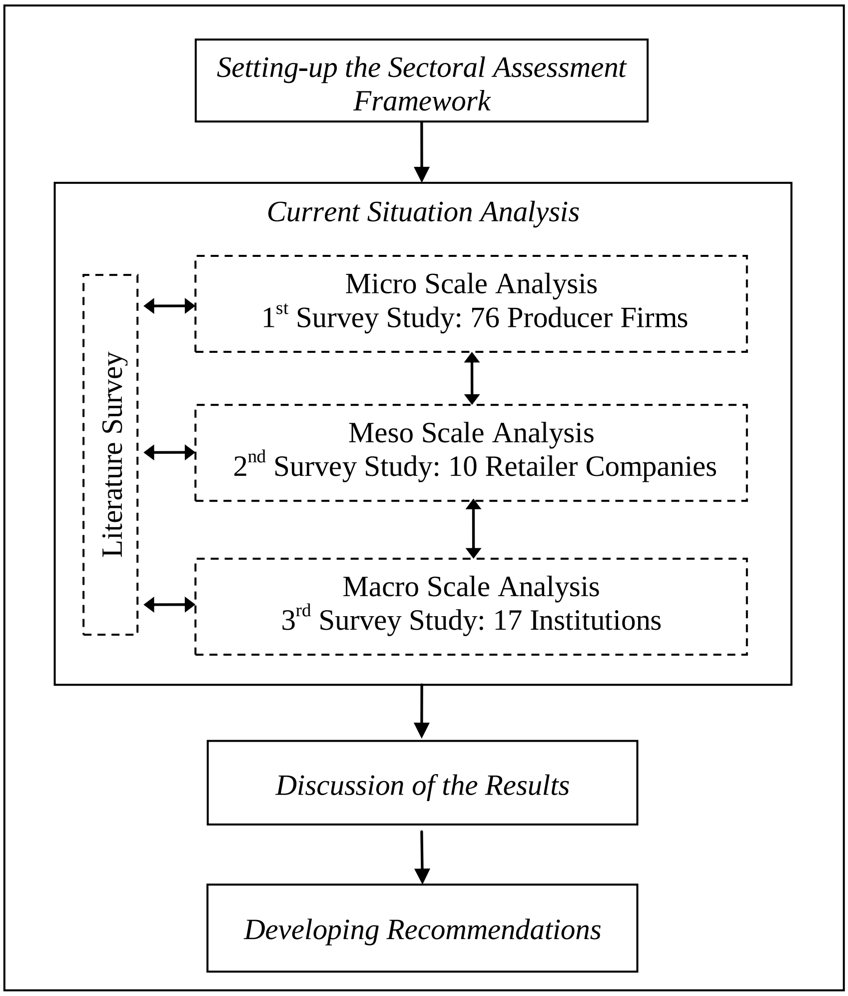


Figure 3.1. Schematic representation of the sectoral assessment methodology

3.2.1. Micro Scale Analysis: Textile Producer Firms

A questionnaire of 41 questions was used to obtain a better understanding on Turkish textile firms' perceptions, awareness and capacity on environmental management and sustainable production (Appendix C). Questions were grouped under six headings below:

1. General environmental policy and perspectives on the environmental legislation
2. The relationship between production processes/systems/technologies and environmental management
3. Measurement, implementation and monitoring activities realized in the context of environmental management
4. Effect of resource/waste management on company's production costs
5. Existing and planned activities for reducing the environmental impacts and associated costs
6. Impact of market conditions and customer relations on environmental performance and related costs

Based on the questions (and the themes) which constitute the questionnaire, environmental situations/of the companies were assessed under six areas:

1. Environmental policies and management practices (based on the answer of questions 1a, 1b, 1c)
2. Perspectives on the environmental legislations (based on the answer of questions 1d, 1e, 1f)
3. General waste management activities (based on the answer of questions 3a, 3b, 3c)

4. Selection of Sustainable Production Processes/Technologies During New Investments or Capacity Increases (based on the answer of questions 2a, 2b, 2c, 2d)
5. Monitoring and management of resources/wastes (based on the answer of questions 3d, 3e, 3f, 3g, 4, 5)
6. Effect of Markets and Customers on the Environmental Performance (based on the answer of questions 6a, 6b, 6c, 6d)

Questionnaires were distributed to the textile producer firms through various means including meetings with the local industrial organizations/associations and direct contacts mainly via e-mail/fax messages and telephone calls. In addition to e-mail/fax messages and telephone calls, site visits were carried out to 21 of the companies in order to get detailed information about their environmental situation/performance through face-to-face interviews. Since textile industry is growing towards developing regions within Turkey (MOIT, 2010), the majority of the firms was chosen accordingly from the areas where textile industry has a growing trend, namely Gaziantep, Kahramanmaraş, Malatya and Adıyaman.

As a result of meetings, email/fax/telephone communications and company visits, the questionnaires were filled by 116 companies. In order to assure the reliability of the survey study, the questionnaires in which less than 80% of the questions were answered were eliminated before the data analyses. In other words, only the questionnaires with at least 80% of answered questions were evaluated in the further analysis. By this way, 76 out of 116 questionnaires were evaluated in the micro scale analysis (Table 3.2). The list of all companies which were evaluated through survey study and/or site visits are provided in Appendix D.

Table 3.2. Distribution of the collected/evaluated questionnaires by cities

City	Evaluated Questionnaires (# of companies)
Gaziantep	26
Kahramanmaraş	18
Malatya	13
Adıyaman	7
Tekirdağ	5
Kayseri	2
Bursa	2
İstanbul	1
Adana	1
Afyonkarahisar	1
Total	76

Based on the answers, the companies were graded between 0–100% for each question. Level of environmental performance/competence of the company for associated area was determined by taking the average of the total grades of the relevant questions. Based on this method, the companies were ranked/scored as follows:

- Level 4 (Companies with 75–100% grade-level) *(The Desired Level)*
- Level 3 (Companies with 50–75% grade-level)
- Level 2 (Companies with 25–50% grade-level)
- Level 1 (Companies with 0–25% grade-level)

At the end of the micro scale analysis, the overall assessment of environmental performance of the companies was presented by using “clustering” analysis (Section 10.3.1.7). Clustering analysis is a statistical technique which enables grouping/categorizing multi-dimensional data sets in clusters based on similarities and dissimilarities (Pandit et al., 2011). In this study ”K-means” clustering algorithm was used by the help of Minitab® v.16 software (Minitab Inc.). ”K-means” algorithm is based on an iterative procedure which provides local solution, minimizing Euclidian distance between the observations and the cluster centers (Austin et al., 2013). In this study, the clustering analysis was used in order to categorize companies according to their environmental performances and perceptions in different areas (e.g. waste management, selection of production processes/technologies). So, the results were discussed by taking different company clusters and their member profiles (e.g. regions, subsectors) into account.

3.2.2. Meso Scale Analysis: Markets and Customer Relations

Since retailer companies (e.g. multinational corporations) are known to be highly influential on the economical, social and environmental performance of textile producers, it is of utmost importance to assess the mechanisms and means they intervene in environmental issues/concerns. A total of 10 retailer companies (4 multinational corporations and 6 large Turkish enterprises/retailers) contributed to the study. Multinational corporations were selected among the firms that have corporate social responsibility (CSR) policies and departments for social/ environmental compliance in Turkey. On the other hand, large Turkish enterprises/retailers were selected among important Turkish garment producers from around the country which cooperate with various textile producer companies from different textile sub-sectors.

A questionnaire with 14 open-ended survey questions (semi-structured interviews) were conducted in order to obtain a better understanding on the relevance of environmental management principles and standards for retailer companies when it comes to selecting their suppliers and auditing their performances (Appendix E). In the scope of meso scale analysis, survey study results were also supported by up-to-date information compiled from recent documents/reports.

Within the scope of "Meso Scale Analysis" below-listed retailer companies including multinational corporations responded to the survey through e-mail and telephone conversations. The contact details of representatives of each of the below companies are provided as Appendix F.

- Hennes and Mauritz AB (H&M)
- Marks and Spencer PLC
- Nike, Inc.
- Lee Cooper (Kipaş Group)
- Li & Fung Limited
- LC Waikiki (Tema Group)
- Cross Jeans (Şık Makas Giyim San. A.Ş.)
- Sunset (Günkar Tekstil Turizm İnş. San. ve Tic. Ltd. Şti)
- Hey Tekstil San. ve Tic. A.Ş.
- Yeşim Tekstil San. ve Tic. A.Ş.

3.2.3. Macro Scale Analysis: Institutional Set-up and Environmental Governance

Institutional set-up and environmental governance affecting textile industry were assessed by receiving information from the major stakeholder institutions in Turkey. The institutions were selected in such a way that information on all aspects of legislative framework, available financial support schemes, research/ development/ demonstration activities as well as informative and technical assistance for textile producers could be obtained. National, regional and sectoral institutions influential on textile industry were aimed to be covered. In this respect, ministries, umbrella organizations, regional development agencies, non-governmental organizations (NGOs), chambers of industry/ commerce and consultancy companies (totally 17 institutions) participated in the survey study from different regions of Turkey including, Ankara, İstanbul, İzmir, Bursa and Gaziantep.

A survey with 17 open-ended questions (semi-structured interviews) was elaborated to institutions of interest so as to obtain a better understanding on the current sectoral structure focusing on environmental management issues (Appendix G). In the scope of macro scale analysis, survey study results were also supported by up-to-date information compiled from recent documents/reports some of which were also referred to during interviews.

The below listed institutions were visited and questionnaires were filled during face-to-face interviews with the survey respondents:

- Ministry of Environment and Urbanization
- Ministry of Science, Industry and Technology
- Ministry of Economy
- Small and Medium Enterprises Development Organization (KOSGEB)
- The Union of Turkish Chambers of Commerce and Industry (TOBB)
- İzmir Development Agency (IDA)
- İpekyolu Development Agency
- Gaziantep Chamber of Commerce
- Gaziantep Chamber of Industry
- Technology Development Foundation of Turkey (TTGV)

The below listed institutions filled in the questionnaire and returned via fax/ e-mail messages:

- İstanbul Textile and Exporters' Associations (ITKIB)
- General Directorate of Electrical Power Resources Survey and Development Administration (EIE)
- TOBB National Council of Textile Organisations
- Bursa Demirtaş Organized Industrial Zone
- Eskon Energy Consultancy (Energy Service Company)
- Uenco Co. (Environmental Consultancy Company)
- Eko-tek Co. (Environmental Consultancy Company)

The contact details of the representatives (survey respondents) from each of the institutions are provided in Appendix H.

3.2.4. Development of Recommendations

The recommendations were developed according to four main headings which are defined as "the main phases for development of the sustainable production concept in a country" (UNEP, 2002):

- Policy and Strategy Reforms
- Financial Mechanisms
- Information Networks and Building Partnerships
- Capacity Building and Awareness Raising

While categorizing each recommendation based on the above listed headings, it has also been specified which scale(s) (micro, meso or macro) the recommendation is relevant to.

CHAPTER 4

GREENING OF PRODUCTION IN METAL PROCESSING INDUSTRY THROUGH PROCESS MODIFICATIONS AND IMPROVED MANAGEMENT PRACTICES

4.1. Introduction

Metal processing/products, machinery and automotive sectors are of utmost importance in Turkey with respect to employment generated as well as the added-value and export shares among the other manufacturing sectors. Turkish machinery sector has experienced an annual growth of 20% since 1990 (MOSIT, 2012b). According to 2011 figures, Turkey is in the 17th rank in the world in motor vehicle production with 621,000 of motor vehicles. Moreover, Turkey is the largest commercial vehicle producer in Europe. Automotive industry assumed the 1st rank in terms of export, comprising 14% of total export of Turkey (MOSIT, 2012c). In total, fabricated metal products (Nace code: 25), motor vehicles (Nace code: 28) and machinery (Nace code: 29) industries create 18.9% of added-value within the whole manufacturing industries in Turkey (MOSIT, 2012b).

Metal processing and similar industries with respect to relevant manufacturing processes such as machining, surface finishing and painting have been considered as polluting industries. Some of the reported environmental issues associated with metal processing/products, machinery and automotive sectors are: (i) consumption of large amounts of raw materials and energy (Kong and White, 2010), (ii) generation of toxic/hazardous wastes containing volatile organics, acid/alkali fumes, hexavalent chrome, nickel, and cyanides (Magalhaes et al., 2005; Telukdarie et al., 2006; Sthiannopkao and Sreesai 2009), (iii) generation of wastewater with high biochemical oxygen demand and oil content (Clarens et al., 2008), (iv) generation of hazardous wastewater treatment sludge (Uçaroğlu and Talinli, 2012) and (iv) emissions to air, especially in the form of SO_x and NO_x (European Commission, 2001).

High polluting character holds for related industries in Turkey as well. In Turkey, metal processing/products, machinery and automotive sectors are associated with various environmental problems. Generation of vast amounts of hazardous waste and heavily contaminated wastewaters are of major environmental concerns in these sectors. Metalworking industry is one of the major hazardous waste producer industries in Turkey (MOEF, 2009a; Ulutaş et al., 2012b). According to Salihoğlu (2010) motor vehicles and trailers industries are in the 5th rank among all manufacturing sectors in Turkey in terms of hazardous waste generation. Motor vehicles and trailers are responsible for the generation of 6% of total hazardous waste generation in Turkish manufacturing industries. For motor vehicles industries most critical environmental issue is stated to be the treatment of wastewater containing heavy metals, oil, grease and other contaminants (MOEF, 2004). According to Turkish Statistical Institute (2008) total amount of wastewater generated from fabricated metal products, motor vehicles and machinery industries are about 12,792,000 m^3/year and it was stated that 53.5% of the wastewater is discharged to receiving environments without being treated. Due to these environmental issues, “Turkish Machinery Industry Sectoral Strategy Document and Action Plan” determined “environmental protection” as one of its six targets to be achieved until 2014 (MOSIT, 2011).

It was demonstrated in various studies that sustainable production approach can be adapted in metal processing industries. Several methods/technologies were listed in the literature which resulted in both economical gains and improvements in environmental performance of companies. Some of the applied methods can be listed as: alternative machining technologies, including cryogenic and high pressure jet assisted machining (Pusavec et al., 2010), surface treatment of steel using Zn–Mn phosphating solution in which there was no nitrite (Li et al., 2010), the use of spent caustics to preneutralize spent process baths, optimizing the pickling baths of the hot dip galvanizer, changing the rinsing cascades (Fresner et al., 2007) good process flow, optimized plant layout, good housekeeping (Kong and White, 2010), and recovery of waste heat from various processes (European Commission, 2006a). Some of these applications enabled the companies to save as much as 50% of water and 50 % of process chemicals such as acids.

Although it was indicated through various studies from around the world that resource efficiency can be adapted in metal processing plants, a very limited number of demonstration projects could be realized in Turkish metal processing industry. According to TTGV (2010), some of the most important reasons behind this situation can be listed as the lack of: (i) legislative framework forcing companies take sustainable production measures, (ii) proper cost management practices for some natural resources (e.g. free-of-charge groundwater use), (iii) public awareness/pressure and (iv) financial mechanisms/incentives. This situation hinders the widespread uptake of sustainable production approaches within this sector (Ulutaş et al., 2012a). In order to fill this gap a demonstration project was carried out in a Turkish metal processing company which produces various parts and accessories for motor vehicles. The aim of this study was to investigate alternative sustainable production options in the company in order to improve environmental performance of the company by increasing water use efficiency and reducing chemical consumption.

4.2. Methodology

4.2.1. General Information and Production Processes of the Company

The company was established in Niğde, Turkey in 1972 and is operational in metal processing and machinery sector as a supplier for automotive industry on a covered area of 20,000 m². Employing 358 workers, it produces various parts and accessories for motor vehicles including, tie rod, stabilizer link, ball joint, and V-torque rod. The company holds several quality certificates namely, environmental management system certificate (ISO 14001), automotive suppliers quality system certificate (ISO/TS 16949:2002) and Ford Q1 quality certificate. In 2008, 2009 and 2010 company produced 3,908,449, 2,716,696 and 3,627,434 pieces of products respectively.

The company has consecutive production processes starting with hot/cold forging of raw material where the raw material is shaped through compressive forces (Figure 4.1). Then, the formed workpieces are heat-treated between 780–900°C to attain certain physical properties (e.g. toughness, ductility, hardness). After heat treatment, workpieces are cut into desired final shapes by means of cutting machines in machining facility. Majority of the workpieces are hardened in induction furnaces at 1,050–1,200°C before surface finishing/coating via zinc phosphating process. Zinc phosphating, a type of phosphate conversion coating, is applied for ensuring corrosion resistance and lubricity. Coated workpieces are assembled together before being dyed as the final process prior to quality assurance/control (QA/QC).

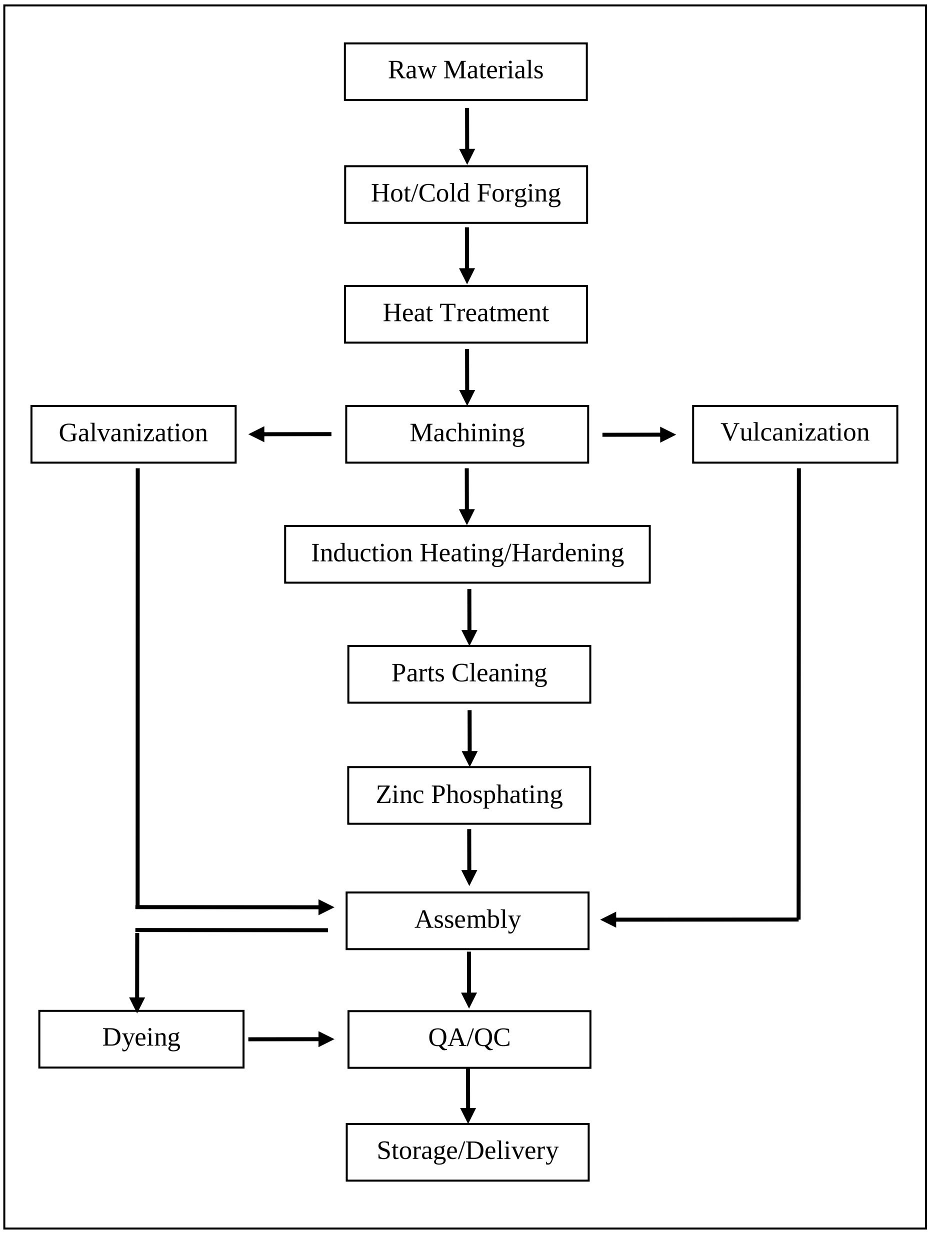


Figure 4.1. Process flow diagram of the company

4.2.2. Data Collection and Environmental Performance Evaluation

Data collection and evaluations were started after an initial walk-through audit in which major production processes and process based water/chemical consumption were determined. Since the objective of the study was to decrease water/chemical consumption as well as to decrease wastewater amount and pollutant load, water/chemical intensive processes were investigated in the company. After several visits and meetings with company officials, a baseline situation was set, collecting 12 months of data covering, annual production amount, resource (e.g. water, chemicals) consumption, waste generation and associated costs in water/chemical intensive processes. Since the company holds ISO 14001 environmental management certificate, associated reporting procedures were rather established in the company. So, company could provide process-based record sheets concerning chemical, water and energy usages besides informative catalogs of equipments and material safety data sheets (MSDS) of chemicals.

Throughout the study, evaluations and reporting was based on specific resource consumption and waste generation data which were determined by dividing respective amounts of consumption/generation by the amount of product. This approach was crucial for both benchmarking and monitoring of environmental performance of the company. Environmental performance of the company was compared (benchmarking) with related literature so as to determine the processes/practices where there is significant improvement potential in terms of environmental and economic performance of the company. It was not possible to evaluate the performance of the company within Turkish metal processing industry as a benchmarking study since no sector specific environmental performance indicators are published in this sector.

4.2.3. Opportunity Assessment for Water/Chemical Savings

Based on environmental performance evaluation, processes/practices which need to be improved in terms of resource consumption and waste generation were determined. Moreover, 5 objectives were set for improving environmental performance and production costs associated with determined processes/practices (Table 4.1). To achieve these objectives, 16 different options were developed.

Table 4.1. Objectives of applications and respective options to achieve

Objectives	Evaluated Options	Reference
Reducing cooling water consumption in heat treatment process	1. Recycle the spent cooling water generated in heat treatment process to main water supply tank of the company	Van Berkel, 2007
	2. Recycle the spent cooling water generated in heat treatment process to the zinc phosphating process	Van Berkel, 2007
Reducing drag-out losses in zinc phosphating process	3. Increase the drip (drainage) time above process baths to decrease drag-outs	Hunt 1988; FDOEP, 2006
	4. Place drain boards between process tanks to prevent drips from workpieces to the floor and recover drag-outs	Dahab and Lund, 1994; Barros et al., 2008; NCDENR, 2009a; RAC/CP, 2002
	5. Shake and rotate the drums for better drainage of solutions	RAC/CP, 2002
	6. Apply compressed air to workpieces during drainage to increase the rate and extent of dripping	Babu et al., 2009
Reducing rinsing water consumption in zinc phosphating process	7. Increase the rinsing time in cold/hot rinsing tanks	European Commission, 2006a
	8. Divide rinsing tanks into two and apply counter current rinsing using two consecutive rinsing stages	RAC/CP, 2002; European Commission, 2006a, Reeve, 2007; Barros et al., 2008
	9. Recycle spent hot rinsing water in previous baths to be used as cold rinsing water	Cagno and Trucco, 2008
	10. Install an integrated automation system for the whole zinc phosphating process	European Commission, 2006a
Reducing evaporation losses and increasing	11. Set lower temperatures for process baths in order to decrease evaporation losses and save energy	Babu et al.2009

Table 4.1. Objectives of applications and respective options to achieve (Continued)

energy efficiency in zinc phosphating process	12. Install covers on top of tanks to prevent evaporation losses of chemicals, water and energy	USAID, 2009a
Increasing chemical process efficiencies and reducing toxic load in zinc phosphating process	13. Increase the operation time periods of process baths to decrease overall chemical consumption	Barros et al., 2008
	14. Establish a regular monitoring scheme for chemical concentrations	Babu et al., 2009
	15. Substitute process chemicals with more environmentally friendly alternatives	Baral and Engelken, 2002; Liu and Ma, 2010; Jiang et al., 2012a
	16. Install stirring equipments into process tanks to increase the rate and efficiency of chemical reactions	Barros et al., 2008

In order to find best possible and applicable solutions for identified issues an opportunity assessment was carried out together with company officials among the options presented in Table 4.1. First step of the opportunity assessment was to determine "assessment criteria". Assessment criteria were determined by referring to 5 studies (Klipova and Bagdonas, 2003; UNEP, 2004; Pandey, 2007; European commission, 2006a; Barros et al., 2008). In these studies it was stated that following criteria should be taken into account when sustainable production options are to be evaluated:

- Environmental requirements, adaptability to employed processes, quality requirements, occupation, health and safety requirements, (Klipova and Bagdonas, 2003)
- Applicability of the technology, economical feasibility, examples of successful applications, level of technology (UNEP, 2004)

- Environmental benefit, complexity of the application, cost saving, scale of innovation, effect on processes/products, (Pandey, 2007)
- Achieved environmental benefits, economics, operational data, applicability, examples of successful applications, cross-media effects (European commission, 2006a)
- Environmental aspects, applicability and characterization, economic aspects, plants where the technique is already implemented, secondary effects (Barros et al., 2008).

Referring to above listed studies, 7 assessment criteria were determined as follows:

- Environmental benefits
- Technical applicability
- Economic viability
- Easiness of implementation
- Long-term sustainability
- Operational and maintenance requirements
- Cross-media effects

4.2.4. Implementation and Monitoring of Selected Options

As a result of the opportunity assessment carried out taking 7 assessment criteria into account, below listed options were selected and implemented as described in the following sections:

- Recycle the spent cooling water generated in heat treatment process to main water supply tank of the company
- Increase the drip (drainage) time above process baths to decrease drag-outs

- Place drain boards between process tanks to prevent drips from workpieces to the floor and recover drag-outs
- Divide rinsing tanks into two and apply counter current rinsing using two consecutive rinsing stages
- Install covers on top of tanks to prevent evaporation losses of chemicals, water and energy

After implementation, resource consumption and waste generation as well as amount of products were monitored and recorded as a monthly basis for 9 months to be able to calculate economic and environmental gains.

4.3. Results and Discussions

4.3.1. Environmental Performance Evaluation of the Company

Although company holds ISO 14001 certificate it was observed that the related requirements are satisfied at a minimum by ordinary environmental reporting and general waste management practices (e.g. wastewater treatment, hazardous waste disposal) also partly due to legislative pressure. However, preventive environmental management practices are not systematically carried out since they are not mandatory. In addition, the company officials, including production managers, engineers and operators, are aware of some sustainable production approaches but did not follow internationally accepted literature and associated best environmental practices (e.g. best available techniques BATs).

Since the company is processing metals by various processes including heat treatment, machining, surface finishing and painting, it consumes considerable amounts of water and chemicals which end up as wastewater. In the company groundwater is used as the single water source without any processing. 48.0% of water is used in heat treatment process for cooling purposes (Table 4.2). In this process cooling is being performed by means of continuous supply of groundwater (once-through cooling) without any recycle/reuse. Since the cooling water did not come into contact with any contaminant, it was discharged to municipal sewerage system without treatment. According to Enderle et al. (2012) cooling can successfully be performed by internal closed-loop cooling cycles which result in substantial reduction in fresh water consumption and wastewater generation in heat-treatment processes employed in automotive industry. Supporting this claim, European Commission (2001) reported that the common practice for heat treatment furnaces is to recycle cooling water completely as closed-loop. These arguments laid down the foundation of the major water saving in the company. Namely recycling of cooling water could be realized in heat treatment process where 2,098 m^3 of water was consumed monthly as the baseline situation.

Table 4.2. Breakdown of water and chemical usage in production processes as the baseline situation

Production processes	Water Consumption		Chemical Consumption	
	(m^3/month)	(%)	(m^3/month)	(%)
Heat treatment	2,098	48.0	-	-
Surface finishing: Zinc phosphating	310	7.1	431	5.3
Dyeing	120	2.7	4,429	69.7
Induction heating/hardening	60	1.4	-	-
Surface finishing: Galvanization	29	0.7	25	0.4
Parts cleaning	13	0.3	57	0.9
Vulcanization	12	0.3	-	-
Others	1,729[a]	39.5	1,505[b]	23.7
Total	4,371	100.0	6,447	100.0

a: Includes evaporation losses, general cleaning and domestic use

b: Lubricating grease, used in the machinery/equipment in various processes

Surface finishing operations including zinc phosphating are regarded as substantial water consuming activities (Telukdarie et al., 2006; Reeve, 2007; Barros et. al, 2008). Indeed, zinc phosphating is among the most water and chemical intensive processes in the company. It was 2nd most water consuming and 2nd most chemical consuming process among other production processes. In addition to that, zinc phosphating is the major wastewater source along with dyeing process. Wastewater generated in zinc phosphating process is mixed with wastewaters from other processes and sent to the wastewater treatment plant of the company. In the treatment plant, wastewater is treated by applying primary and secondary treatment. In primary treatment, suspended solids are allowed to settle in a sedimentation tank and supernatant wastewater is directed to secondary treatment via an open channel. After primary treatment, wastewater is treated chemically as the secondary treatment for enhanced floc formation and eventual precipitation in the secondary sedimentation tank. Since various acids, degreasing chemicals and heavy metals (e.g. zinc) are consumed in this process it is also the major hazardous waste generation process.

Drag-out (the liquid film that covers workpieces and transferred from baths) of water and chemicals is an important environmental issue in the company associated with zinc phosphating process. RAC/CP (2002) states that drag-out is the most significant source of chemical loss from the processing tanks and of rinsing water contamination. One of the main reasons for high drag-out rates is short drip-off times allowed above the tanks. As it can be seen in Table 4.3, 4–10 seconds of drip times are applied in the company. These figures are well below the reported values in the literature which suggests 10–30 seconds of drip times for successful drainage of water and chemicals. Another reason for significant drag-out losses is the lack of drain board usage between process baths. Since there is no drain board placed between process tanks some portion of materials are dripped into the floor during transfer of the workpieces from one process tank to another.

Surface finishing of workpieces are carried out through sequential operations of degreasing, pickling, coating and drying by dipping workpieces contained in a drum into process tanks in the company. Between these major operations, single rinsing steps are applied by immersing the workpieces into water tanks. It is stated in numerous studies that rinsing is by far the largest water consuming operation in surface finishing processes (European Commission, 2006a; Telukdarie et al., 2006). Although the figure is changeable due to high fragmented structure of surface finishing processes, rinse waters represent roughly 95% of the total water used (Barros et al., 2008). According to RAC/CP (2002) single rinsing is one of the worst rinse systems that the company can have although it is almost the most widespread practice. Since the rinse-waters carry all the process chemicals from an activity it is also the primary source of waste generated in surface finishing (European Commission, 2006a; Telukdarie et al., 2006).

The term “rinsing ratio” is used for expressing the quality of the rinse which should be determined by companies depending on their quality requirements (RAC/CP, 2002). Since a rinsing ratio is not specified in the company, the actual requirement of rinsing water is not known exactly (Table 4.3). Current practice is to feed the rinsing tanks with constant flowrate of freshwater as overflow without taking any rinsing ratio into consideration. When total specific water consumption in the zinc phosphating process (66.1 L/m^2) in the company is compared with the figures reported in the related literature, it is observed that a considerable water saving potential is present. According to European Commission (2006a) 40.0–50.0 L/m^2 is typical in the sector, while Barros et al. (2008) claims as low as 1.0 L/m^2 is achievable. Specific rinsing water consumption data is also parallel with the previous statement. In other words, the company consumes higher amounts of water (19.5 L/m^2) in order to rinse the same surface area of workpieces reported in the literature.

In the company zinc phosphating operation is carried out in open tanks which result in evaporation losses of chemicals, water and energy. This situation also creates an undesirable environment in terms of health and safety of workers.

Table 4.3. Benchmarking of water consumption and drip-off (hanging) operation in surface finishing processes

Type of Hanging System	Total Specific Water Consumption (L/m^2)	Specific Rinsing Water Consumption[a] (L/m^2)	Rinsing Ratio	Drip Time (seconds)	Specific Degreasing Chemical Consumption (g/m^2)	Specific Pickling Chemical Consumption (g/m^2)	Reference
Rack	-	-	-	10	-	-	Hunt, 1988
Drum	-	-	-	23	-	-	Dahab and Lund, 1994
Drum	-	-	-	10	-	-	Roberts, 1996
Rack/Drum	-	8	500–10,000	-	-	-	RAC/CP, 2002
Rack/Drum	40–50	3–20	2,000–15,000	-	2–90	20–1,010	EC[b], 2006
Rack/Drum	-	-	-	10-30	-	-	FDOEP, 2006
Rack	-	-	2,000–5,000	10	-	-	Fresner et al., 2007
Rack/Drum	1–500	-	-	-	-	-	Barros et al., 2008
Rack/Drum	-	-	-	10	-	-	NCDENR, 2009a
Rack	-	-	-	10–20	-	-	USAID, 2009a
Drum	66.1	19.5	Not specified	4–10	12.5	37.2	This Study

a: Calculated per rinsing tank used

b: European Commission

4.3.2. Reducing Cooling Water Consumption in Heat Treatment Process

Van Berkel (2007) reported that a car part manufacturer company reduced cooling water consumption by half in heat treatment process installing a closed-loop recycling system. As a similar approach in this study, a recycling system was introduced in order to store and pump the spent cooling water generated in heat treatment process into the main water storage tank of the factory. The implemented system consists of a storage tank, submersible pump and piping equipment.

A vertical water storage tank made of polyethylene was installed to store cooling water rejected from heat treatment line. It operates as a batch-wise system within its storage capacity of 5 m^3. A submersible pump (WILO TWU 4-1615-C, 4kW power, 4–14 m^3/h pumping capacity, 65–90 m working head) was installed into the water storage tank to pump the collected cooling water. American Iron and Steel Institute (AISI) 304 grade stainless steel water pipes and connectors were used for water transmission between cooling water storage tank and main water supply tank of the factory.

As depicted in Figure 4.2 after installing the water recycling system water discharge was eliminated in heat treatment process which was calculated as 6.44 L/piece of product produced before applications. By this application an average of 2,211 m^3/month water was saved in the monitoring period. The decrease in cooling water consumption led a significant decrease in total water consumption of the company from 13.42 L/piece of product to an average of 8.85 L/piece of product after applications.

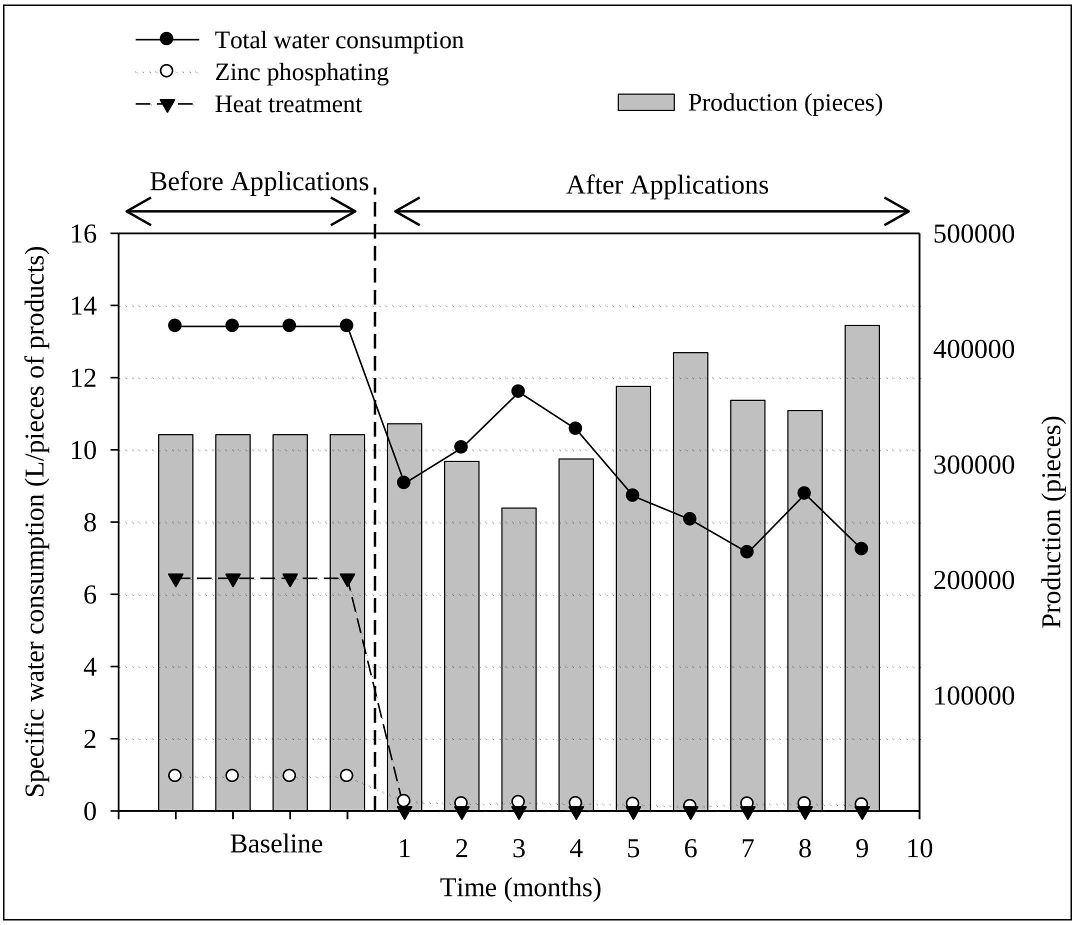


Figure 4.2. Change of specific water consumption as a result of applications

4.3.3. Reducing Drag-out Losses in Zinc Phosphating Process

For different rinsing practices a simplified relation between rinsing water requirement (Q), rinsing-ratio (D_r), drag-out rate (q) and number of rinsing stages (n) is given in Eq 4.1. Relation between concentration of chemicals in process solution prior to rinsing (C_o) and concentration of process chemicals in last (n^{th}) rinse tank (C_n) is given in Eq 4.2 (European Commission, 2006a).

$$Q\ (m^3/h) = q\ (m^3/h) \times (D_r)^{1/n} \qquad \text{(Eq 4.1)}$$

$$D_r\ (\text{unitless}) = C_o/C_n \qquad \text{(Eq 4.2)}$$

According to Eq 4.1, apart from changing the rinsing configuration, drag-out reduction is the other way of water saving in surface finishing operations. Besides water saving, chemical losses are targeted to decrease chemical consumption and pollutant load of wastewater. So as to achieve these objectives first measure was to increase drip times above process tanks. It was reported in the literature that 15 seconds increase in the drip time may reduce the drag-out by as much as 50% (FDOEP, 2006). Hunt (1988) calculated 70% of reduction in drag-out when 10 seconds of drip-time was practiced instead of 1 second. As it is tabulated in Table 4.2 up to 30 seconds of drip times are practiced in various surface finishing operations. Accordingly current drip time of 4–10 seconds was increased to 30 seconds to allow better dripping in the zinc phosphating process. Another measure to reduce drag-out losses was to install drainboards between all process tanks in zinc phosphating process. Suggested in various studies, placing drainboards prevent chemicals from dripping into the floor simultaneously reducing chemical consumption and water requirements in rinsing steps (Dahab and Lund, 1994; Barros et al., 2008; NCDENR, 2009a; RAC/CP, 2002).

4.3.4. Reducing Rinsing Water Consumption in Zinc Phosphating Process

Rinsing water requirement is closely related with the rinsing ratio and drag-out losses. According to Eq 4.1, it is possible to decrease rinsing water requirement without compromising rinsing quality (rinsing ratio) either by increasing the number of rinsing stages (multiple rinsing) as cascade rinsing or decreasing drag-out. Full-scale applications from different surface finishing plants proved that replacing single rinsing with multiple stage counter-current rinsing is a very successful measure for water saving without decreasing rinsing-ratio (European Commission, 2006a; Reeve, 2007; Barros et al., 2008). Hunt (1988) claims that 90-97% of water use can be reduced by introducing two counter current rinse tanks instead of single rinse. Similarly, NCDENR (2009a) advocates that rinse water consumption can be reduced more than 90% by adding a second counter flowing rinse to a single rinse tank. Based on these discussions, partitions were installed in three existing rinse tanks of the company in order to set up a counter-flow multiple rinsing by introducing post-rinsing stages (Figure 4.3). Introduced system operated in way that fresh water is fed into the post-rinsing tank. Then, the contaminated rinse water was fed into rinsing tank as the opposite direction of the rinsed workpieces.

Improving rinsing efficiency is accepted as one of the most significant water reduction alternative for surface finishing processes (NCDENR, 2009a). In the company, implementation of multi-stage counter-current rinsing reduced the specific water consumption of total specific zinc phosphating water consumption by 80.4% or from 0.95 to 0.19 L/piece of product on average (Figure 4.2). In other words, altering rinsing configuration was the primary measure leading to a decrease in water requirement by 261 m^3/month in zinc phosphating process

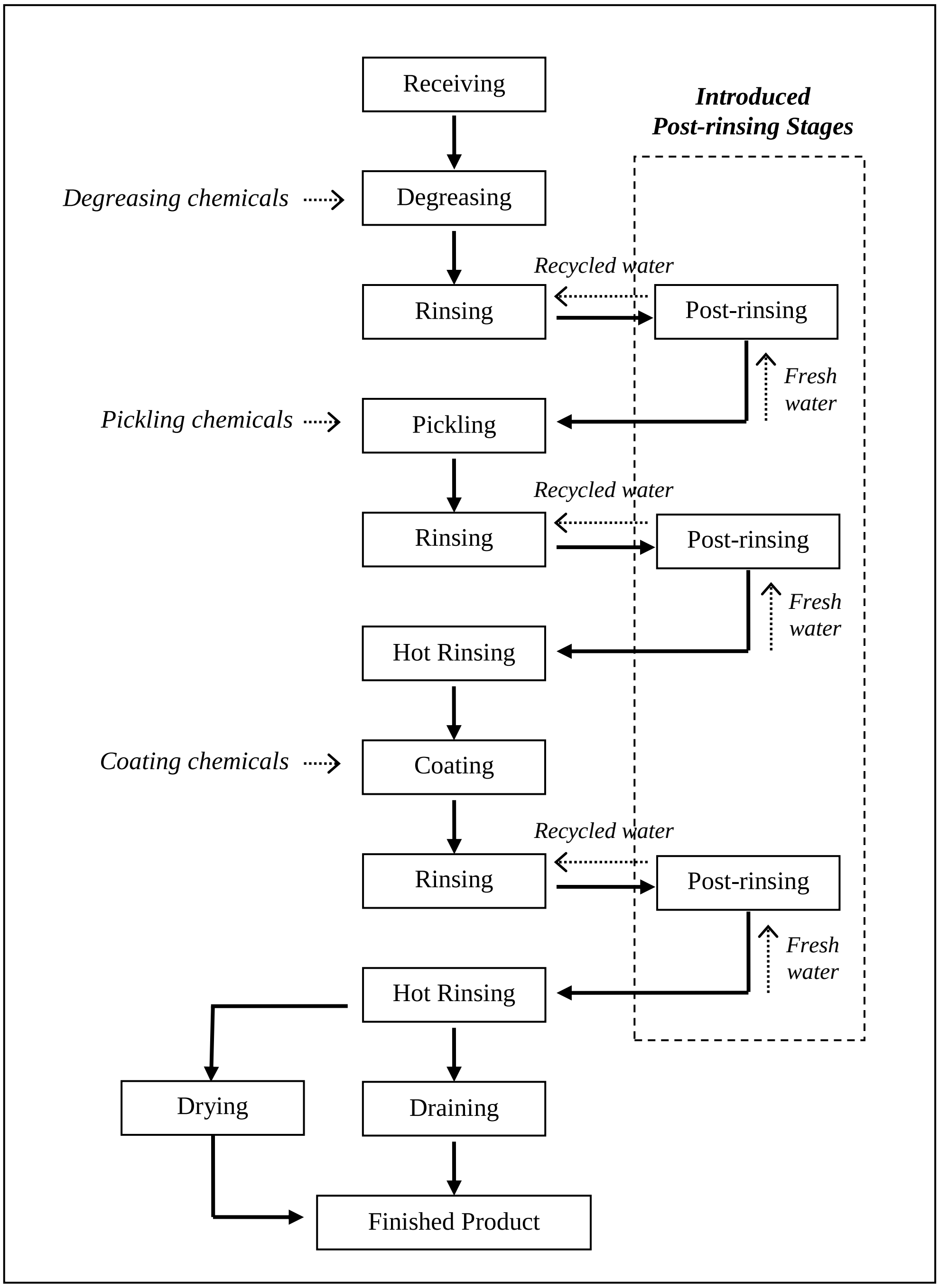


Figure 4.3. Process flow diagram in zinc phosphating after process modifications

As presented in Figure 4.3 three major type of chemicals are in use in the zinc phosphating process, namely (i) degreasing, (ii) pickling and (iii) coating chemicals. Reducing drag-out losses as well as rinsing water consumption resulted in considerable decreases in the consumption of each of these chemical groups (Figure 4.4). When compared to baseline situation, specific degreasing, pickling and coating chemical consumption was decreased respectively by 17.0, 13.0 and 40.2%. As a result, total specific chemical consumption in zinc phosphating process was reduced from 1.32 to 0.98 g/piece of product in average, a reduction of 26.1%. The effect of chemical reduction was also reflected to wastewater treatment sludge generation in the wastewater treatment plant of the company. The specific treatment sludge amount was decreased from 1.36 to 1.13 g/piece of product (16.9%). This decrease accounts for 388 kg/month.

4.3.5. Reducing Evaporation Losses and Increasing Energy Efficiency in Zinc Phosphating Process

Barros et al. (2008) states that heating loss from process baths should be minimized in order to decrease environmental and health risks caused by hot process baths. In addition to that USAID (2009a) claims that covering process baths during idle or down times prevent chemicals from volatilizing. As a result of the opportunity assessment carried out together with company officials it was decided to place covers on top of tanks to prevent evaporation losses of chemicals, water and energy. Covers were manufactured from 2 mm AISI 304 grade stainless steel sheets and mounted on top of tanks enabling closure during idle or down times. In addition to reducing water, energy and chemical usage working environment was improvement in terms of the temperature and volatilized chemicals at the surface finishing facility.

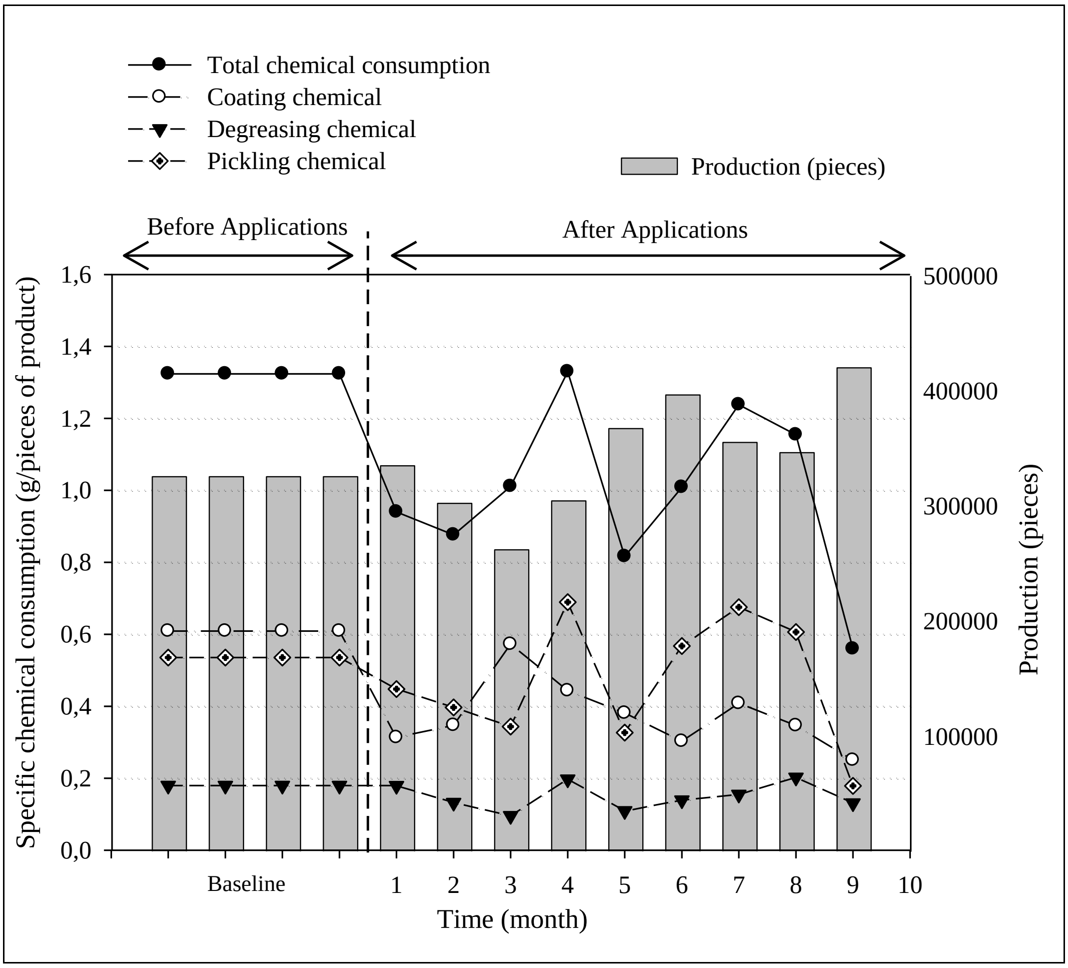


Figure 4.4. Change of specific chemical consumption as a result of applications

4.3.6. Economic Gains and Payback Calculations

One of the most important drivers of the implementations was to achieve cost savings besides improvements in environmental performance. The major economic gain was resulted from the increased efficiency in chemical consumption in zinc phosphating process. 26.1% reduction of chemical consumption decreased the associated costs by 8,442 $/year (Table 4.4). In addition to process chemicals, groundwater supply and wastewater treatment sludge disposal costs were decreased. In Turkey, companies are not charged for groundwater use. So the related cost saving was due the reduced electricity cost which was spent for pumping the groundwater. It is worth noting that reduced volume and pollutant load of the wastewater decreased the wastewater management costs (e.g. wastewater pumping and treatment costs) as well as increasing treatment efficiency in the wastewater treatment plant. Since company operates a wastewater treatment plant of its own it is not charged for wastewater disposal. Still, the applications enabled the company to better comply with the wastewater discharge standards and stay on the safe side of environmental legislations/fines. Total annual cost saving was calculated to be 14,760 $/year by multiplying specific cost saving with annual product production which was 3,627,434 pieces in 2010. During the implementation of sustainable production measures 34,233 $ was spent for the equipments. The equipments were partly financed by UNIDO as a grant of 29,011 $ while the remaining share (5,222 $) was invested by the company. The payback period of the implementations was approximately 2.3 years.

Table 4.4. Cost savings as a result of applications

Cost Item	Specific Cost Saving ($/1000 pieces of products)	Total Annual Cost Saving ($/year)
Process chemicals	2.33	8,442
Groundwater supply	1.41	5,101
Wastewater treatment sludge disposal	0.34	1,216
Total	4.08	14,760

4.4. Conclusions

In this study it was aimed at investigating process modifications and management practices to increase water and chemical use efficiency thus increasing environmental and economic performance of a company from metal processing industry. As a result of environmental performance evaluation, heat treatment and zinc phosphating processes were determined to be high potential processes in terms of resource saving and associated waste/wastewater reduction. Based on an opportunity assessment, following applications were realized in the heat treatment and zinc phosphating processes:

- Recycle the spent cooling water generated in heat treatment process to main water supply tank of the company
- Increase the drip (drainage) time above process baths to decrease drag-outs
- Place drain boards between process tanks to prevent drips from workpieces to the floor and recover drag-outs
- Divide rinsing tanks into two and apply counter current rinsing using two consecutive rinsing stages
- Install covers on top of tanks to prevent evaporation losses of chemicals, water and energy

As a result of the applications, total water consumption of the company was reduced by 34.1% corresponding to an annual water saving of 18,831 m^3 (Table 4.5). Moreover, total chemical consumption in zinc phosphating as one of the most chemical intensive processes in the company, was decreased by 1,401 kg/year (26.1%). Applications in zinc phosphating process led to a significant decrease in the amount of treated wastewater and wastewater treatment sludge which is labeled as hazardous waste according to national legislations. Total wastewater generation was decreased by 3,255 m^3/year (50.9%) while wastewater treatment sludge was reduced 4,656 kg/year (16.9%). Moreover, energy consumption of the company was reduced by 32.647 kWh/year which corresponds to 36% energy saving in water pumping. In addition to these tangible improvements in the environmental performance of the company, working environment was also improved in terms of health and safety of the workers reducing evaporation of the chemicals and eliminating dripping to the floor. Implementation cost of the applications were 34,233 $ which is expected to paid back in 2.3 years according to calculations.

"Sustainable production" which is based on the concept of creating more goods and services while using fewer resources and creating less waste and pollution is one of the options that Turkish manufacturing industry can apply for climate change adaptation purposes. Along with other resources, water is expected to become scarce in Turkey directly affecting the competitiveness of manufacturing industries, highly depending on it. As one of the resource intensive industries metal processing industry is associated with various environmental problems including high resource consumption and generation of toxic/hazardous wastes in Turkey. This study is expected to fill a gap in Turkey by demonstrating that environmental performance in metal processing industry could be improved by process modifications and better management practices resulting in tangible economic gains. In addition, this study will serve as a building block for climate chance adaptation efforts in Turkey by showing that companies can keep their competitive position when they adapt to produce consuming less.

Table 4.5. Summary of environmental performance of the company before and after applications

Resources/Wastes	Specific Consumption/Emission Values		
	Before Applications	After Applications	Change (%)
Water Consumption (L/piece of product):			
- Heat treatment	6.44	0	- 100.0
- Zinc phosphating	0.95	0.19	- 80.4
- Total water consumption	13.42	8.85	- 34.1
Chemical Consumption (g/piece of product):			
- Degreasing chemicals	0.18	0.15	- 17.0
- Pickling chemicals	0.54	0.47	- 13.0
- Coating chemicals	0.61	0.36	- 40.2
Wastewater (L/piece of product):			
- Total treated wastewater	1.67	0.82	- 50.9
Wastewater Treatment Sludge (g/piece of product):			
- Total	1.36	1.13	- 16.9
Electricity Consumption (kWh/ piece of product):			
- Groundwater supply	0.025	0.016	- 34.1
CO_2 Emissions [a] (g/piece of product):			
- Groundwater supply	14.75	9.44	- 34.1

a:1 kWh Electricity = 590.0 g CO_2

CHAPTER 5

REDUCING WATER AND ENERGY CONSUMPTION IN CHEMICAL INDUSTRY BY SUSTAINABLE PRODUCTION APPROACH: A PILOT STUDY FOR POLYETHYLENE TEREPHTHALATE (PET) PRODUCTION

5.1. Introduction

Chemical industry is indispensable for the growing economy of Turkey during current shift from agricultural- to industrial-based development. In Turkey, with more than 13 billion $ of export, chemical industry has a share of 9.7% in total export of the country (MOSIT, 2012d). In terms of created added-value, the chemical industry is in the 4th place among other manufacturing sectors. In addition to its export capacity and created added-value, the chemical industry is also very important when its contribution to employment (more than 230,000 employees) is taken into consideration (MOSIT, 2013). Turkish chemical industry has a product portfolio composed of variety of products including organic/inorganic chemicals, synthetic fibers, soaps/detergents, pharmaceuticals, fertilizers, essential oils, petrochemicals, paints, cosmetics and personal care products (MOE, 2013b).

Although the chemical industry is of utmost importance in terms of its contribution to the national economy, its negative environmental impacts draw particular attention. According to Turkish Statistical Institute, chemical industry produces 378,341 tons of hazardous waste annually which makes it the single most hazardous waste producer industry in Turkey or 33.3% of total (TSI, 2008a). When the total solid waste production is of concern, the chemical industry is in the 4th place after basic metal, other non–metal mineral products and food industries, being responsible for 6.7% (830,039 tons/year) of total industrial solid waste generation (TSI, 2008b). Apart from hazardous and solid waste production, chemical industry is one of the major water consuming industries. In 2008, chemical industry consumed 67.5 million m^3 of water, corresponding to 5.1% of total industrial water consumption as the 4th most water consuming industry in Turkey (TSI, 2008c). Intensive energy consumption and associated greenhouse gas emissions are other important environmental issues associated with the chemical industry (MOSIT, 2013; Ulutaş et al., 2012b) states that chemical industry consumed 8,755,850 MWh of electricity in 2010. This figure corresponds to 11.0% of total industrial electricity consumption of Turkey.

Above discussed environmental issues seriously affect the competitiveness of the chemical industry. In Turkey it is reported that only 30% of chemical industry SMEs can comply with the environmental norms and standards set out by the European Union (EU), which is a big barrier in front of cross border trade with the EU (MOSIT, 2013; Ulutaş et al., 2011). On the other hand, energy costs can be as high as 60% of total production cost in some subsectors of chemical industry (e.g. soda ash production) (SPO, 2007). High energy, water and raw material prices are listed among the major weaknesses of the chemical industry in various national strategy documents (MOSIT, 2013; SPO, 2007). Thus, Ministry of Science Industry and Technology determined that the adoption of environmentally friendly technologies, best available techniques (BATs) and emission control measures are among the actions which are targeted to be taken until 2016 (MOSIT, 2012d). This strategic decision is also in line with the “Chemical Industry Roadmap” which aims to achieve high efficiency, environmentally conscious and sustainable production before the year 2023 (TUBITAK, 2003b).

According to European Technology Platform for Sustainable Chemistry, chemical and refinement industries are responsible for the abstraction of 50% of all water consumed in manufacturing industry in Europe (SUSCHEM, 2012). In chemical industry it is possible to save water and energy by good-housekeeping practices and process modifications as well as technology changes that result in both increased environmental performance and profitability. Zhang et al. (2012) stated that evaporative condenser cooling technology is applicable in chemical industry offering 50% water and 30-50% energy saving compared to conventional water cooling systems. According to Garcia et al. (2013), water and chemicals can be recovered from wastewaters of chemical industry by pervaporation followed by distillation processes. Abou–Elela et al. (2007) claims that recycling of washing water of reaction vessels (reactors) and closed circuit cooling system for the high–pressure pumps are among cleaner production technologies which result in water saving in chemical industry. In addition, it is possible to reuse the condensate waters in polymerization processes (Zheng et al., 2006). Besides water saving, introducing more efficient motors, variable speed drivers and switch to the most efficient membrane electrolysis process can substantially lower energy consumption in chemical and petrochemical sectors (Saygın et al., 2011). Recovery of waste heat energy from combustion processes are among other generic energy efficiency applications (Shen et al., 2010) while in-depth studies such as selectivity improvements of reagents in chemical reactions using better catalysts in certain chemical reactions (Neelis, 2007) can be listed as process based energy efficiency approaches.

The aim of this study was to investigate potential water saving applications in a chemical plant which could simultaneously reduce energy consumption of the company leading to a cost effective and sustainable solution to intensive resource consumption. Through this study it is expected to fill a gap in Turkish chemical sector by demonstrating a full-scale application with tangible environmental and economic benefits.

5.2. Methodology

5.2.1. General Information and Production Processes of the Company

The firm is established in 1966 in Adana, Turkey. It is active in the chemical products sector (Nace code: C.20.60 - Manufacture of man-made fibers) by producing polyester fibers, filaments, various polymers and intermediate chemicals including thermoplastic polyester elastomers (TPE) and dimethyl terephthalate (DMT). The firm is regarded as one of the biggest polyester producers in the world, employing more than 1,200 employees, operating on a production area of 1,000,000 m^2 and having 750 tons/day DMT production capacity. The company holds ISO 9001 quality management certificate. Annual total production of the company was recorded as 303,048, 298,657 and 469,857 tons for 2008, 2009 and 2010, respectively.

DMT production is achieved in four steps: (i) oxidation, (ii) esterification, (iii) distillation, and (iv) crystallization (Figure 5.1). The production processes starts with the oxidation of paraxyylene (p–Xylene). Then, the generated acid mixture is esterified in the presence of methanol (MeOH). After esterification the crude ester mixture is distilled to remove impurities. At the end of these consecutive processes DMT is crystallized into its final form. DMT is used as the main feedstock for polyethylene terephthalate (PET) production in the polymerization process. In the polymerization process DMT is reacted with monoethylene glycol (MEG) in the presence of catalyst to form PET as the final product. PET chips are melted and spun to produce raw fibers in the polyester fiber production facility of the firm. After spinning, drawing takes place in order to increase the resilience, tenacity and strength of the fibers. Fibers are cut into final shapes before being used for filament production as the final stage of production of the firm.

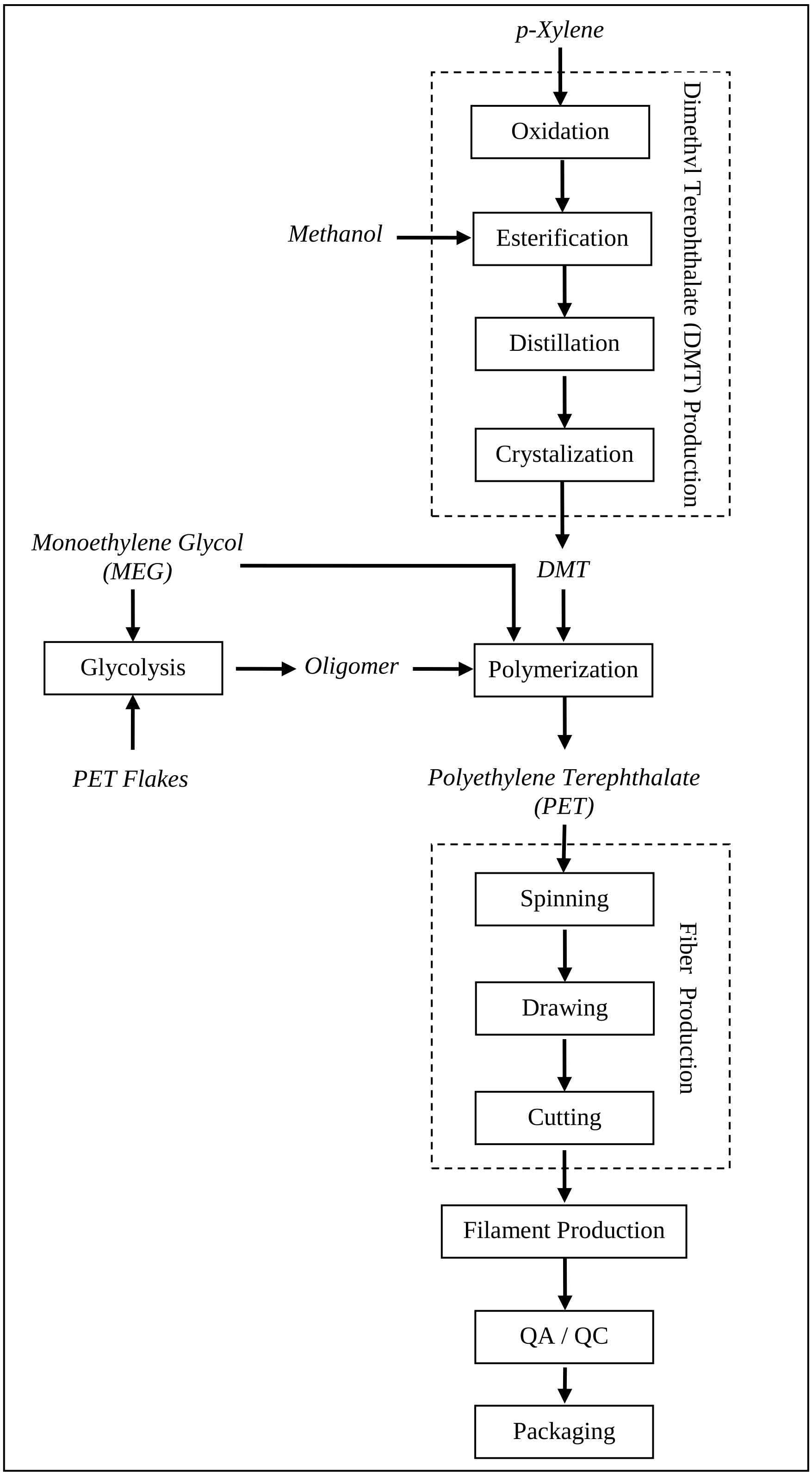


Figure 5.1. Process flow diagram of the company

5.2.2. Data Collection and Environmental Performance Evaluation

An initial walk-through audit was carried out together with company officials before gathering detailed process-based numerical data about water consumption and associated energy use. As a result of this half-day walk-through audit, the process flow diagram of the company was developed by getting information on inputs and outputs of major processes (Figure 5.1). Since the objective of the study was to decrease water consumption and related energy use, only the water intensive processes/practices were investigated in the company. Then, monthly water consumption and corresponding expenditures were compiled from different sources provided by the staff of the company. For this purpose, information sources like process-based record sheets as well as water bills were analyzed. Moreover, informative catalogs of equipments and material safety data sheets (MSDS) of chemicals were used for data collection.

In order to ensure a dependable baseline before water/energy saving applications, the monthly water and energy consumption data was averaged for 2009. Then the average monthly water/energy consumption in 2009 was regarded as the baseline situation throughout the study for comparison purposes. As part of the analyses, environmental benchmarking was carried out by using Environmental Performance Indicators (EPIs) which are specific water/energy consumption and waste/emission generation data (Alkaya and Demirer, 2013a). According to Thoresen (1999) EPIs can be used by industrial enterprises to control performance of processes and set goals as well as benchmark with competitors' performance. In this study EPIs were calculated by dividing water/energy consumption or waste/emission generation data by 1 ton of manufactured product (Environment Agency, 2003). Then, specific resource consumption and waste/emission generation data (e.g. m^3/ton, GJ/ton) was used for analysis/benchmarking of water consumption. In other words water intensive processes/practices were comparatively evaluated with environmentally friendly alternatives referred to in the literature including Best Available Techniques - BATs (European Commission 2001 and 2007a).

5.2.3. Opportunity Assessment and Implementation of Selected Options

Based on the environmental performance evaluation (EPE) processes/practices which need to be improved in terms of resource consumption and waste generation were determined. Moreover, 2 objectives were set for improving environmental performance and production costs associated with determined processes/practices (Table 5.1). To achieve these objectives, 7 different options (6^{th} and 7^{th} options are the same option serving for both objectives) were developed.

Table 5.1. Objectives of applications and respective options to achieve

Objectives	Evaluated Options		Reference
Reducing cooling water consumption	1.	Decrease evaporation and drift losses in water cooling towers	CIRAS, 2005
	2.	Treat and reuse the blow-down as the make–up water for cooling towers (e.g. jet cooling towers)	Panjeshahi, 2009
	3.	Recycle the blow-down to be used for facility cleaning	European Commission, 2001
	4.	Increase the cycles of concentration by reducing the frequency of the blow-down in water cooling towers	European Commission, 2001; Koeller and Company, 2006; Seneviratne, 2007
	5.	Install separate effluent collection systems for cooling tower discharges	European Commission, 2007a
	6.	Substitute water-cooled heat transfer pumps with air-cooled centrifugal pumps	Arneth and Dötsch, 2006; CIRAS, 2005; Environment Agency, 2003; Werner, 2006

Table 5.1. Objectives of applications and respective options to achieve (Continued)

Reducing soft water and energy consumption in heat transfer systems	7.	Substitute water-cooled heat transfer pumps with air-cooled centrifugal pumps	Arneth and Dötsch, 2006; CIRAS, 2005; Environment Agency, 2003; Werner, 2006
	8.	Substitute "EFF-3 Standard Efficiency" class motor mounted heat transfer pumps with "EFF-1 High Efficiency" class motor mounted pumps.	European Commission, 2001

In order to find best solution for identified issues, an opportunity assessment was carried out together with company officials among the options presented in Table 5.1. First step of the opportunity assessment was to determine "assessment criteria". Assessment criteria were determined by referring to relevant studies (Barros et al., 2008; European commission, 2007a; Klipova and Bagdonas, 2003; Pandey, 2007; UNEP, 2004). In these studies it was stated that following criteria should be taken into account when sustainable production options are to be evaluated:

- Environmental requirements, adaptability to employed processes, quality requirements, occupation, health and safety requirements, (Klipova and Bagdonas, 2003)
- Applicability of the technology, economical feasibility, examples of successful applications, level of technology (UNEP, 2004)
- Environmental benefit, complexity of the application, cost saving, scale of innovation, effect on processes/products, (Pandey, 2007)
- Achieved environmental benefits, economics, operational data, applicability, examples of successful applications, cross–media effects (European commission, 2007a)
- Environmental aspects, applicability and characterization, economic aspects, plants where the technique is already implemented, secondary effects (Barros et al., 2008).

Referring to above listed studies, 7 assessment criteria were determined as follows:

- Environmental benefits
- Technical applicability
- Economic viability
- Easiness of implementation
- Long-term sustainability
- Operational and maintenance requirements
- Cross-media effects

As a result of the opportunity assessment, below listed options were selected and implemented as described in the following sections:

- Substitute water-cooled heat transfer pumps with air-cooled centrifugal pumps
- Substitute "EFF-3 Standard Efficiency" class motor mounted heat transfer pumps with "EFF-1 High Efficiency" class motor mounted pumps.

Applications of proposed sustainable production measures were realized stepwise in 2010 during a period of 90 days. The implementation period was 90 days, while it took 75 days to monitor the results of sustainable production applications. So, graphs showing the trend of water consumption before and after applications were prepared for 165 days.

5.3. Results and Discussions

5.3.1. Environmental Performance Evaluation of the Company

As the baseline situation (year 2009) 181,921 m^3/month of water was consumed in the company as process water and cooling water (Table 5.2). Water was also used for other activities such cleaning and domestic purposes at lower amounts (4.1% of total consumption). Groundwater is the only water source of the company which is used primarily for cooling of equipments in almost all of the processes without any pretreatment comprising 61.4% of total water consumption. On the other hand groundwater is pretreated via an ion exchange system to be used as soft water in all of the processes as process water. Soft water is also used for cooling of heat transfer systems which are in operation to transfer heat transfer oils at 300-350 ^{o}C to the processes where heat is required. In this operation 27,025 m^3/month (8.1%) soft water was used instead of groundwater to prevent scaling in the heat transfer pumps. Thus, 70.8% of the water consumption of the company is due to cooling needs in various processes. According to Seneviratne (2007), cooling water may account up to 85% of total water consumption in a chemical plant. So, based on this information resource efficiency measures targeting cooling water consumption will reduce total water demand of the company significantly as it is the case for similar plants in chemical sector.

Table 5.2. Breakdown of water consumption in production processes as the baseline situation

Production processes	Water Consumption (m^3/month)	Specific Water Consumption (m^3/ton product)	Percent of Total Water Consumption (%)
DMT production	22,831	0,92	12.5
Polymerization (batch)	5,991	0,24	3.3
Polymerization (continuous)	5,733	0,23	3.2
Fiber production	282	0,01	0.2
Filament production	921	0,04	0.5
Cooling [a]: -with groundwater	111,683	4,49	61.4
- with soft water [b]	27,025	1,09	14.9
Others	7,455	0,30	4.1
Total	181,921	7,31	100.0

a: Sum of the cooling water amounts used in all of the production process (e.g. DMT production).
b: Consumed in heat exchange systems for cooling purposes

Table 5.3 presents the specific resource (water and energy) consumption and waste generation data of the company comparatively with the literature. European Commission (2007a) states that it is possible to produce 1 ton of PET through DMT process by consuming 0.1–2.2 m^3 of water. However, the company consumes 7.3 m^3 of water for ton of PET produced with DMT process. This finding is regarded as the first evidence that significant water saving is possible in the company. Supporting this claim, the specific cooling water consumption of the company (5.6 m^3/ton) was higher than the reported values in the literature for producing various polyesters (0.5–2.5 m^3/ton). Since the cooling is by far the highest water consuming activity of the company, this fact also explains the excessive total water consumption.

When it comes to energy consumption, company operates within the reported data range in the literature with its 4.2 GJ/ton of specific energy consumption (Table 5.3). However, EC states that as low as 2.5 GJ/ton of specific energy consumption in DMT based PET production is achievable when proper energy efficiency measures are taken (European Commission, 2007a). Energy efficiency measures can be seen as indispensible for the company in terms of cost saving since the energy expense corresponds to 16.7% of total expenditures and the only increasing cost item (3.7% increase) of the company between 2008 and 2009. For comparison; raw materials decreased 10.5% while labor costs and other costs decreased respectively by 26.5% and 8.7% during the same period in the company. Generated wastewater amount (5.5 m^3/ton product) and organic load it carries (34.4 kg COD/ton product) are also among major environmental issues of the company. The literature indicating that wastewater generation as low as 0.8 m^3/ton is possible is another indication of excessive water consumption and related wastewater generation in the company under investigation (European Commission, 2007a). Organic load of the generated wastewater is considerably higher than other PET producers (2–16 kg COD/ton product) including facilities running DMT based processes. Since the company operates a wastewater treatment facility which comprises consecutive physical treatment (screening, sedimentation etc.), biological treatment (aerobic and anaerobic) and sludge stabilization units, reduced wastewater quantity and pollutant load will ensure significant reduction in the operational costs.

Table 5.3. Benchmarking of specific resource (water and energy) consumption and waste generation in polymer production processes

Product	Employed Process	Total Water Consumption (m^3/ton product)	Cooling Water Consumption (m^3/ton product)	Energy Consumption (GJ/ton product)	Wastewater Generation (m^3/ton product)	Wastewater Organic Load [a] (kg COD/ton product)	Reference
PET	DMT based	0.1–2.2	-	2.5–7.4	-	8.0–16.0	European Commission , 2007a
PET	TPA based	0.4–10.0	-	2.1–4.5	-	2.0–16.0	
PET	DMT-BPU based	7.5–122.0	-	5.1–11.9	-	3.0–5.2	
GPPS	CSTR or PFR	1.1–1.2	0.5–0.6	1.1–1.8	0.8–6.0	-	
HIPS	CSTR or PFR	1.1–1.2	0.6	1.5–1.8	0.8–6.0	-	
EPS	Batch	3.2–6.2	1.7–2.5	1.8–2.5	5.0–9.0	-	
UP	Polycondensation	1.0–13.0	-	3.5–5.8	-	-	
PVC	Suspension	3.1	-	2.7–4.1	-	-	
PVC	Emulsion	-	-	7.4–11.2	-	-	
LDPE	High pressure	1.7	-	2.9–9.0	-	-	
HDPE	Gas phase or suspension	1.9	-	2.1–5.4	-	-	
LLDPE	Gas phase or solution	1.1	-	2.1–4.1	-	-	
PET	DMT based	7.3	5.6	4.2	5.5	34.4	This Study

a: Before being sent to the wastewater treatment plant (WWTP)

Environmental benchmarking based on process-specific water consumption data shows considerable saving potential as well (Table 5.4). According to European Commission (2007a) 0.1–8.5 m^3 water is consumed in polymerization process for producing 1 ton of PET spinning chips. However, the company uses 12.0 m^3 of water to produce the same amount of PET spinning chips. Since polymerization process is the 2nd highest water consuming process after DMT production (Table 4.2) this comparison points out improvement potential in terms of water use in polymerization process. As tabulated in Table 4.4, it can be speculated that the company performs quite well in fiber and filament production processes. The high performance achieved in these two processes could not be reflected to the total specific water consumption of the company mainly because these processes are only responsible for 0.7% of total water consumption of the company when combined.

Table 5.4. Benchmarking of process–based specific water consumption in PET processing

Type of Product	Employed Process	European Commission, 2007a (m^3/ton product)	This Study (m^3/ton product)
Spinning chips	Polymerization	0.1–8.5	12.0
Staple fibers	Fiber production	1.1–15.0	0.1
Filament yarns	Filament production	0.5–35.2	2.1

5.3.2. Analysis/Benchmarking of Cooling Water Consumption of the Company

Environmental performance evaluation given in the previous section indicated that significant water savings can be achieved in cooling operations as well as other processes. Since cooling operations account for 70.8% of total water consumption of the company a more detailed analysis was conducted for cooling systems. Reduction of water consumption in cooling system is expected to bring additional environmental benefits in the company such as reduced; (i) emissions of cooling water additives, (ii) use of energy in cooling towers, (iii) emissions into air, (iv) noise and (v) wastes due to replacement of cooling tower fill (European Commission, 2001).

In the company, 138,708 m^3/month of cooling water is circulated in open recirculating cooling systems which connects production processes (e.g. polymerization process) and cooling towers where spent cooling waters are cooled down. Nine cooling towers are located within the company to serve to 9 open recirculating cooling systems. Two of these cooling towers (Tower-A and Tower-B) operate differently since they receive 27,025 m^3/month spent soft cooling water from heat transfer systems in addition to other production processes. Operating principles of both of these cooling towers are the same and was depicted in Figure 5.2. Thus, the capacities of these two cooling towers are considerably higher than the rest of the cooling towers and they utilize 43.6 % of total cooling water in the company. Therefore, these two towers are subjected to comparative analyses/benchmarking in order to determine inefficiencies and develop water saving measures (Table 5.5 and 5.6).

As depicted in Figure 5.2, the cooling towers (Tower-A and B) continuously supply cooling water to polymerization process (Line 4) while heat transfer systems are cooled down continuously by means of soft water (Line 5). Since only pure water and volatile impurities evaporate (Line 6), all the remaining non-volatile impurities (e.g. calcium, chlorides, iron and suspended solids) concentrate in the cooling water (Seneviratne, 2007). A constant blow-down discharge of concentrated water (Line 3) and make-up of fresh groundwater (Line 1) maintains the required quality/quantity of the cooling water.

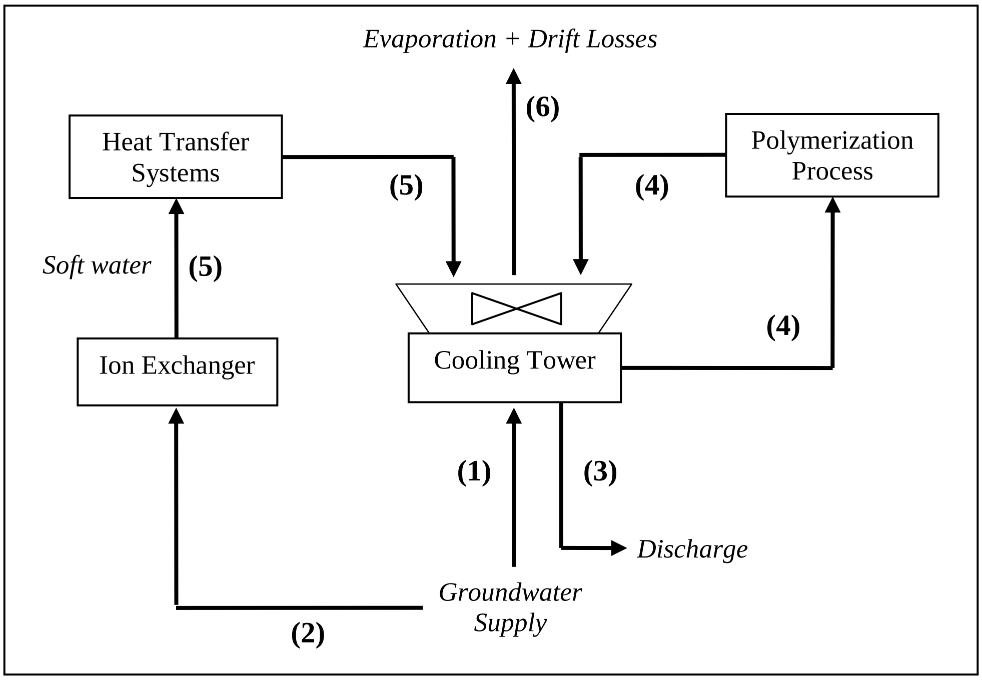


Figure 5.2. Schematic diagram of water circulation in cooling towers “Tower-A” and “Tower-B”

Table 5.5 shows that the cooling water recirculated in Tower-A (Line 4) has higher concentrations of impurities and associated parameters (e.g. electrical conductivity, total/calcium hardness, chloride) than that of make-up groundwater (Line 1) as expected. When Tower-A and B are compared in terms of the characteristics of recirculated cooling water (Line 4), it is noted that Tower-B has remarkably lower concentrations of impurities even lower than that of make-up groundwater (Line 1). This situation can be explained by the contribution of spent soft cooling water to the respective cooling towers. In Tower-B spent soft cooling water with very low concentration of impurities contributes to 68.6% of total water input while in Tower-A contribution of spent soft cooling water is only 28.8%. This result shows that in Tower-B high rates of spent soft water introduction dilutes the cooling water quality parameters at lower levels than required.

Table 5.5. Quantity and characteristics of water circulated through cooling towers “Tower-A” and “Tower-B”

Cooling Tower	Tower-A	Tower-B	Tower-A	Tower-B	Tower-A	Tower-B	Tower-A	Tower-B
Parameters	Line (1) Line (2)	Line (1) Line (2)	Line (3) Line (4)	Line (3) Line (4)	Line (5)	Line (5)	Line (6)	Line (6)
Flowrate (m^3/month)	(1) 25,854 (2) 10,458	(1) 7,604 (2) 16,617	(3) 10,585 (4) 3,038,625	(3) 12,410 (4) 1,533,000	10,458	16,617	25,727	11,811
Elect. Conductivity (µS/cm)	770	770	2,900	860	550	550	–	–
Total Hardness (mg/L $CaCO_3$)	306	306	912	150	14	14	–	–
Ca^{+2} Hardness (mg/L $CaCO_3$)	212	212	455	78	5.4	5.4	–	–
Suspended Solids (mg/L)	0–1	0–1	100	100	0–1	0–1	–	–
TOC (mg/L)	0.72	0.72	40	22	1.28	1.28	–	–
COD (mg/L)	0	0	25	25	0	0	–	–
Cl^- (mg/L)	85	85	390	150	71	71	–	–
Total Fe (mg/L)	0.02	0.02	0.40	0.50	0.04	0.04	–	–
PO_4-P (mg/L)	0	0	3.3	2.0	0	0	–	–
pH	7.6	7.6	8.4	8.4	9.6	9.6	–	–

Cooling water management practices in Tower-A and B were evaluated comparatively with the related literature through the benchmarking study as shown in Table 5.6. Various studies conducted on cooling towers indicate that the cycles of concentration (CR) is maintained between 2.0–6.0. CR is the ratio of concentration of any particular solute (e.g. chloride) in the recirculating cooling water (C_{cw}) to that in the make-up water (C_{mu}) (Eq 5.1) (Zhai and Rubin, 2010). According to Panjeshahi (2009), most of the cooling towers are designed to achieve a cycles of concentration of 3. In Tower-A cycles of concentration of 3.8 (based on electrical conductivity) is an indication of a balanced operation of the cooling tower. On the other hand cycles of concentration value of 1.1 is an indication of excessive water consumption. It is advocated in various studies that to reduce water and chemical usage in cooling water systems cycles of concentration can be increased by minimizing blow-down (European Commission, 2001; Koeller and Company, 2006; Seneviratne, 2007) or by introducing different water reuse options (You et al., 2001).

$$CR \text{ (unitless)} = C_{cw} \text{ (mg/L)} / C_{mu} \text{ (mg/L)} \qquad \text{(Eq 5.1)}$$

Specific make-up water use is also higher in Tower-B (3.4 $m^3/h\text{-}MW_{th}$) compared to Tower-A (2.6 $m^3/h\text{-}MW_{th}$). Bloemkolk (1997) states that 2.0 m^3/h of make-up water is used for 1 MW_{th} cooling rate. So both cooling towers consume higher rates of make-up water, Tower-B being the highest. On the other hand, both cooling towers operates within limits (0.54–2.88 $m^3/h\text{-}MW_{th}$) when specific rate of blow-down is of concern. Finally, benchmarking of electrical conductivity, total hardness and Ca^{+2} hardness values of cooling towers proves that the recirculated cooling water in Tower-B is diluted much below the tolerated levels of these parameters in similar cooling systems. This finding supports the argument that excessive spent soft cooling water is introduced (Line 5).

Table 5.6. Benchmarking of cooling water management practices in cooling towers “Tower-A” and “Tower-B”

Cycles of Concentration	Specific Make-up Water Use (m^3/h-MW_{th})	Specific Rate of Blow-down (m^3/h-MW_{th})	Electrical Conductivity[a] (µS/cm)	Total Hardness [a] (mg/L $CaCO_3$)	Ca^{+2} Hardness [a] (mg/L $CaCO_3$)	Reference
3.0–5.0	-	0.54–2.88	-	-	-	European Commission, 2001
2.0–4.0	2.0	-	-	-	-	Bloemkolk, 1997
2.0–3.0	-	-	1,894	620	390	Wang et al., 2008
3.0–6.0	-	-	up to 6,000	up to 1,000	-	You et al., 1999
3.0–6.0	-	-	-	-	-	Koeller and Company, 2006
4.0	-	-	-	-	-	Zhai and Rubin, 2010
-	-	-	-	-	100–1,000	Seneviratne, 2007
3.8	2.6	0.8	2,900	912	455	Tower-A (This Study)
1.1	3.4	1.7	860	150	78	Tower-B (This Study)

a: Concentrations in recirculated cooling water (Line 4)

5.3.3. Substituting Water-cooled Heat Transfer Pumps with Air-cooled Centrifugal Pumps

"Analysis/Benchmarking of Cooling Water Consumption of the Company" section of this study indicated that spent soft cooling water which is fed to Tower-B is excessive and can be reduced without compromising the cooling system efficiency. In addition, a decrease in the amount of soft cooling water input to the Tower-B will reduce the total cooling needs and associated energy/chemical consumptions in the tower. The company employs 4 heat transfer systems for circulating heat transfer media, the thermal oil (up to 350 °C), to the processes where heat is required. Totally 19 heat transfer pumps are in operation which pump the thermal oil and have varying electrical power of 2–45 kW each. Soft water is used for cooling these heat transfer pumps to prevent any fouling.

It is stated in the literature that water cooling should be reconsidered where air can be used as an alternative cooling medium in the cooling systems (Environment Agency, 2003; European Commission, 2001). According to CIRAS (2005), the amount of equipment that cooled by water must be reduced in chemical industry by using more advanced, less heat sensitive materials. Indeed there are commercially available heat transfer pumps which rely on airstream for cooling purposes and do not require any water (Arneth and Dötsch, 2006; Werner, 2006). Based on these discussions, 6 different types of soft water cooled heat transfer pumps (11 of total 19 pumps) were replaced with air-cooled pumps in order to reduce soft cooling water consumption in heat transfer systems. Installed pumps are of horizontal volute centrifugal type and operate as single-flow and single-stage with optimized bearing support (consisting of housing cover including throttle/cooling section and bearing support).

Since the major objective of the substitution of heat transfer pumps was to decrease water consumption of the company, soft cooling water consumption was monitored for 165 days (Figure 5.3). As a result of elimination of cooling water use in 11 of 19 pumps soft cooling water consumption was reduced in each of the 4 heat transfer systems. Through this application total specific soft cooling water consumption in heat transfer systems was reduced 46.7% from 1.09 to 0.58 m^3/ton product manufactured. Thus, the total soft water consumption of the company was decreased from 62.783 to 50,164 m^3/month (20.1%).

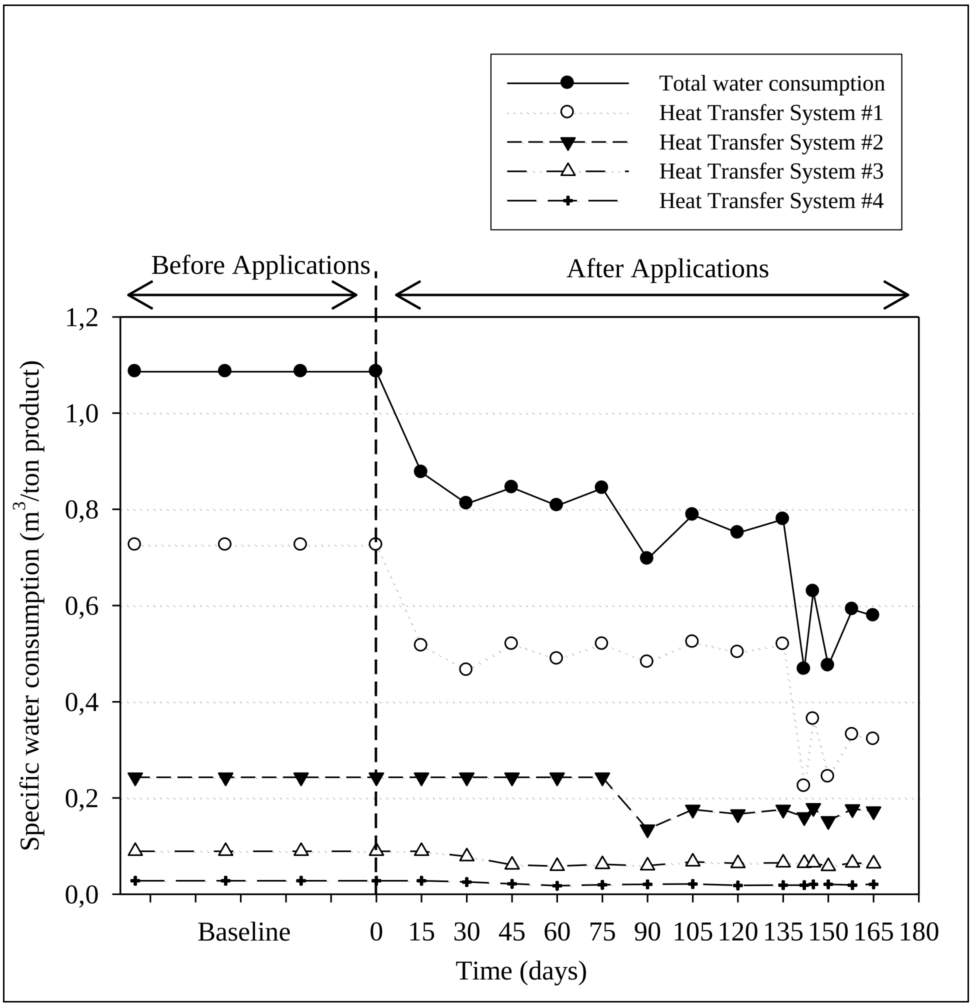


Figure 5.3. Specific soft cooling water consumption in heat transfer systems before and after applications

The electric motors of the removed pumps were labeled as “Eff-3: Standard Efficiency” according to voluntary labeling scheme set by European Committee of Manufacturers of Electrical Machines and Power systems (CEMEP). However, the electric motors of installed pumps are labeled as “Eff-1: High Efficiency” in terms of energy consumption. As presented in Table 5.7, the substitution of the pumps resulted in 40,848 kWh/year of energy saving due to increased efficiency in electric motors of the pumps. The decrease in electricity consumption resulted in reduced indirect carbon emissions resulted from heat transfer systems by 24,100 kg CO_2/year.

Table 5.7. Comparison of removed and installed pumps in terms of energy usage and seal cost

Heat Transfer Pumps	Quantity of Pumps	Total Power (kW)	Energy Use Efficiencies			Carbon Reduction [a] (kg CO_2/year)
			Removed Pumps (%)	Installed Pumps (%)	Energy Saving (kWh/year)	
Type-A	2	90	92.5	93.9	11,038	848
Type-B	3	45	89.4	91.3	7,490	4,419
Type-C	1	75	93.6	94.6	6,570	3,070
Type-D	2	80	92.0	93.3	9,110	5,375
Type-E	2	4	84.2	88.3	1,437	6,512
Type-F	1	33	91.4	93.2	5,203	3,876
Total	11	327	-	-	40,848	24,100

a: 1 kWh electricity = 590.0 g CO_2

5.3.4. Economic Gains and Payback Calculations

In addition to environmental benefits like water resource conservation and carbon emission reductions, applications brought significant economical returns to the company (Table 5.8). Cost reduction was achieved primarily in the soft water generation system, the ion exchange unit, where 0.52 $ is spent per m^3 of soft water produced. Since total annual soft water saving was calculated as 151,428 m^3, company reduced related costs by 78,152 $/year. As discussed previously, energy is one of the major cost items of the company. 40,848 kWh/year of electricity saving in electric motors were coupled with 77,000 kWh/year electricity saving in pumps/fans of cooling Tower-B. Owing to total 117,848 kWh/year energy saving company saved 12,074 $/year.

Auxiliary material consumption was also reduced in the company. The reason is that the removed pumps were equipped with mechanical seals which should be replaced in 6-24 months by regular maintenance to prevent liquid penetration between the moving shaft and stationary casing. However, the installed pumps require less maintenance and have longer service life (24 months) due to their different design (e.g. mechanical seals are located behind heat barrier, stuffing box with downstream throttle/cooling section). In addition, seals of installed pumps cost less than the seals of removed pumps which improves the economic viability of the investment. European Commission (2001) supports this argument by advocating that maintenance costs for air cooling systems are lower partly because they do not require anti-scaling and mechanical cleaning of the water-contact surface area. Thus, the reduced seal replacement cost of installed pumps brought an annual saving of 14,679 $ to the company.

Table 5.8. Change in resource cost as a result of applications

Cost Item	Change in Specific Resource Cost ($/ton product)	Change in Annual Resource Cost ($/year)
Soft water	– 0.26	– 78,152
Electricity	– 0.04	– 12,074
Seals of pumps	– 0.05	– 14,679
Total	– 0.35	– 104,905

Total annual cost saving was calculated to be 104,905 $/year. Total cost of installed air-cooled heat transfer pumps (11 pumps) were 50,082 $. So, the payback period of the investment was approximately 6 months (0.48 years).

5.4. Conclusions

The aim of this study was to investigate potential water saving applications in a chemical plant which could simultaneously reduce its energy consumption. Thus, a cost effective and sustainable solution to the intensive water and energy of this company would be developed. Processes/practices where groundwater and soft water are being consumed were investigated for potential sustainable production applications. "Environmental Performance Evaluation" and "Analysis/ Benchmarking of Cooling Water Consumption of the Company" were conducted in order to determine processes/practices where significant improvement potential is present. Based on the analyses 6 different types of soft water cooled heat transfer pumps (11 of total 19 pumps) were substituted with air-cooled pumps in order to reduce soft cooling water consumption in heat transfer systems.

As a result of the applications, soft cooling water consumption was reduced by 46.7% (Table 5.9) which corresponds to a water saving of 151,428 m^3/year. In addition to water, 117,848 kWh/year of energy was saved due to electricity saving in electric motors of pumps (1.2%) of heat transfer systems as well as pumps/fans of cooling towers (7.4%). Owing to the improved energy efficiency, total carbon emissions of the company was reduced by 69,530 kg CO_2/year. Auxiliary material (mechanical seal) consumption was also reduced since maintenance requirements of heat transfer pumps were minimized. Achieved total cost saving was 104,905 $/year while the payback period was calculated as 6 months (0.48 years).

This study is expected to contribute to the efforts devoted to the sustainable exploitation of scarce resources including water and energy sources in Turkey (Alkaya and Demirer, 2013b). Water cooling is a very common practice in many sectors and is by far the largest (59.3% of total) water consuming activity within whole manufacturing industry in Turkey (TSI, 2008c). On the other hand pumping systems account for approximately 20% of the world's demand for electric energy (CIRAS, 2005). Therefore, if the results of this study would successfully be replicated in other sectors where similar utility systems (e.g. heat transfer systems) are in practice, tremendous environmental and economic gains can be achieved. This study will also serve as a building block in Turkey for the integration of climate change adaptation and mitigation approach in industry since water efficiency (adaptation) and carbon reduction (mitigation) is achieved simultaneously.

Table 5.9. Summary of environmental performance of the company before and after applications

Resources/Wastes	Specific Consumption/Emission Values		
	Before Applications	After Applications	Change (%)
Water Consumption (m^3/ton product):			
- Soft water consumption for cooling	1.09	0.58	– 46.7
- Total soft water consumption	2.52	2.02	– 20.1
- Total cooling water consumption	5.57	5.07	– 9.1
- Total water consumption	7.31	6.80	– 6.9
Energy Consumption (kWh/ton product):			
- Electricity in heat transfer systems	11.86	11.72	– 1.2
- Electricity in cooling towers	3.48	3.23	– 7.4
CO_2 Emissions [a] (kg/ton product):			
- Heat transfer systems (electricity)	7.00	6.92	– 1.2
- Cooling towers (electricity)	2.06	1.90	– 7.4
Auxiliary Materials (pieces/year)			
- Mechanical seals for pumps	10	7	– 32.5

a: 1 kWh electricity = 590.0 g CO_2

CHAPTER 6

MINIMIZATION AND VALORIZATION OF SEAFOOD PROCESSING WASTES BY ONSITE RECYCLING AND REUSE

6.1. Introduction

Over the next 40 years it is expected that global population will exceed 9 billion and the demand for food products increase dramatically by more than 60 percent (Place and Meybeck, 2013). This tremendous change has a potential to lead drastic environmental changes particularly on the natural resources since food production and consumption have credible impact on the environment. Videira et al. (2012) stated that the overexploitation and degradation of soil and water resources in many parts of the world are due to intensive food production. In addition to the change in the intensification of the resource consumption, a shift is observed in demand for the type of food products. Freibauer et al. (2011) claimed that rising household income levels in emerging economies is shifting diets towards more protein rich foods (e.g meat, seafood) which stimulates massive production of livestock.

The consequences of aforementioned trend are clearly reflected in seafood and fish production in the world over the last 30 years. Annual global production of seafood has increased at an average rate about 8% since 1980, a growth higher than any other major animal food production (Campbell and Pauly, 2013). According to The Food and Agriculture Organization of the United Nations - FAO (2013), the global seafood production is expected to reach the record level in 2013, reaching to 160 million tones for the first time. It is projected that seafood production will increase to 181 million tones at the end of 2022. During the same period, seafood production is expected to increase even at a higher level in emerging economies from 125 million (81.5% of total world production) to 152 million tones (83.7% of total world production) (OECD, 2013b).

As an emerging economy, Turkey has been facing a rapid development in seafood industry. İzmir Development Agency's - IDA (2013) records indicates that seafood production was almost doubled from 364.661 tones/year (1991) to 703,545 tones/year (2011) over the last two decades in Turkey. Moreover it has experienced a boost in the export of seafood products for the last 9 years from about 96 million $ (2002) to 395 million $ (2011), an increase of about fourfold (Hekimoğlu and Altındeğer, 2012). Turkey currently ranks in the 7th position in terms of total seafood production in Europe. Comprising 32.5% of total amount of seafood capture/production among all species, anchovy has by far the largest share in seafood industry in Turkey (IDA, 2013b).

Due to recent increase in aquacultural and industrial activities (e.g. fish processing) within seafood sector, natural resources are under increasing pressure of overconsumption and pollution. Significant environmental issues associated with seafood processing can be listed as: (i) the consumption of large volumes of water (Bugallo et al., 2013; Casani et al., 2006; Barros et al., 2009), (ii) intensive energy use which contributes to air pollution and climate change (Anh et al., 2011; Cappell et al., 2007; European Commission, 2006b), (iii) generation of wastewater with high organic load (Uttamangkabovorn et al., 2005; Hall, 2010; Morry et al., 2006), (iv) by-product and solid waste production (Knuckey et al., 2004; Bugallo et al., 2012) and (v) odor/aesthetic problems (Anh et al., 2011; Cappell et al., 2007; European Commission, 2006b).

As it was proved through various studies from around the world cleaner (sustainable) production practices (e.g. waste minimization and recycling) can help seafood industry to diminish or reduce its environmental impacts while bringing competitive advantage. Bezama et al. (2012) indicated that six biggest fish processing companies of Chile took part in a cleaner production program for reduced pollution intensity and increased productivity. As a result of waste minimization and recycling activities companies reduced their energy usage by 24%, solid waste generation by 40% and water consumption by 28%. According to Thrane et al. (2009) Danish fish processing companies substantially reduced their environmental impacts during 1989-2005 period by adopting good-housekeeping practices and process modifications. Results revealed that companies reduced their water consumption up to 70% by implementing measures like substituting wet collection of wastes with dry collection and mechanical herring transport instead of waterborne. Anh et al. (2011) advocated that by-products/wastes generated in seafood production industry can be valorized in Vietnam via effective recycling and reuse. The researchers developed a model that maximizes energy use efficiency and minimizes waste generation through eco-agro industrial cluster development. It is proposed in the model that by-products and wastes can be turned into chitosan and animal feed which are valuable products in Vietnamese market.

Although it was indicated through various studies from around the world that the waste minimization and recycling can be adapted in seafood processing plants, no full-scale demonstration projects could be realized in Turkish seafood processing industry yet. In order to fill this gap, this study aims at investigating waste minimization and recycling opportunities in a Turkish seafood manufacturing company and presenting tangible achievements through successful full-scale implementations.

6.2. Methodology

6.2.1. General Information and Production Processes of the Company

The firm was established in 1960 as an agricultural products processing and exporting company in Adana, Turkey. Seafood processing department was started operation within the company in 1975. Since then, seafood processing (Nace code: C.10.2.0 - Processing and preserving of fish, crustaceans and mollusks) has become the major field of activity of the firm. Main products of the company are marinated products (e.g. anchovy, shrimp) and frozen products (e.g. escargot, squid). The processing facility is based on a covered area of 15.000 m^2. Employing 120 workers the firm manufactured 1,362, 1,170 and 1,007 tons of products in 2008, 2009 and 2010 respectively (Table 6.1). As presented in Table 6.1 production of anchovy increased throughout the years and it became major product of the company comprising 60.2 % of total production in 2010.

Table 6.1. Annual amount of manufactured products

Products	2008 (tons/year)	2009 (tons/year)	2010 (tons/year)
Anchovy	169	378	607
Others	1,193	792	400
Total	1,362	1,170	1,007

Although production procedures/practices of the company change based on the type of seafood to be processed and the products to be manufactured, a general process flow scheme could be developed for anchovy which is the major product of company (Figure 6.1). As the initial step of production line, anchovies are received and stored frozen at -10 ^oC to prevent microbial activity before being processed. According to the demand from customers, anchovies are sent from storage area to thawing zone where anchovies are thawed/de-iced by the help of continuous fresh groundwater supply. This step also serves for simultaneous rinsing. Thawed anchovies are then transferred to manual processing line that starts with deheading followed by gutting. In the gutting step belly flap is cut manually and belly cavity is cleaned to remove entrails. By this way entrails are separated from filleted fish. Rinsing of belly cavity as well as final washing of the fish is accomplished after this step, which ends up with filleted anchovies. Then, filleted anchovies are cooked according to various recipes by including some additives (e.g. vegetables, sauce). At the end of the process cooked anchovies are packed and stored frozen until shipment.

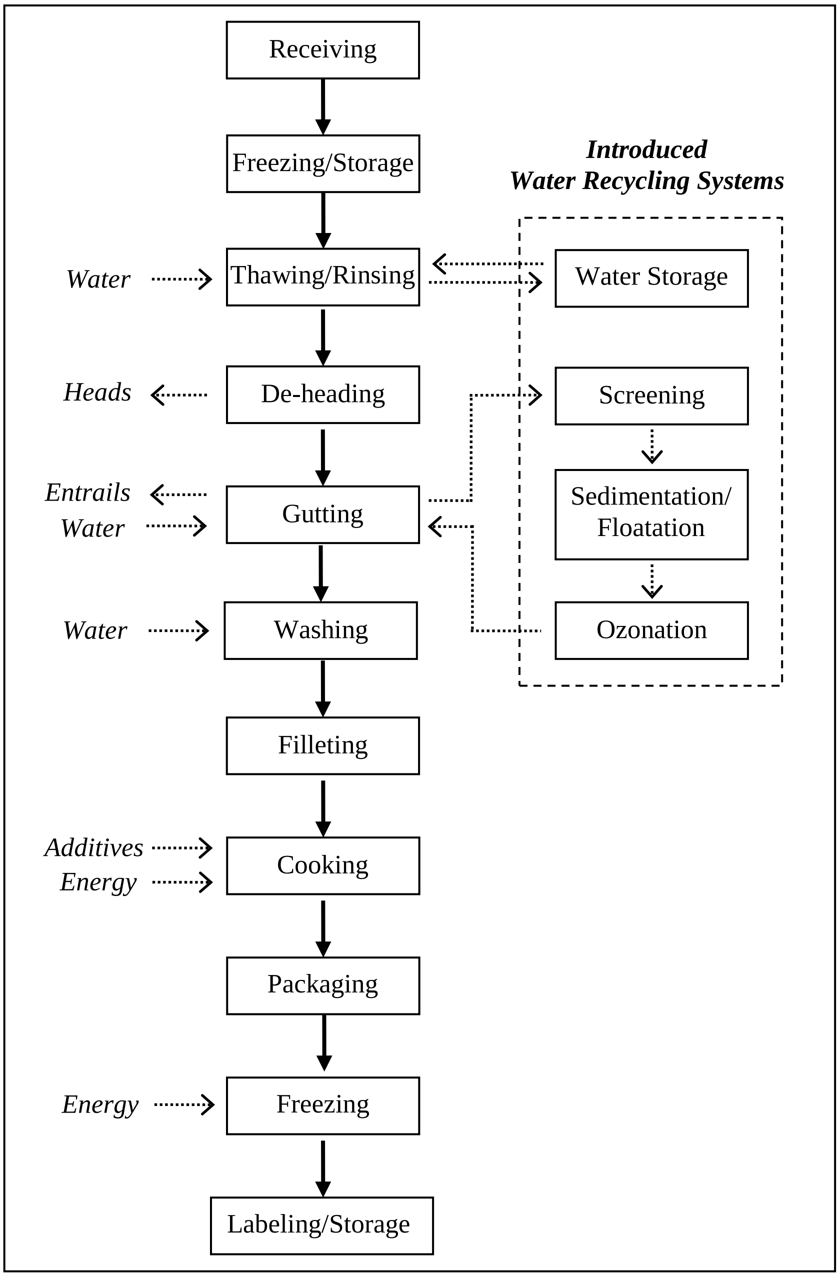


Figure 6.1. Process flow diagram and introduced water recycling systems

6.2.2. Data Collection and Environmental Performance Evaluation

As the initial step of data collection, a half-day walk-through audit was carried out together with company officials. During the walk-through audit inputs/outputs of major processes were determined and process flow diagram of the company was developed (Figure 6.1). Since the primary objective of the study was to investigate waste minimization and recycling opportunities, resource (e.g. water, energy) intensive and polluting processes were focused on. For this purpose process-based numerical data were gathered about water and energy consumption as well as solid waste production in the major processes. Then monthly resource (e.g. water, energy) consumption and corresponding expenditures were compiled from different sources provided by the staff of the company. To this purpose, information sources like water and energy bills as well as process-based record sheets were analyzed.

The baseline situation was developed by using the data gathered from the company for the year 2009 as the starting point before waste minimization and recycling applications. After setting a baseline situation, an “Environmental Performance Evaluation” was carried out for determining the processes/practices where improvements may lead to significant results in terms of environmental performance and cost savings in the company. As described by the International Organization for Standardization (ISO) “environmental performance evaluation is a process to facilitate management decisions regarding an organization’s environmental performance by selecting indicators, collecting and analyzing data and assessing information against environmental performance criteria” (Dias-Sardinha and Reijnders, 2001). Thus, in order to identify the processes/practices which need to be improved in manufacturing enterprises environmental performance evaluation methodologies are being developed and widely used in various sectors (Jiang et al., 2012a). According to Thoresen (1999) environmental performance indicators (EPIs) can be used by industrial enterprises to control performance of processes and set goals as well as benchmark with competitors’ performance. To be able to carry out an environmental benchmarking among similar production facilities reported in the literature namely specific water/energy consumption (e.g. m^3/ton raw material, kWh/ton raw material) and solid waste generation (e.g. ton/ton raw material) were calculated in this study. In other words, the resource intensive and polluting processes/practices were comparatively evaluated with environmentally friendly alternatives referred to in the literature including Best Available Techniques - BATs (European Commission, 2006b).

Based on the environmental performance evaluation and benchmarking, processes/practices which need to be improved in terms of water/energy consumption and solid waste generation were determined. Moreover, four objectives were set for improving resource efficiency and valorizing solid wastes/by-products (Table 6.2). To achieve these objectives, 18 different techniques/measures were developed.

Table 6.2. Objectives of applications and respective techniques/measures to achieve

Objectives	Techniques/Measures to Achieve the Objectives	Reference
Reducing water consumption in production processes	1. Eliminate water use in cleaning by introducing dry cleanup techniques	Barros et al., 2009; Thrane et al., 2009; USAID, 2009b
	2. Transport and remove fats/entrails by vacuum systems instead of water	European Commission, 2006b
	3. Recycle thawing water through a closed-circuit water recirculation system	Archer et al., 2008; European Commission, 2006b
	4. Treat and reuse wastewater generated in gutting process	Bugallo et al., 2013; Cappell et al., 2007; European Commission, 2006b; Hall, 2010; UNEP, 2004
	5. Replace water with compressed air where appropriate	UNEP, 2004
	6. Introduce automated controls for start/stop of water	Bugallo et al., 2013
	7. Install high-pressure low-volume water spray washing systems which also involves nozzles	USAID, 2009b; Uttamangkabovorn, 2005

Table 6.2. Objectives of applications and respective techniques/measures to achieve (Continued)

Reducing energy consumption in production processes	8.	Insulate pipework of heating/cooling systems	Bugallo et al., 2013; UNEP, 2000
	9.	Eliminate leakages in steam transmission systems	UNEP, 2000
	10.	Insulate cooking ovens to eliminate heat losses	Bugallo et al., 2013
	11.	Produce biogas from wastewater to be used as fuel for steam generation	Barros et al., 2009; Bugallo et al. 2013
Developing valuable by-products and reducing waste load	12.	Separate/segregate solids, fats and oils from waste streams for valorization of by-products and reduction of pollutant load	Barros et al., 2009; ETBPP, 1999; Hall, 2010; Thrane et al., 2009
Valorizing solid wastes and by-products	13.	Convert seafood shells into calcium carbonate	Barros et al., 2009
	14.	Produce flours from skins, spines and heads of fishes	Bugallo et al. 2013
	15.	Produce fishmeals from seafood shells and other organic solids	Bezama et al., 2012; Bugallo et al. 2013
	16.	Compost solid wastes in order to produce phosphate rich fertilizers	Knuckey et al., 2004
	17.	Extract chemicals from shrimp shells for producing chitin and chitosan which have various applications in medical sector	Cappell et al., 2007
	18.	Produce pharmaceuticals including collagen and gelatin	European Commission, 2006b

Three applications were selected from the list of resource efficiency and solid wastes/by-product valorization techniques given in Table 6.2 and implemented together with the company officials:

- Recycling the thawing water through a closed-circuit water recirculation system
- Treating and reusing the wastewater generated in the gutting process
- Separating/segregating solids, fats and oils from waste streams for valorization of by-products and reduction of pollutant load

Applications of proposed techniques/measures were finalized in December 2009 after an implementation period of 4 months. Monitoring of the results of water saving techniques/measures lasted 15 months (January 2010 – March 2011).

6.3. Results and Discussions

6.3.1. Environmental Performance Evaluation

Since anchovy is the major product of the company, anchovy processing is the highest water consuming activity. As presented in Table 6.3, anchovy thawing was responsible for 3.000 m^3/month water consumption, which represents 48% of total water consumption of the company. Another production process, anchovy gutting is the process where 29.3% of total water consumption takes place. In other words, anchovy processing comprised 77.3% of total water consumption of the company. This initial analysis indicates that anchovy thawing and gutting are very influential in total water consumption of the company.

Table 6.3. Breakdown of water consumption in the company

Processes	2008		2009 (baseline situation)	
	m^3/month	%	m^3/month	%
Anchovy thawing	1,583	41.3	3,000	48.0
Anchovy gutting	833	21.7	1,833	29.3
Others	1,417	37.0	1,417	22.7
Total	3,833	100.0	6,250	100.0

In addition to water consumption, energy consumption was also analyzed to determine processes/practices which have improvement potential. As presented in Table 6.4, energy consumption was decreased substantially from 554,717 (year 2008) to 307,835 kWh/month (year 2009). This decrease is a direct result of the difference between products produced respectively in 2008 and 2009. As it was tabulated in Table 6.1, anchovy production was more than doubled from 169 tons/year (year 2008) to 378 tons/year (year 2009) while other products decreased during the same period. Anchovy processing is carried out manually without requiring major energy use. Thus company decreased its energy intensity by shifting major production from other products to anchovy through the years. When this information is combined with the data presented in Table 6.3 it can be claimed that increased anchovy processing throughout the years increased water dependence of the company while decreasing overall energy use.

Table 6.4. Sources and amount of energy consumption in the company

Energy Sources	2008		2009 (baseline situation)	
	kWh/month	%	kWh/month	%
Electricity	209,578	37.8	156,751	50.9
Natural Gas	345,139	62.2	151,083	49.1
Total	554,717	100.0	307,835	100.0

According to Table 6.5, the total specific water consumption of the company for anchovy processing (74.9 m^3/ton raw fish) was significantly higher than the reported values in the relevant literature (1.0–32.0 m^3/ton raw fish). On the other hand, processing of other products require much less amount of water (21.5 m^3/ton raw fish) when compared to anchovy processing. A more detailed investigation on anchovy processing indicated that the company consume water very intensively in thawing and gutting processes. Table 6.5 shows that water consumption as low as 0.7 m^3 is enough to thaw 1 ton of frozen fish (Uttamangkabovorn et al., 2005). According to Environmental Technologies Best Practice Programme - ETBPP (1999) up to 16.6 m^3 water may be needed to thaw 1 ton of fish. However in this study specific thawing water consumption of the company was calculated as 28.4 m^3/ton raw fish in anchovy processing. This finding was an indication that the company was not performing well enough in terms of water consumption in thawing process. Indeed the company was using fresh groundwater for thawing frozen anchovies once-through without any recycling or reuse. With specific water consumption of 46.5 m^3/ton raw fish, gutting process requires even more water than thawing process in the company. Relevant literature revealed that 5–11 m^3 water would be enough to gut 1 ton of raw fish (Table 6.5). This benchmarking evaluation showed that an important water saving potential was present in anchovy gutting process. In the company gutting is carried out manually during which water taps are left running and entrails are transported away from the gutting area by means of continuous flume of water. As it was the case for anchovy thawing, gutting process is accomplished without any water recycling or reuse.

As discussed above, anchovy processing demands less specific energy consumption (434 kWh/ ton raw fish) when compared to other products processing (5,554 kWh/ ton product) in the company. When compared with the related literature, it can be stated that specific energy consumption for anchovy processing stands within the range reported in the literature (62–638 kWh/ ton raw fish). Since major product of the company is anchovy and the production other products has been getting less throughout the years, the energy consumption and related carbondioxide (CO_2) emissions are not the major environmental concerns of the company. There is still an improvement potential present, since as low as 62 kWh energy consumption is achievable per ton of raw fish processed according to the literature (UNEP, 2000).

According to the United Nations Environment Programme - UNEP (2000), up to 70% of total processed raw fish (on weight basis) ends up as solid waste in processing plants (Table 6.5). On the other hand, the Regional Activity Centre for Cleaner Production - RAC/CP (2001) advocates that solid waste production can be reduced to %20 of processed raw fish when in-plant waste valorization options are realized. In the company 39–40% of solid waste is produced depending on the product produced. Major solid wastes of the company can be listed as entrails of anchovies, escargot shells, shrimp shells and crab waste which need to be valorized into valuable products.

Table 6.5. Benchmarking of environmental performance of the company with the related literature

Seafood Product	Total Specific Water Use (m^3/ton raw fish)	Specific Water Use in Thawing (m^3/ton raw fish)	Specific Water Use in Gutting (m^3/ton raw fish)	Specific Energy Use (kWh/ton raw fish)	Specific Solid Waste Generation (tons/ton raw fish)	Reference
Jack mackerel	1.8	-	-	117	0.29	Bezama et al., 2012
Herring	1.0–3.4	-	-	-	-	Thrane et al., 2009
Canned tuna	13.0	0.7	-	-	0.38	Uttamangkabovorn et al., 2005
Not specified	8.9	-	-	-	0.55	Nimnu, 1998
Not specified	-	3.7–5.6	-	-	0.66	Knuckey et al., 2004
Canned fish	9.0–16.0	-	-	397	0.47–0.60	Visvanathan, 2007
Not specified[a]	5.0–11.0	-	-	91–638	-	IFC, 2007a
Whitefish	9.5–24.0	-	5.0–7.4	-	-	Cappell et al., 2007;
Not specified[b]	3.3–32.0	1.0	-	-	0.20–0.60	European Commision, 2006b
Not specified	20.4–24.1	-	-	-	0.20–0.50	RAC/CP, 2001
Not specified[c]	1.0–15.0	5.0	5.0–11.0	62–190	0.50–0.70	UNEP, 2000
Whitefish and herring	5.0–24.0	4.5–16.6	5.0–7.4	-	-	ETBPP, 1999
Anchovy	74.9	28.4	46.5	434	0.39	This study
Not Specified[d]	21.5[e]	-	-	5,554[e]	0.40	

a: includes whitefish, herring, mackerel and fish-meal
b: includes whitefish, herring, mackerel and shrimp
c: includes whitefish, herring and tuna
d:includes shrimp, escargot and squid
e: calculated per ton of product

6.3.2. Recycle and Reuse of Thawing/Gutting Process Waters and Segregate Solid Wastes

Environmental performance evaluation indicated that water consumption can substantially be reduced in the company when measures are taken in anchovy thawing and gutting processes. Before water recycling and reuse applications, anchovy thawing was performed on a flat stainless steel platform (one storey), in which water is sprayed from the top to the plastic boxes placed on the platform and filled with anchovies. European Commission (2006b) and Archer et al. (2008) state that thawing water can be recycled and reused by means of a closed-circuit water recirculation system without compromising product quality in the seafood processing industry. Based on this information a water recycling system was introduced in anchovy thawing process (Table 6.6).

Table 6.6. Components of implemented water recycling system in anchovy thawing process

Components of the System	Technical Specifications
Multi-storey stainless steel thawing system	American Iron and Steel Institute (AISI) 304 grade stainless steel was used for manufacturing of the 4-storey thawing system. The system is equipped with showering nozzles to spray the water to frozen anchovies from top of the system. The dimensions of the system are 338 x 150 x 140 cm which enables 60 boxes (900 kg) of frozen fish to be thawed at once. Total weight of the system is 450 kg.
Stainless steel water pump	A mechanical centrifugal pump made of AISI 304 grade stainless steel was installed. By the help of this pump water is continuously recirculated within the multi-storey thawing system (from bottom storage to top nozzles). Pumping capacity and elevation were set as 30 m^3/h and 15 m respectively.
Stainless steel and polyethylene pipes	AISI 304 grade stainless steel pipes were installed between water pump and multi-storey thawing system. Nominal operating pressure of the water pipes was set as 6 bars.
Electrical instrumentation	The applied electrical instrumentation (control panel, cabling etc.) is in compliance with the standards set by Turkish Standards Institution (TSI) for electric appliances.

Table 6.7. Components of implemented water treatment and recycling system in anchovy gutting process

Components of the System	Technical Specifications
Water collection channel	2-mm-thick stainless steel water collection channels were assembled, replacing traditional water transmission systems. The proposed system was manufactured from AISI304 grade stainless steel. Comprising the system open and closed channels collect and transmit wastewater to drum filter.
Screening Unit	A drum filter is used for the screening of suspended matter present in the wastewater. It is made of AISI304 grade stainless steel. Pore size of the filter is 0.1 mm in diameter. Asynchronous motor (3 phase) is operated to rotate the filter at 20-25 rounds/min velocity. Hydraulic capacity of the filter is 50 m^3/h. A mechanical centrifugal pump made of AISI304 grade stainless steel is used to pump the screened water to sedimentation/ floatation unit. Pumping capacity and elevation were set as 30 m^3/h and 10 m respectively.
Sedimentation /Floatation Unit	25 m^3 polyethylene water tank (vertical) is used for the purpose of sedimentation/floatation. A discharge valve (5 cm in diameter) was integrated at the bottom of the tank. Water is fed to tank from the top. Oil and grease separator was installed on top of the sedimentation/floatation tank. It is composed of a rotational stainless steel panel. It separates the oil/grease built up on the surface of the tank resulting from density difference.
Ozonation Unit	A vertical 15 m^3 polyethylene water tank is used as ozonation basin. A discharge valve (5 cm in diameter) was mounted at the bottom of the tank. Water is fed to tank from the top. Ozone generator is an air purifier type. Ozone generation rate was set as 15 g/h. Injection of the produced ozone is practiced by means of diffusers installed at the bottom of the ozonation tank. A mechanical centrifugal pump made of stainless steel (AISI304) is installed to pump the treated water to be recirculated to the gutting line.
Monitoring and Control Unit	The mounted control panel is in compliance with the standards set by Turkish Standards Institution (TSI). The electrical equipments and operation of the whole system is controlled by PLC programming.

In addition to anchovy thawing, gutting process was targeted for decreasing the water use in the company. Various studies from around the world proved that gutting process wastewater can successfully be treated and reused in the same process for water saving (Bugallo et al., 2013; Cappell et al., 2007; European Commission, 2006b; Hall, 2010; UNEP, 2004). In this study, a water recycling system was implemented which was contained the following units: water collection channel, screening unit, sedimentation/floatation unit and ozonation unit (Figure 6.1 and Table 6.7).

As a result of applications, the water consumption of the company was reduced significantly in both anchovy thawing and gutting processes (Figure 6.2). In thawing process specific water consumption was reduced from 28.4 to 10.0 m^3/ton raw fish which corresponds to water saving of 64.9%. In gutting process even higher percentages (77.2%) of water saving could be achieved. In the baseline situation specific water consumption was recorded as 46.5 m^3/ton raw fish which was decreased to 10.6 m^3 per processed raw fish. In total, the water consumption was reduced by 72.6% in anchovy processing line of the company. Since anchovy processing has become the major operation of the company through the years percent of total water saving was calculated as 45.0% (as m^3/ton product).

Another major outcome of the applications was to produce valuable by-product from gutting wastewater in the form of fish oil/grease. Since implemented water treatment and recycling system enables to separate and segregate fish oil/grease from the wastewater, 140 kg/month of fish oil/grease was produced as by-product. Moreover organic load of waste water was reduced by decreasing oil/grease content of the wastewater by 47.3 mg/L.

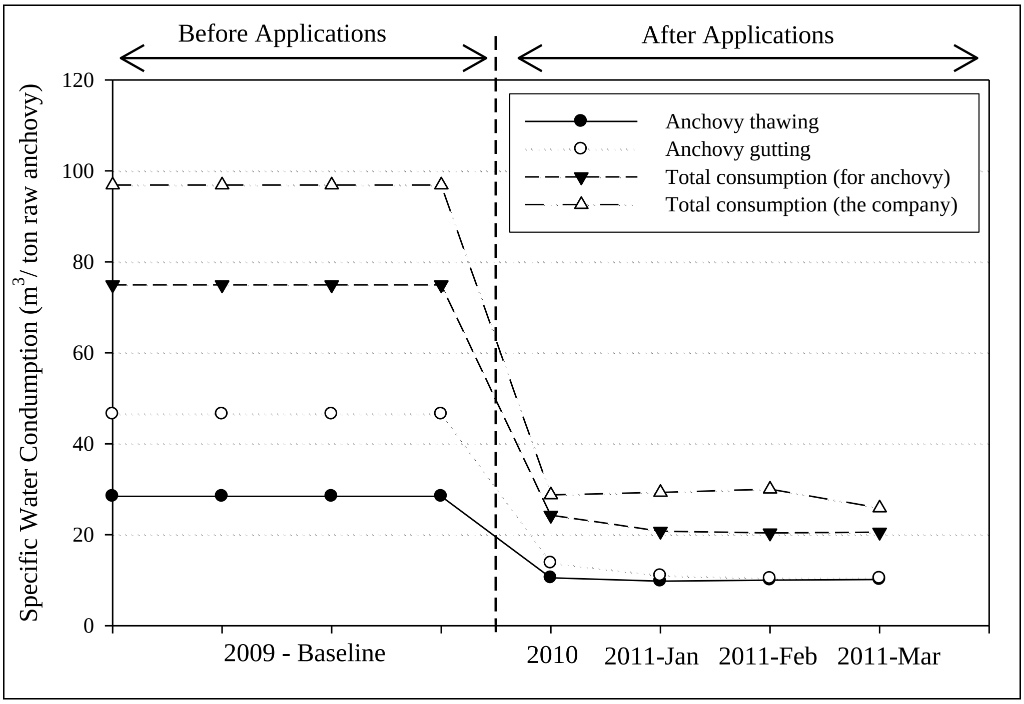


Figure 6.2. Specific water consumption in the company before and after applications

6.4. Conclusions

The major objective of this study was to demonstrate that waste minimization and recycling can be adapted in Turkish seafood processing plants. For this purpose, an investigation was carried out in a company which produces marinated products (e.g. anchovy, shrimp) and frozen products (e.g. escargot, squid). Since anchovy is the major product of the company anchovy processing was focused on. An Environmental Performance Evaluation was carried out in the company for determining the processes/practices where improvements may lead to significant results in terms of environmental performance and cost savings in the company.

Based on environmental performance evaluation and benchmarking study three applications were proposed and implemented in the company:

- Recycle thawing water through a closed-circuit water recirculation system
- Treat and reuse wastewater generated in gutting process
- Separate/segregate solids, fats and oils from waste streams for valorization of by-products and reduction of pollutant load

As a result of waste minimization and recycling applications, the water consumption was substantially reduced in the company. Specific water consumption was decreased by of 64.9% and 77.2% in anchovy thawing and gutting processes respectively (Table 6.8). Since major product of the company is anchovy, applications led to 45.0% of total water saving. Annual total water saving of the company was calculated as 29,002 m^3. Water recycling system introduced in gutting process enabled the company to produce valuable fish oil/grease. In total 76,900 $ was spent for the equipments while 48,175 $ was saved annually due to water and energy saving. Thus, the payback period of implementations was calculated as 1.6 years.

This study indicated that tangible environmental and economic gains can be achieved if waste minimization and recycling applications are successfully realized in seafood processing industry. So, it can be stated that in Turkey companies should carry out environmental performance evaluation and benchmark their performances in order to determine the processes/practices where there is improvement potential. This systematic approach would bring both increased environmental performance and competitive advantage in the whole seafood industry which currently shows a tremendous growing trend in Turkey.

Table 6.8. Summary of environmental performance of the company before and after applications

Resources/Wastes	Specific Consumption/Emission Values		
	Before Applications	After Applications	Change (%)
Water Consumption (m^3/ton raw fish):			
- Anchovy thawing	28.4	10.0	– 64.9
- Anchovy gutting	46.5	10.6	–77.2
- Water consumption (anchovy)	74.9	20.6	–72.6
- Total water consumption[a]	64.1	35.3	–45.0
Energy Consumption (kWh/ton raw fish):			
- Energy consumption (anchovy)	434	409	–5.7
CO_2 emissions (kg/ ton raw fish) [b]:			
- CO_2 emissions (anchovy)	256	241	–5.7
Wastewater Generation (m^3/ ton product):			
- Total wastewater generation	64.1	35.3	–45.0

a: calculated as m^3/ton product

b: 1 kWh Electricity = 590.0 g CO_2

CHAPTER 7

SUSTAINABLE TEXTILE PRODUCTION: A CASE STUDY FROM A WOVEN FABRIC MANUFACTURING MILL IN TURKEY

7.1. 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 (TSI, 2008c). 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 ground water 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 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 twofold: 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 15-79% (European Commission, 2003; NCDENR, 2009b; Shaikh 2009). Moreover wastewater volume reductions up to 70% were reported as a result of sustainable production applications in textile factories (NCDENR, 2009b).

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 (TTGV, 2010; MOIT, 2010; Ulutaş 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.

7.2. 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 Hoquee 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, sulphur 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^{o}C temperature of the first de-sizing agent tank and 90^{o}C temperature for the second de-sizing agent tank and (iii) dipping time of 7 seconds. Applying these conditions more than 89% of the sizing agent was eliminated from production processes.

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 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) claims 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 indicate that the optimized scheme reduced water consumption by 20-30%, wastewater amount by about 20% and production time by 10-15%. In addition to these studies, 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) advocates that the knowledge and awareness on energy efficiency is not yet at desired level in textile producer companies and action should be taken to introduce and implement comprehensive measures in these plants. Thiede et al. (2013) states that a seven-step approach developed for textile industry leads to significant reduction in the energy consumption. These steps are; (i) macro-analysis, (ii) energy portfolio, (iii) measurement, (iv) modeling/analysis, (v) identification (vi) evaluation and (vii) implementation. The approach allows identification of potentials, calculation of key performance indicators and assessment of improvement measures. Application of the approach in a textile company resulted in a 6% reduction of energy consumption. Hasanbeigi and Price (2012) reviewed 184 energy efficiency measures applied in textile industry. According to their research results energy efficiency improvement opportunities could lead energy savings: (i) up to 60% in electric motors, (ii) up to 20% in compressed air systems, (iii) up to 75% in pumping systems, (iv) up to 49% in fan systems, (v) up to 60% in lighting systems and (vi) up to 26% in steam systems. In addition, Hasanbeigi (2010) proposed three emerging technologies in detail which offer significant energy saving and carbon emission reduction in textile wet processing namely, (i) supercritical dyeing technique, (ii) ultrasonic assisted wet-processing and (iii) foam technology.

Improvement of economic performance of companies due to sustainable production approaches were also investigated by several authors. Nishiatini et al. (2011) emphasized the direct relationship between the pollution prevention/reduction and economic performance of firms. The study is based on a theoretical model derived from the CobbeDouglas production function and the inverse demand function. The results of the study show that the prevention approach is more preferable than the control approach in companies by increasing the demand to the company and improving the productivity. Zeng et al. (2010) used structure equation model (SEM) to analyze the relationship between sustainable production and business performance. The model involves path analysis, multiple regression analysis and confirmatory factor analysis. An overall positive impact of sustainable production was determined on business performance. According to the research results, less visible to stakeholders low-cost measures have higher contribution to economic performance in short terms when compared to high-cost measures. Because high-cost measures (e.g. clean technologies) require significant investments which may not result in immediate return. However high cost-measures are more visible to stakeholders and can be easily communicated thus increasing corporate reputation. A study conducted by Schmidt (2010) reveals that the use of materials and energy accounts for about 46% of the gross value of goods produced by companies in Germany. Analyzing 236 projects carried out by German Material Efficiency Agency (DEMEA), the author claims that average saving potential in material cost is approximately 2.5% of the annual sales of small and medium-sized enterprises (SMEs).

7.3. Methodology

7.3.1. General Information and Production Processes of the Company

The company has been producing woven fabrics for woman's clothing in its production facility located in Bursa since 2003. The company employs 147 workers and operates in a covered area of 10.000 m^2. The fabrics produced by the company are of different kinds including polyester, cotton and lycra based. The company holds Oeko-Tex® 100 standard. Annual fabric production of the company was recorded as 1,865, 2,193 and 2,621 tons/year in 2009, 2010 and 2011, respectively.

Both yarns and raw fabrics are used as the raw materials in the company. They end up as finished fabrics after several production processes (Figure 7.1). Yarn is first turned into raw woven fabric by warping followed by weaving. After weaving, raw fabric is prepared to dyeing through singeing, desizing, scouring, bleaching and mercerizing processes. Fabric preparation (pretreatment) is followed by dyeing and finally finishing processes to produce finished fabrics.

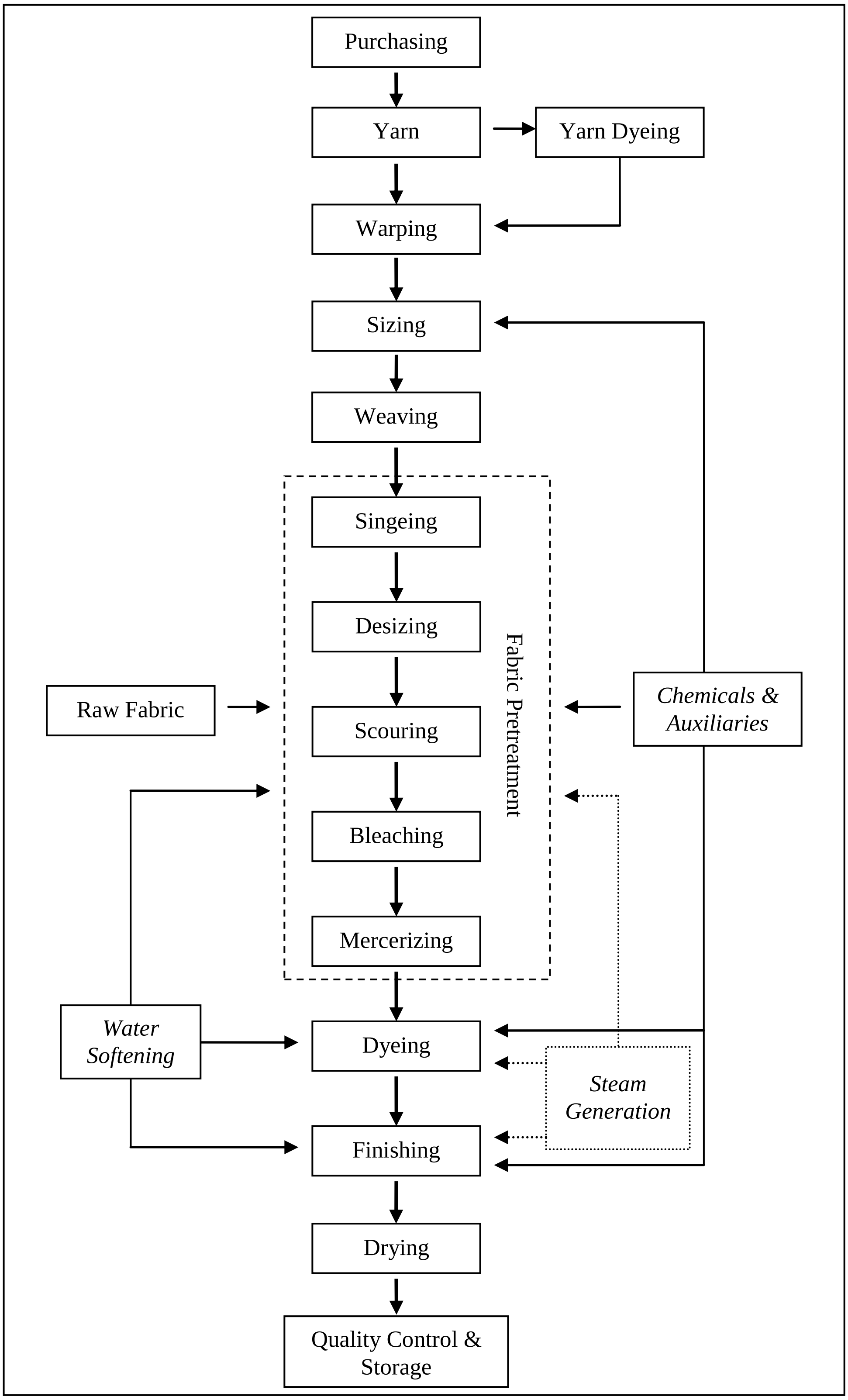


Figure 7.1. Process flow diagram of the company

7.3.2. Data Collection and Environmental/Economic Performance Evaluation

In the framework of this study, data collection was started during the walk-through sustainable production audit in the company which was carried out together with the company staff in late 2010. A project team was established within the company which was composed of general manager, administrative coordinator and a mechanical engineer. During the initial walk-through audit data was gathered about the production processes, products, consumed resources and generated wastes/emissions. After walk through audit company was asked to provide more information about its main production processes. So, based on the data provided by the company, production processes and related environmental concerns were determined.

Environmental Performance Evaluation (EPE) was carried out by using the data collected before sustainable production applications. As described by the International Organization for Standardization (ISO) "environmental performance evaluation is a process to facilitate management decisions regarding an organization's environmental performance by selecting indicators, collecting and analyzing data and assessing information against environmental performance criteria" (Dias-Sardinha and Reijnders, 2001). So, in order to identify the processes/practices which need to be improved in manufacturing enterprises environmental performance evaluation methodologies are being developed and widely used in various sectors (Jiang et al., 2012a).

In order to ensure a dependable baseline before sustainable production applications, a period of 8 months was considered. On the other hand, environmental benchmarking was carried out by using Environmental Performance Indicators (EPIs) that are specific resource consumption and waste/emission generation data. According to Thoresen (1999) EPIs can be used by industrial enterprises to control performance of processes and set goals as well as benchmark with competitors' performance. In this study EPIs were calculated by dividing resource consumption or waste/emission generation data by fabric production data. Then, specific resource consumption and waste/emission generation data was used for environmental benchmarking.

Applications of proposed sustainable production measures were realized stepwise during a period of 4 months. The implementation period was 4 months, while it took a year (12 months) to monitor the results of sustainable production applications. So, Figure 7.2, showing the trend of resource consumption before and after applications was prepared for 24 months, including all three periods. Namely, 8 months of baseline, 4 months of implementation and 12 months of monitoring periods. In order to determine change in environmental performance of the company after applications, EPIs were calculated both for baseline and monitoring periods and compared. The EPI's used were (i) water consumption and wastewater generation, (ii) energy consumption and greenhouse gas emissions and (iii) salt (NaCl) consumption.

Processes with soft water, energy and salt (NaCl) consumption were investigated for potential sustainable production applications. These processes included wet processes (fabric preparation, dyeing and finishing), cooling processes and utility operations. Furthermore, unaccounted water losses (evaporation, leaks, faulty valves, etc.) were subjected to careful inspection with close cooperation of facility officials. Current practices/techniques where soft water is consumed were comparatively evaluated with the Best Available Techniques (BATs) referred by European Commission (2003). In addition to that, literature was surveyed to come up with sustainable production alternatives for associated water consumption areas. In addition, economic performance evaluation was carried out by compiling and evaluating resource costs of the company (raw materials, labor, consumables etc.). In order to identify cost-intensive processes/practices and strengthen economic rational of proposed measures a link was established between resource consumption, waste generation and associated costs.

As a result of the evaluations, five sustainable production applications were proposed and implemented in 2011 to decrease water consumption and associated wastewater generation, energy consumption and resulting greenhouse gas emissions as well as salt (NaCl) consumption (Table 7.1).

Table 7.1. Applied sustainable production applications in different processes

Processes	Proposed Sustainable Production Applications	Reference
Fabric preparation, dyeing and finishing	1. Use of drop-fill washing instead of overflow	ETBPP, 1997; European Commission, 2003; NCDENR, 2009b; Shaikh, 2009
Cooling processes	2. Reuse of stenter cooling water 3. Reuse of singeing cooling water	European Commission, 2003; NCDENR, 2009b; Shaikh, 2009; Greer et al., 2010; Chougule and Sonaje, 2012
Utility operations	4. Renovation of water softening system	ETBPP, 1997; Kalliala and Talvenmaa, 2000; European Commission, 2003
Unaccounted losses	5. Renovation of various valves and fittings in water transmission system	European Commission, 2003; NCDENR, 2009b; Greer et al., 2010

7.4. Results and Discussions

7.4.1. Environmental Performance Evaluation

In the company 85.4% of total water consumption was recorded in production processes, cooling systems and utilities in which soft water is used. As the major production processes, fabric preparation, dyeing and finishing processes were the most water intensive operations in the company, comprising 61.1% of total water consumption. Indeed it is stated in numerous studies that the washing and/or rinsing steps at the end of each production step require more water then the rest of the processes (Chougule and Sonaje, 2012; NCDENR, 2009b; Shaikh, 2009). When compared to production processes, cooling processes require less amount of water with a specific consumption figure of 10.4 L/kg fabric (7.5% of total water consumption). In other words, 2,068 m^3/month soft water was consumed and discharged without any major contamination since it does not come into contact with fabric. Regarding utility operations, water is consumed in steam boiler as make-up water for the steam losses and exhausts. In addition to steam boiler, water is also consumed in water softening system (ion-exchange system) for regeneration (backwash) of resins three times a day. Calculations indicated that 10.6% of water is lost either during production processes (e.g. evaporation) or transmission of water through pipes (e.g. leaks, faulty valves).

When the total specific water consumption of the company (138.9 L/kg product) was compared with relevant data reported in the literature, it is determined that the company was using relatively high amounts of water to produce unit quantity of product (Table 7.2). According to some studies a specific water consumption between 50.0-100.0 L/kg product is achievable (European Commission, 2003; Kalliala and Talvenmaa, 2000; Ren, 2000; Rosi et al., 2007; Shaikh, 2009). This result indicated that there was a significant potential in the company in terms of water savings.

Table 7.2. Benchmarking of environmental performance of the company with the related literature

Specific Water Consumption (L/kg product)	Electrical Conductivity (µs/cm)	COD (mg/L)	Specific COD (kg/ton product)	Thermal Energy Use (MWh/ton product)	Electricity Use (MWh/ton product)	Total Energy Use (MWh/ton product)	Reference
-	-	850-1,200	-	-	-	-	ETBPP, 1997
100.0	-	-	150.0	5.6-7.0	5.6-7.0	11.1-13.9	Ren, 2000
50.0-500.0	-	-	-	13.9-42.3	1.4-3.9	15.3-42.3	Kalliala and Talvenmaa, 2000
50.0-100.0	200-4,500	334-4,600	43.0-303.0	-	0.5-1.5	8.0 -20.0	European Commission, 2003
80.0-100.0	-	-	115.0-175.0	-	-	-	Rosi et al., 2007
113.7	-	-	-	-	-	-	NCDENR, 2009b
60.5-177.2	-	-	-	-	-	-	Shaikh, 2009
125.0	-	-	-	-	-	-	Chougule and Sonaje, 2012
-	-	-	-	8.1-112.2	1.2 -3.6	14.9-121.2	Hasanbeigi et al., 2012
138.9	4,466	653	81.0	6.5	2.0	8.5	This study

The wastewater is generated mainly in the wet production processes in the company, namely fabric preparation, dyeing and finishing. It is discharged to the sewer system connected to the central wastewater treatment facility of the organized industrial zone in which the company operates. Two of the most important parameters in textile wastewater, namely electrical conductivity and COD were compared with the values reported in the literature for the same subsectors, woven textile dyeing and finishing which employ the same processes with the company (Table 7.2). As it can be seen in Table 7.2, the electrical conductivity of the company (4,466 μs/cm) was very close to the highest value of 4,500 μs/cm reported in the literature which was the indication of high salt (NaCl) consumption. On the other hand, reported average COD concentration of 653 mg/L was determined to be relatively low when compared to the data published in other studies.

Hasanbeigi et al. (2012) stated that the dominant type of energy used in wet textile processing is thermal energy as opposed to electricity, because of the existence of many high-temperature processes requiring steam. According to Greer et al. (2010), generation of steam is by far the largest energy-consuming activity in a textile mill. Indeed two types of energy sources are used in the company: natural gas (1,295,677 kWh/month) and electricity (394,661 kWh/month), former being the dominant source. Natural gas is directly burned in three processes which are steam generation, drying and singeing. Among these steam generation is most energy intensive process which is responsible for 45.5% of total energy consumption of the company. Since, steam is used for heating the water baths in wet processes it can be postulated that almost half of the total energy of the company was consumed to heat-up the process water to temperatures between 60-120 ^{o}C depending on the type of process and fabric to be processed.

Another process which relies on thermal energy is drying where natural gas is burned in stenters to dry finished fabric on conveyor belts. Drying is found to be responsible for 30% of total energy consumption of the company. As opposed to the natural gas which is used intensively in only three processes, electricity is used in almost all processes but comparatively with lower rates in kWh.

Before the sustainable production applications, the total CO_2 emissions of the company was calculated as 467.9 ton/month while specific emissions were 2,343 kg/ton fabric (1 kWh Natural Gas = 181.4 g CO_2, 1 kWh Electricity = 590.0 g CO_2). If total specific energy consumption is taken into account it can be easily sated that the energy consumption of the company is rather low when compared to other studies (Table 7.2). Still there could be some potential for improvement according to European Commission (2003) which reported that even lower specific energy consumption values are attained in the sector. The same situation holds separately for thermal energy and electricity. Company shows rather good performance in terms of energy efficiency in both areas where still some lower specific energy consumption cases are present (Table 7.2).

It is underlined in many studies that high salt (NaCl) consumption and associated salinity in receiving water bodies are among important environmental issues in textile sector (European Commission, 2003; Rosi et al., 2007). As discussed above and tabulated in Table 7.2, the electrical conductivity values were determined to be considerably high. This could be an indication of high salt consumption. In reactive dyeing where NaCl is used for increasing the dye uptake 88.1 kg of salt is consumed to produce unit amount (1 ton) of fabric. This value corresponds to 40.3% of total NaCl consumption of the company which was 43,993 kg/month before sustainable production applications. On the other hand NaCl consumption was even higher (59.7% of total NaCl consumption) in water softening where ion-exchange resins are regenerated by means of concentrated NaCl solutions. As reported by Kalliala and Talvenmaa, (2000), the specific salt consumption of 60.0 kg/ton product is possible without compromising dyeing efficiency and product quality. When compared to this value total salt consumption of the company, which was 218.7 kg/ton product, assumed to be comparably high which can be reduced via taking specific measures.

Environmental performance evaluation indicated that there are quite important improvement potentials in water consumption and associated wastewater generation as well as energy and salt (NaCl) consumption. It is advocated in various studies that in a textile mill where wet processes are in place, high water consumption is not only an important but also a cross-cutting issue influencing the rest of the areas including wastewater generation, energy consumption and chemical usage (European Commission, 2003; Greer et al., 2010; Hasanbeigi et al., 2012; NCDENR, 2009b; Shaikh, 2009).

7.4.2. Economic Performance Evaluation

As it is the case for almost all textile companies (except for sub-contractors) raw material is the major cost item with a share of 61.0% in the company (Table 7.3). Second biggest cost item is labor force which accounts for 9.7% of total expenditures. After human resources, consumable resources take place as energy, chemicals/dyes and water respectively corresponding to 6.6, 4.7 and 0.3% of total cost. In other words, consumable resources which are also major concerns in terms of environmental performance are responsible for 11.6% of total cost of the company. If this cost share of consumable resources is compared with the literature values (5-20%) it can be stated that the company is in the acceptable range (Table 7.3). Still, total annual consumable resource cost of the company, which account for 1,519,000 $, is approximately five times higher than the annual profit of the company (323,000 $). This analysis indicates that even 10% of saving in consumable resources could create an economic return which is equal to almost half of the annual profit of the company.

Table 7.3. Benchmarking of economic performance of the company with the related literature

Cost Item	Palamutcu, 2010 (%)	Hasanbeigi and Price, 2012 (%)	MOSIT, 2012d (%)	This Study (%)
Raw materials	55.0–65.0	49.0	33.0	61.0
Labor	5.0–20.0	4.0	25.0	9.7
Energy	5.0–10.0	9.0	9.0	6.6
Chemicals/dyes	-	4.0	11.0	4.7
Water	-	-	-	0.3
Others	9.0–35.0	34.0	22.0	17.7
Total	-	100.0	100.0	100.0

7.4.3. Water Consumption and Wastewater Generation

Washing/rinsing processes are regarded to be among the processes where there is significant potential for sustainable production (NCDENR, 2009b). Washing/ rinsing practices which are carried out between different processes were determined to be responsible for relatively high water consumption in the company. Before the sustainable production applications, the practice overflow washing/rinsing was practiced. As opposed to overflow washing/rinsing, step-wise batch washing/rinsing (drop/fill method) was recommended in the relevant literature (ETBPP 1997; NCDENR, 2009b; Shaikh, 2009). According to European Commission (2003) by replacing each overflow rinse by 2–4 drop/fill cycles a reduction of 50–75% water consumption is achievable. On the other hand, NCDENR (2009b) states that it is possible to save 46.9% of water when overflow washing/rinsing was replaced with drop/fill method. Supporting these arguments Shaikh (2009) suggests drop/fill process instead of overflow washing/rinsing stating that 15–79% of water saving is reported through this approach. Thus, overflow washing/rinsing was replaced with drop/fill method in the company.

In the company, stenters are used for drying the fabric after finishing. Before sustainable production applications, fresh soft water was consumed in this process to cool down the fabric by means of heat exchangers without any reuse or recycle (direct once-through cooling). After cooling process, heated water was being discharged to the wastewater collection channel. In European Commission (2003) it is suggested to reuse cooling waters which do not come into contact with fabric or chemicals/auxiliaries. It is also underlined in various studies that cooling water generated in different processes can easily be collected and reused beneficially in various processes (Chougule and Sonaje, 2012; Greer et al., 2010; NCDENR, 2009b; Shaikh, 2009). Referring to these studies, a recycling system was introduced to pump the stenter cooling water to the hot water storage tank, which supplies water to various processes including dyeing.

Similar to stenter machine, a water-cooled system is present to cool down the fabric in singeing process. The coolant water is passed through a roller and is not allowed to come into direct contact with fabric. Before sustainable production applications heated water (coolant water) was being discharged to the to the wastewater collection channel as it was the case for stenter cooling water. According to Greer et al. (2010), 3.2–7.4 L of water saving could be achieved per 1 kg of produced fabric when once-through cooling system was replaced with closed loop cooling in singeing process. Thus, in this study water recirculation system was put into practice to recycle cooling water in singeing.

Soft water (hardness lower than 10 mg/L as $CaCO_3$) was used in the company in all processes. Since groundwater is the main water source of the company a cationic ion-exchange system was in operation before sustainable production applications to remove Mg^{2+} and Ca^{2+} ions. Since the previous system was operated based on relatively old technology, salt (NaCl) was being dosed manually by operators for preparing concentrated brine to be used for regeneration of the cationic resins. The whole process of regeneration was being controlled manually. In the related literature it is advocated that application of automatic chemical dosing considerably increases the resource efficiency (ETBPP 1997, European Commission, 2003; Kalliala and Talvenmaa, 2000). So, in the scope of this study the existing water softening device was replaced with a new ion-exchange system which operates automatically, regulated by a flow meter. In the old practice the resins were being subjected to backwash with a brine concentration of 30 g/L NaCl. In the new system brine concentration was increased to 75 g/L decreasing the need for soft water dilution.

Environmental performance evaluation indicated that 10.6% of produced soft water could not be accounted in the water balance of the company. In other words more than 10% of soft water was lost during the production processes through evaporation or leaks from damaged pipes, valves and fittings. The importance of the maintenance was regarded as indispensable for establishing sustainable production in textile mills (European Commission, 2003). Up to 5% of total water consumption may be due to the water losses as leaks in water transmission systems in textile manufacturing firms (Greer et al., 2010). Faulty valves should be repaired/replaced and leaks from pipes and joints be avoided through maintenance (NCDENR, 2009b). Therefore, a maintenance program was commenced as part of this study. Some faulty valves were replaced and leaks from pipes and fittings were prevented through maintenance.

As it is depicted in Figure 7.2, specific soft water consumption started to decrease considerably, following the sustainable production applications which were started to be implemented in the company in the 8^{th} month. Since only production processes rather than cleaning or domestic purposes are targeted within the scope of this study, no change was observed in the water consumption for cleaning and domestic purposes. Soft water consumption was decreased between 8th-12th months (implementation period) as a result of sustainable production applications. Then it was rather stabilized throughout the rest of the monitoring period (12th-24th months).

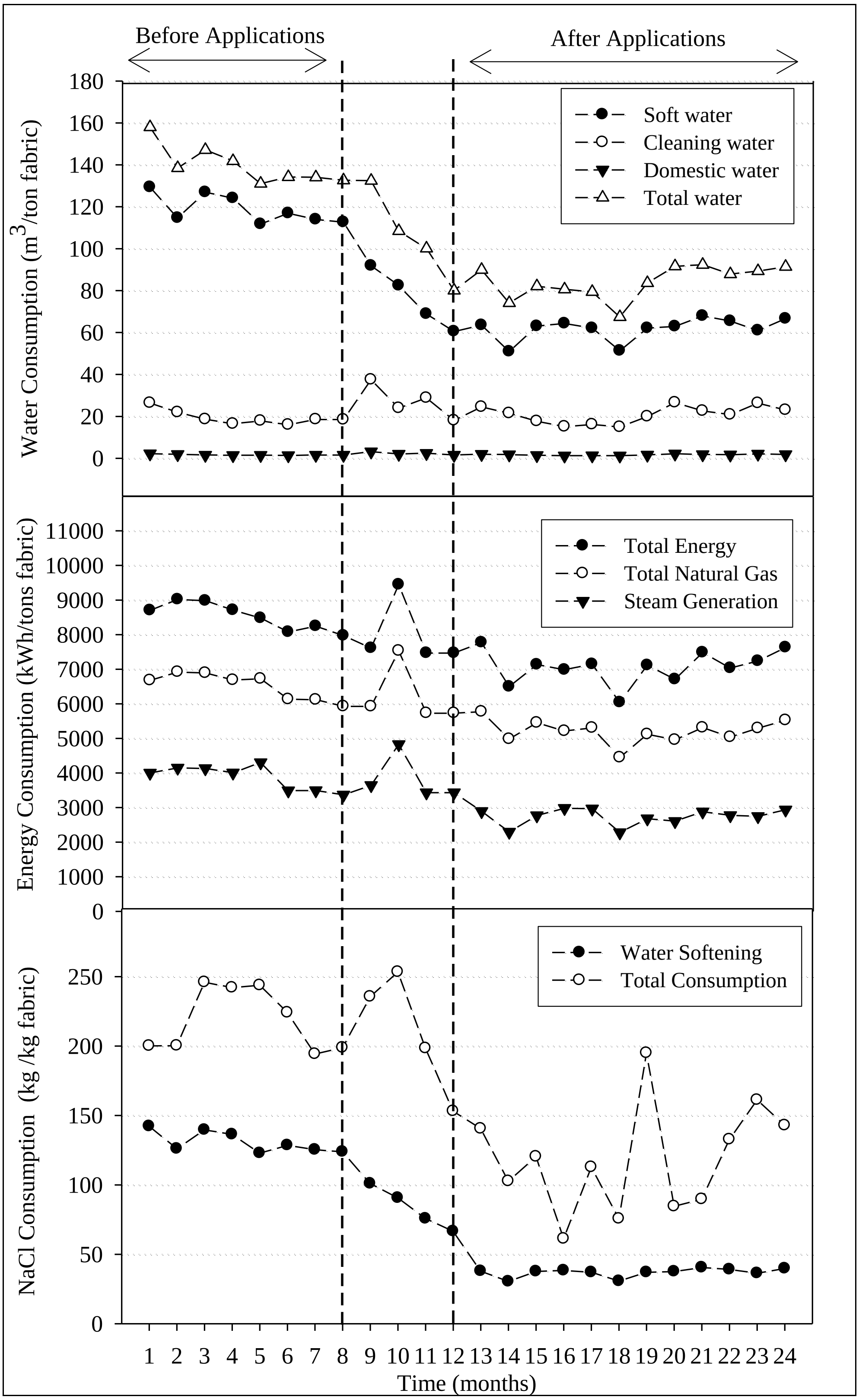


Figure 7.2. Change of specific water, energy and salt (NaCl) consumption

Sustainable production measures which were taken in various processes resulted in reductions of soft water consumption in production processes, cooling processes and utility operations (Table 7.4). The highest water saving in terms of total monthly water consumption was observed in wet production processes, namely fabric preparation, dyeing and finishing. Water consumption was decreased from 16,940 to 8,925 m^3/month as a result of the shift from overflow washing/rinsing to drop-fill method. Consequently, specific water consumption in wet production processes was decreased from 84.8 to 40.9 L/kg fabric corresponding to a percent decrease of 51.8%. On the other hand, the highest percent decrease of specific water consumption was determined in water softening system. 86.9% reduction of water consumption is associated with both the renovation of ion-exchange system and decrease in soft water demand as a result of all sustainable production measures taken in the company. Although steam generation was not targeted in any of the sustainable production applications, reduction of water consumption in production processes decreased the need for steam which is mainly used for increasing the temperature of water baths in the company. So, 37.8% decrease was recorded in terms of specific water consumption in steam generation.

The change in each wastewater parameter as a result of sustainable production applications is given in Table 7.5. Monthly average specific wastewater generation was decreased from 124.1 to 70.2 L/kg fabric which corresponds to a decrease of 43.4%. The percent decrease in specific wastewater generation (43.4%) was very close to the percent decrease in total specific water consumption of the company (40.2%), which is an expected result. These results are also in line with the statements in related literature. For example, according to NCDENR (2009b) wastewater reductions as high as 70% is possible if careful auditing and implementation of sustainable production measures are ensured.

Table 7.4. Breakdown of water usage before and after applications

Areas of Water Consumption	Total Water Use (m^3)		Specific Water Use (L/kg fabric)		
	Before	After	Before	After	Change (%)
Production processes [a]	16,940	8,925	84.8	40.9	- 51.8
Cooling processes	2,068	814	10.4	3.7	- 64.0
Utility operations:					
- Steam generation	952	648	4.8	3.0	- 37.8
- Water softening	747	107	3.7	0.5	- 86.9
Cleaning	3,755	4,357	18.8	19.9	+ 6.1
Domestic use	317	349	1.6	1.6	+ 0.6
Unaccounted losses	2,945	2,926	14.8	13.4	- 9.2
Total	27,724	18,126	138.9	83.0	- 40.2

a: Fabric preparation, dyeing, finishing

Since water consumption was reduced considerably concentration of COD and electrical conductivity were increased 33.1% and 29.6 % respectively. However, if the specific values are taken into consideration organic load was decreased 25.5%. This decrease in organic load could not directly be associated with sustainable production applications, since the use of organic chemicals/auxiliaries was not targeted in this study. Still the decrease in water consumption could have triggered the increased efficiency in chemical/auxiliary use. On the other hand, one of the other important results of this study is the 26.1% decrease in the load of specific electrical conductivity. Since salt (NaCl) consumption was decreased substantially, electrical conductivity was decreased accordingly.

Table 7.5. Characteristics of wastewater generated in the company

Parameter	Before Applications	After Applications	Change (%)
Flowrate: - total (m^3/month)	24,779	15,200	- 38.7
- specific (L/kg fabric)	124.1	70.2	- 43.4
COD (mg/L)	653	869	+ 33.1
Organic load: - total (kg COD/month)	16,181	13,209	- 18.4
- specific (kg COD/ton fabric)	81.0	60.5	- 25.4
Electrical conductivity - EC (µs/cm)	4,466	5,788	+ 29.6
EC load: - total (µs-m^3 / cm-month)	111,554	90,078	- 19.2
- specific (µs-m^3 /cm-ton fabric)	0.56	0.41	- 26.1
pH	9.70	9.51	-

7.4.4. Energy Saving and Emission Reductions

It is advocated in the European Commission (2003) that reduced water consumption results in reduced energy consumption especially when rinsing steps which requires hot/warm water are taken into consideration. Since in this study water consumption was decreased in washing/rinsing processes it was expected to attain higher efficiencies in energy consumption. As it was depicted in Figure 7.2, steam generation was decreased considerably after sustainable production applications, which reduced natural gas use and total energy consumption of the company as well. During the period in which the applications are realized fluctuations in energy consumption can be associated with the variations of produced fabrics and accordingly varied energy requirements. Supporting this claim high salt consumption in 10^{th} month is the direct result of an increase in the reactive dyeing only applied to cotton fabrics, which can be the reason for the increased energy consumption in the 10^{th} month as well.

Monthly average energy consumption for steam generation was decreased from 769,155 kWh to 596,155 kWh as a result of applications. When the monthly average fabric production is also taken into consideration specific energy consumption was calculated to be decreased from 3,852 kWh to 2,730 kWh. In other words, specific energy consumption for steam generation was decreased 29.1%. Since majority of natural gas is consumed for steam generation total specific natural gas and total specific energy consumption of the company was reduced 20.2% and 17.1%, respectively. Direct CO_2 emissions from the stack of steam boiler was decreased 20.2% since it is directly associated with natural gas consumption. Moreover total CO_2 emission reduction was calculated as 13.5%.

7.4.5. Salt (NaCl) Consumption

As part of the sustainable production applications, renovation of the water softening system resulted in remarkable decrease in salt (NaCl) consumption (Figure 7.2). Both the renovation of ion-exchange system and decrease in soft water demand as a result of all sustainable production applications decreased the frequency of regeneration in the ion exchange system. This situation explains the reduction of salt (NaCl) consumption. In the scope of this study, only water softening system was targeted for reducing the salt consumption. Monthly average salt (NaCl) consumption in the ion-exchange system was reduced from 25,999 kg/month to 8,000 kg/month. Accordingly total specific salt (NaCl) consumption of the company was reduced 45.9%, from 218.7 kg/ton fabric to 118.2 kg/ton fabric. So, total salt consumption of the company was decreased from 43,993 kg/month to 25,110 kg/month.

7.4.6. Economic gains and payback calculations

Since sustainable production applications resulted in considerable reductions in resource consumption (water, energy, NaCl) as well as in wastewater/emission generations, economic returns could be achieved. Natural gas is one of the most costly resources among dyes and chemicals/auxiliaries used in the company. As a reflection of this situation 20.2% decrease in natural gas consumption ensured a specific cost saving of 39.3 $/ton fabric (Table 7.6). On the other hand, although soft water consumption of the company was decreased 48.1% only 2.4 $/ton fabric cost saving could be achieved for groundwater supply (source of soft water). This is due the groundwater cost management practices in Turkey. Since companies are not charged for their groundwater use in Turkey, the only cost associated with the groundwater use is pumping (electricity) cost.

Table 7.6. Cost savings as a result of sustainable production applications

Cost Item	Specific Cost Saving ($/ton fabric)	Total Annual Cost Saving ($/year)
Natural gas	39.3	103,060
Wastewater disposal	12.1	31,756
Salt (NaCl)	11.3	29,740
Groundwater supply	2.4	6,311
Total	65.2	170,868

Total annual cost saving was calculated to be 170,868 $/year by multiplying specific cost saving with annual fabric production which was 2,621 ton in 2011. During the implementation of sustainable production measures 21,936 $ was spent for the equipments. So the payback period of the implementations was approximately 1.5 months (0.13 years). Van Hoof and Lyon (2013) reported an average payback period of 0.77 years for sustainable production projects carried out within the scope of Mexico's Sustainable Supplier Program. As a result of a profitability analysis of 134 industrial sustainable production project reports, Cagno et al. (2005) calculated 2.4 years of average payback period for implementations in various industries including textile industry. Therefore 0.13 years of payback period can be regarded as the indication of a highly cost-effective investment when compared to the literature. Moreover annual cost saving of 170,868 $ corresponds to 53% of annual profit of the company made in 2010. These figures show that the competitiveness of the company is remarkably increased by the sustainable production applications.

7.5. Conclusions

In this study, processes where soft water, energy and salt (NaCl) is being consumed were investigated for potential sustainable production applications. These processes are wet processes (fabric preparation, dyeing and finishing), cooling processes and utility operations. In addition to these processes unaccounted water losses (evaporation, leaks, faulty valves, etc.) were subjected to careful inspection with close cooperation of facility staff.

After evaluating the environmental performance of the company, the following sustainable production applications were realized:

- Use of drop-fill washing instead of overflow
- Reuse of stenter cooling water
- Reuse of singeing cooling water
- Renovation of water softening system
- Renovation of various valves and fittings in water transmission system

As a result of these applications total water consumption of the company was decreased 40.2% while generated wastewater amount was reduced 43.4% (Table 7.7). Since natural gas is primarily consumed for heating the water baths, reduced water consumption decreased the energy consumption as well. Accordingly total energy consumption of the company was decreased 17.1% while direct CO_2 emissions which are directly related with natural gas consumption decreased 20.2%. Renovation of ion-exchange system and decrease in soft water demand as a result of all sustainable production applications decreased the amount of salt (NaCl) consumption for the regeneration of ion exchange system. So, the total salt (NaCl) consumption of the company was decreased 46.0%. The payback period of the implementations was calculated as approximately 1.5 months.

Table 7.7. Summary of environmental performance before and after applications

Resources/Wastes	Specific Consumption/Emission Values		
	Before Applications	After Applications	Change (%)
Water Consumption (L/kg fabric):			
- Soft Water	118.5	61.4	- 48.1
- Total	138.9	83.0	- 40.2
Wastewater:			
- Flowrate (L/ton fabric)	124.1	70.2	- 43.4
- Organic Load (kg COD/kg fabric)	81.0	60.5	- 25.4
- EC Load (µs-m^3 / cm-ton fabric)	0.56	0.41	- 26.1
Energy Consumption (kWh/ton fabric):			
- Natural Gas	6,489	5,176	- 20.2
- Total	8,466	7,021	- 17.1
CO_2 Emissions (kg/tons fabric):			
- Direct emissions	1,177	939	- 20.2
- Total emissions	2,343	2,028	- 13.5
Salt (NaCl) Consumption (kg/ton fabric):			
- Water Softening	130.6	36.8	- 71.8
- Total	218.7	118.2	- 46.0

All sustainable production applications realized within the scope of this study were among “Best Available Techniques” referred in “Communiqué of Integrated Pollution Prevention and Control in Textile Sector” which has been put into effect by Ministry of Environment and Urbanization in December 2011. So, this study can be regarded as an example of adoption of the communiqué with successful economical and environmental achievements in woven fabric production, a sub-sector of 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 even without heavy investments for technology changes. 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.

This study targeted woven fabric manufacturing sub-sector within the textile sector which is regarded as a very fragmented and heterogeneous sector. Since the environmental performance evaluation and benchmarking was carried out specifically for this sub-sector, generated results can effectively be used for comparison/benchmarking in the same sub-sector. Although sustainable production applications realized in the company can be replicated in various other textile sub-sectors employing similar processes (e.g. water softening, stenter drying), first conducting a detailed environmental performance evaluation based on specific data for the corresponding sub-sector would be needed. Future research is needed for developing successful demonstration projects in different sub-sectors of textile industry. Further, demonstration projects should be supported by policy-level studies (sectoral assessments, roadmaps etc.) in order to stimulate the dissemination of sustainable production approach in Turkish textile industry.

CHAPTER 8

IMPROVING RESOURCE EFFICIENCY IN SURFACE COATING/PAINTING INDUSTRY: PRACTICAL EXPERIENCES FROM A SMALL-SIZED ENTERPRISE

8.1. Introduction

According to European Commission (2010), the long term challenges namely “globalization, pressure on resources and aging" intensify in the world. Based on this statement, “Europe 2020”, a vision of Europe’s social market economy for the 21st century, puts forward “Sustainable Growth” as one of its three mutually reinforcing priorities. The motto was determined as “promoting resource efficient, greener and more competitive economy” for the priority theme “Sustainable Growth”. In order to catalyze the progress under this theme, European Commission launched the “Resource Efficient Europe” initiative (European Commission, 2011a). One of the core objectives of the Commission is to improve the efficiency of the production processes in manufacturing enterprises (particularly small and medium-sized enterprises - SMEs) by structural and technological changes. It is stated in the strategy document “Roadmap to Resource Efficient Europe” that, although many firms have already taken serious measures for improving their resource (e.g. energy, water, chemical) efficiency, there is still important potential for improvement (European Commission, 2011b). So, from the Commission side, it is becoming of utmost importance to assist manufacturing SMEs by providing continuous advice/support to identify and improve their resource efficiency.

SME's are regarded as one of the integral parts of European economy generating 58% of gross value added (GVA) with about 20.7 million enterprises. In European Union (EU) SMEs are accounting for more than 98% of all firms and 67% of total employment (Wymenga et al., 2012). When it comes to surface coating sector, SMEs generated 30 billion € employing about 330,000 jobs in 22,000 companies across EU countries (Zimmer et al., 2011). In this sector, substantial growth of 65% over the last ten years was attributed to high innovation potential. According to Zimmer et al. (2011), over the years SMEs in surface coating industry have shown remarkable progress towards resource efficient and environmentally conscious production. However, the potential environmental innovation in the sector has by far not been fully exploited yet. Still, high energy and water consumption, low efficiency, costly wastewater treatment, high volatile organic carbon (VOC) emissions, excessive solvent use, corrosive fluoride and toxic lead, as well as highly toxic cadmium and cyanide contaminated wastes are among major environmental issues which need to be tackled via cost effective measures. Due to these environmental issues and strict legislative limitations on the use of certain toxic chemicals/metals (e.g. chromium, cadmium, cyanide), surface coating industry is facing a structural technological change.

Cadmium electroplating is one of the significant examples among various surface coating sub-sectors from which a transformation should be experienced towards more eco- and resource-efficient techniques/technologies. According to EU Water Framework Directive "cadmium and its components" are listed among 33 "priority hazardous substances", which are targeted for progressive reduction and eventual cessation or phase-out in the European market. Moreover, "cyanide" which is used extensively in cadmium plating was listed both among "main pollutants" and "substances subject to review for possible identification as priority substances or priority hazardous substances" (European Commission, 2008). In 2011, European Commission restricted the use of "cadmium" as one of the six "hazardous substances" in electrical and electronic equipments (European Commission, 2011c).

Liu and Ma (2010) stated that due to these important developments in environmental regulations, enterprises should adopt environmental friendly coating processes in order to sustain their competitiveness in the European market.

As it is the case in the EU, SMEs are the backbone of Turkish economy by employing 78% of the work force and having a share of 55% of value added of non-financial companies in the economy (OECD, 2012). In Turkey, more than 99% of all firms are SMEs, majority of which are being micro- and small-sized enterprises and having 60% share in the export of goods and services (KOSGEB, 2012). Although their contribution to the national economy is vital, the environmental issues associated with their manufacturing activities in certain sectors (e.g. chemical products, textile, surface coating) surpass their economic performance. Since Turkey is an EU accession country, it has to adopt policies and strategies set by the European Commission within the "environment chapter" of negotiations which directly affect competitiveness of SMEs in the polluting sectors like surface coating.

Therefore, "resource efficiency" should be a key concept for Turkish SMEs in surface coating for greening their production processes and sustaining their competitive position throughout the EU accession period. Ulutaş et al. (2012a) advocates that, in Turkey there is a lack of best practice examples which integrate environmental and economic benefits of resource efficiency in manufacturing industry. So in this study, a Turkish small-sized enterprise in surface coating/painting sector was chosen for a demonstration project in order to indicate tangible benefits of improved resource efficiency. It is also expected to fill a knowledge gap in the Turkish surface coating industry by investigating alternative processes/practices which in turn provides competitive advantage to SMEs.

8.2. Methodology

8.2.1. General Information and Production Processes of the Company

The company was founded in 1996 in Ankara, Turkey. Employing 12 workers, it operates on a covered area of 1,350 m^2. Located in Ivedik Organized Industrial Zone, it currently provides metal coating and painting services (Nace code: C.25.6.1 - Treatment and coating of metals) to various firms from military, aerospace and automotive sectors. The services it offers includes surface treatment and coating as well as wet and electrostatic powder painting of aluminum, ferrous materials and other metal alloys. In 2010, company processed workpieces with a total surface area of 486,000 m^2 and generated an annual turnover of 512,500 $.

In the company, workpieces are processed into finished products by consecutive production processes (Figure 8.1). First the workpieces to be processed are received and stored after visual inspection. Then, the inspected materials are coated either in the chromium conversion coating or cadmium plating line. Both surface coating practices are performed through stepwise batch-type operations including degreasing, deoxidation/pickling, coating/plating and rinsing. After surface coating processes, some parts of workpieces masked prior to painting. At this stage, undercoat painting is applied prior to painting process if it is required. There are two types of painting processes in use in the enterprise namely wet painting and electrostatic powder painting. Both painting operations are carried out manually by spray guns. Painted workpieces are dried/cured at 80–200 ^{o}C before being inspected for quality assurance and quality control (QA/QC). At the end of the production process, products are sent to packaging. The products are packaged manually and stored for shipping.

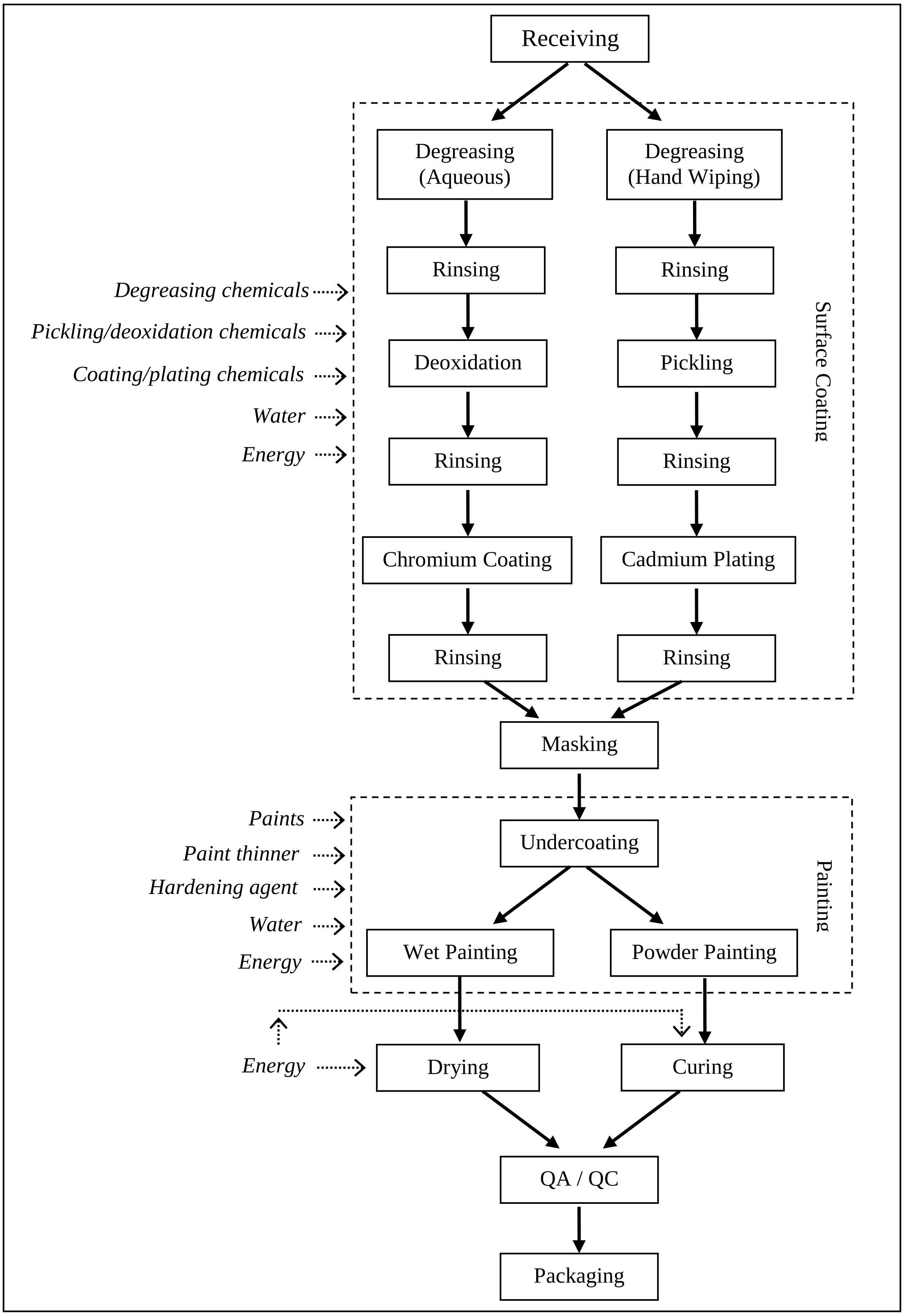


Figure 8.1. Process flow diagram of the company

8.2.2. Data Collection and Environmental Performance Evaluation

Before gathering detailed process-based numerical data about resource consumption and waste generation, an initial walk-through audit was carried out together with company officials. As a result of this half-day walk-through audit, the process flow diagram of the company was developed by getting information on inputs and outputs of major processes. Then monthly resource (e.g. water, chemicals, energy) consumption and corresponding expenditures were compiled from different sources provided by the staff of company. For this purpose, information sources like water, chemical and energy bills as well as process-based record sheets were analyzed. In addition, informative catalogs of equipments and material safety data sheets (MSDS) of chemicals were used for data collection.

In order to evaluate/benchmark the environmental performance and associated costs of the company, the baseline which indicates the situation before process changes was evaluated. Thus, the monthly resource consumption data and related costs were analyzed to determine the processes/practices where improvements may lead to significant results in terms of environmental performance and cost savings. To be able to carry out an environmental benchmarking among similar production facilities reported in the literature, environmental performance indicators (EPIs) namely specific chemical/water/energy consumption (e.g. L/m^2-product, kWh/m^2-product) were calculated. Moreover, resource and cost intensive processes/ practices were comparatively evaluated with environmentally friendly alternatives referred to in the literature including best available techniques (European Commission, 2006a and 2007b).

8.2.3. Opportunity Assessment and Implementation of Selected Options

As a result of environmental performance evaluation, three objectives were set to decrease the negative environmental impacts and production costs associated with the high impact processes/practices (e.g. solvent degreasing, cadmium plating, wet painting). To achieve these objectives, 14 options were developed as seen in Table 8.1.

Table 8.1. Objectives of applications and respective options to achieve

Objectives	Evaluated Options	Reference
Reducing chemical consumption and associated pollutant load of wastewater	1. Increase the drip (drainage) time above process baths to decrease drag-outs from process baths	European Commission, 2006a; Telukdarie et al., 2006
	2. Install ultra sound generators into the vats to increase process efficiencies	Baum and Schiffrin, 1997
	3. Replace chemical/labor intensive solvent based degreasing (hand wiping) process with alternative degreasing practices	Envirowise, 2003; European Commission, 2006a
	4. Substitute cadmium plating process with a less toxic and more environmentally friendly alternative coating process	European Commission, 2006a; Heimann and Simpson, 2005; RAC/CP, 2002; USAID, 2009a
Reducing paint consumption and related volatile organic carbon emissions (VOC)	5. Introduce a higher transfer efficiency painting system instead of conventional high pressure spraying in wet painting process	Envirowise, 2003; European Commission, 2007b; MOEF, 2009b; Randall, 1992
	6. Use suction fan to recover bounced back and overspray paints	Envirowise, 2003
	7. Install automation systems to increase the transfer efficiencies in painting processes	Barros et al., 2008; European Commission, 2006a
	8. Substitute solvent-based paints with water-based paints in wet painting process	Babu et al., 2009; European Commission, 2006a

Table 8.1. Objectives of applications and respective options to achieve (Continued)

Introducing energy efficiency measures and reducing direct/indirect carbon dioxide (CO_2) emissions	9.	Optimize the drying and curing oven temperatures	Barros et al., 2008
	10.	Optimize bath temperatures	Telukdarie et al., 2006
	11.	Recover waste heat from the exhaust pipe of curing oven to be used for heating the process baths	Galitsky and Worrell, 2008
	12.	Insulate the vats to prevent heat losses	Babu et al., 2009
	13.	Insulate the ovens to prevent heat losses	Galitsky and Worrell, 2008
	14.	Use solar energy for heating the process baths	Galitsky and Worrell, 2008

In order to find best possible and applicable solutions for identified issues an opportunity assessment was carried out together with company officials among the options presented in Table 8.1. First step of the opportunity assessment was to determine “assessment criteria”. Assessment criteria were determined by referring to 5 studies (Barros et al., 2008; European commission, 2006a; Klipova and Bagdonas, 2003; Pandey, 2007; UNEP, 2004). In these studies it was stated that following criteria should be taken into account when sustainable production options are to be evaluated:

- Environmental requirements, adaptability to employed processes, quality requirements, occupation, health and safety requirements, (Klipova and Bagdonas, 2003)
- Applicability of the technology, economical feasibility, examples of successful applications, level of technology (UNEP, 2004)
- Environmental benefit, complexity of the application, cost saving, scale of innovation, effect on processes/products, (Pandey, 2007)

- Achieved environmental benefits, economics, operational data, applicability, examples of successful applications, cross-media effects (European commission, 2006a)
- Environmental aspects, applicability and characterization, economic aspects, plants where the technique is already implemented, secondary effects (Barros et al., 2008).

Referring to above listed studies, 7 assessment criteria were determined as follows:

- Environmental benefits
- Technical applicability
- Economic viability
- Easiness of implementation
- Long-term sustainability
- Operational and maintenance requirements
- Cross-media effects

As a result of the opportunity assessment, below listed options were selected and implemented as described in the following sections:

- Replacing chemical/labor intensive solvent based degreasing (hand wiping) process with alternative degreasing practices.
- Substituting cadmium plating process with a less toxic and more environmentally friendly alternative coating process.

8.3. Results and Discussions

8.3.1. Environmental Performance Evaluation of the Company

Major environmental issues related with the activities of the company are due to chemical intensive processes as it is the case for almost all surface finishing/coating enterprises. Totally 1,785 kilograms of chemicals were used on a monthly basis in four major process lines namely: (i) chromium coating, (ii) cadmium plating, (iii) wet painting and (iv) powder painting (Table 8.2). Intensive chemical consumption of the company is also reflected to its resource cost breakdown (Table 8.3). Chemical consumption of the company is responsible for 60.9% of total resource cost of the company, energy is in the second rank with 33.6% share. Cadmium plating line is determined as the most chemical intensive process accounting for 65.9% of total chemical consumption of the company. Painting operations were other significant resource consuming areas where one third of chemicals (33.2% of total) were consumed.

Table 8.2. Chemical consumption in production processes as the baseline situation

Production processes	Type of Chemical	Amount of Consumption (kg/month)	Percent of Total Chemical Consumption (%)
Chromium Coating Line	Degreasing Chemical	16	0.9
	Cr-Coating Chemical	1	0.1
Cadmium Plating Line	Degreasing Solvent	637	35.7
	Cadmium Oxide (CdO)	103	5.8
	Sodium Cyanide (NaCN)	435	24.4
Undercoating and Painting	Paint Thinner	113	6.3
	Hardening Agent	60	3.4
Wet Painting	Paints (Wet)	300	16.8
Powder Painting	Paints (Powder)	120	6.7
Total		1,785	100.0

In cadmium plating line, an organic based degreasing solvent which comprises n-butyl acetate and 2-methylpropan-1-ol is used by hand wiping practice. The degreasing solvent is applied to all workpieces manually by workers using rags. Solvent degreasing is associated with high VOC emissions and solvents negatively affect central nervous system. Based on this fact, hand wiping practice is only recommended when large, quality-critical and/or high-value parts are to be degreased (European Commission, 2006a). Therefore, in the company solvent degreasing is not only the single most chemical consuming activity with 637 kg/month (35.7% of total chemical consumption) but also questionable in terms of the risks it creates on health and safety of workers. Table 8.4 indicates that 15.7 grams of organic solvent is used in the company to degrease 1 m^2 of surface area. However as low as 2 g/m^2 was achieved in similar facilities for degreasing solvent use (Table 8.4). This finding indicates that there is a huge potential in terms of solvent saving and reduction of VOC emissions in the company. Moreover, water based (aqueous) degreasing systems were proven to be superior to solvent based systems when the environmental impacts are concerned (European Commission, 2006a).

Table 8.3. Cost breakdown of resource use as the baseline situation

Cost Item	Cost ($/month)	Specific Cost ($/1,000 m^2)	Percent of Total Cost (%)
Wet Paint	2,813	69.44	27.3
Liquefied Petroleum Gas (LPG)	2,344	57.87	22.7
Cadmium Plating Chemicals	1,238	30.56	12.0
Powder Paint	1,125	27.78	10.9
Degreasing Solvent	1,105	27.29	10.7
Electricity	781	19.29	7.6
Natural Gas	339	8.36	3.3
Mains Water	94	2.31	0.9
Auxiliary materials	473	11.68	4.6
Total	10,310	254.58	100.0

Table 8.4. Benchmarking of water, chemical and energy consumption in surface coating processes

Total Specific Water Consumption (L/m^2)	Specific Rinsing Water Consumption (L/m^2)	Specific NaCN Consumption (g/m^2)	Specific Degreasing Chemical Consumption (g/m^2)	Specific Energy Consumption (kWh/m^2)	Reference
-	8.0	-	-	-	RAC/CP, 2002
197.0	-	-	-	-	Kliopova and Bagdonas,2003
40.0–50.0	3.0–20.0	8.3–24.0	2.0–90.0	-	European Commission, 2006a
-	-	-	10.2	-	Telukdarie et al., 2006
52.1	-	-	-	-	Fresner et al., 2007
1.0–500.0	-	-	-	-	Barros et al., 2008
400.0	-	-	-	-	Koefoed and Buckley, 2008
0.8–2.5	-	-	-	0.57	Willumeit, 2010
0.8	0.5	10.7	15.7	0.79	This Study

Cadmium oxide (CdO) and sodium cyanide (NaCN) are used as the major chemicals in the cadmium plating line of the company. The toxic and carcinogenic effects of cadmium was well-proven and restricted to be used in many countries for health reasons (RAC/CP, 2002; European Commission, 2006a; Telukdarie et al., 2006; USAID, 2009a; Liu and Ma, 2010). In addition to cadmium, cyanide is highly toxic to humans and should be substituted with less hazardous chemicals (Barros et al., 2008; USAID, 2009a; Liu and Ma, 2010). Commercially available and environmentally benign alternatives to cadmium plating can be listed as: tin/silver plating, thermal treatments, vacuum sputtering (RAC/CP, 2002), zinc-nickel plating, zinc-cobalt plating (USAID, 2009a) and treatment with silicate/silane based chemicals (Heimann and Simpson, 2005). Apart from their toxic effects, cadmium plating chemicals are in the 3rd place among the highest-cost inputs with a figure of 30.56 \$/1,000 m^2-surface coated. In fact specific sodium cyanide (NaCN) consumption of the company (10.7 g/m^2) is within the range (8.3–24.0 g/m^2) calculated for facilities from similar sectors (European Commission, 2006a). However, it is possible to totally eliminate cyanide consumption in the company by substituting cadmium plating with environmentally benign alternatives.

In the company, 80.2% of workpieces (396.000 m^2/year) are wet painted while the remaining 19.8% (90,000 m^2/year) are powder painted after coating operations. As a result of this, wet paint expense (2,813 \$/month) corresponds to the highest resource cost (27.3% of total resource cost) of the company. During wet painting, either water or solvent based paints are used. Solvent based paints comprise 80.0% of paint consumption while the balance is water based. Since solvent based paints contribute to high VOC emissions, they should be replaced with the alternatives such as water based, high solids or 2-component paints whenever possible (European Commission, 2007b). In the wet painting line of the company, paints are applied to the surface of materials via a conventional high-pressure siphon-feed spray gun. An air-operated diaphragm pump is used to supply compressed air to the spray gun with a maximum fluid working pressure capacity of 100 psi. As tabulated in Table 8.5, the conventional high pressure spray guns have the lowest paint transfer efficiency (20–60%) among other painting systems. In other words, 40–80% of solvent based paints are oversprayed during painting where substantial amount of VOC is emitted and a critical economic loss is calculated (1,125–2,250 $/month).

Table 8.5. Transfer efficiencies of different painting systems as percentage

Type of Painting Systems	Randall, 1992 (%)	Envirowise, 2003 (%)	European Commission, 2007b (%)	MOEF, 2009b (%)
Conventional sytems[a]	30–60	30–50	30–60	20–60
Hot spraying	-	-	40–60	25–65
Air assisted airless spraying	-	60–65	35–70	30–70
Airless spraying	-	55–70	40–75	30–70
HVLP[a]	-	65–80	40–80	40–70
Electrostatic atomizing processes	65–85	-	95–100	-
High rotating discs[b]	85–95	80–90	up to 95	up to 85
Powder coating	90–99	up to 97	80–95	-

a: Conventional high pressure spraying

b: High volume low pressure spraying

c: Electrostatically assisted

Energy is primarily used for drying and curing purposes after painting operations. Different drying methods are applied to wet and powder painted materials. Depending on the material to be dried, wet painted materials are either dried at room temperature or at 80 ^{o}C in a temperature controlled chamber. On the other hand, powder painted materials are cured in an oven at 200 ^{o}C. For drying and curing purposes 1,250 kg/month (15,850 kWh/month) of LPG is combusted which makes it 2nd highest cost item (22.7% of total resource cost) among other resources. In addition to LPG, 5,000 kWh/month electricity is consumed in the company for various purposes including heating of process baths in surface coating and running electric/electronic equipments. Besides LPG and electricity, natural gas as being the third energy source is used for space heating. Total carbon dioxide (CO_2) emission of the company is calculated as 8,364 kg/month (1 kWh LPG = 214.7 g CO_2, 1 kWh Electricity = 590.0 g CO_2, 1 kWh Natural Gas = 181.4 g CO_2) while specific total energy consumption is 0.79 kWh/m^2. When total specific energy consumption of the company is compared with the figures reported in the related literature (0.59 kWh/m^2), it is observed that a considerable energy saving potential is present (Table 8.4).

When Table 8.3 and 8.4 are analyzed it can be stated that water consumption is not a major environmental issue for the company. As shown in Table 8.4, total specific water consumption of the company is equal to the lowest reported figure (0.8 L/m^2) in the literature. The company shows even a better performance in terms of rinsing water consumption (0.5 L/m^2) when compared with the literature. Water consumption corresponds to only 0.9% of total resource consumption which indicates that water saving measures may not be a priority concern for the company. Without any pretreatment company is allowed to discharge the produced wastewater to the sewerage pipeline connected to the central wastewater treatment plant of the organized industrial zone.

8.3.2. Replacing Solvent Based Degreasing (Hand Wiping) Process with Aqueous Degreasing Process

As it was analyzed in the "Environmental Performance Evaluation of the Company" solvent based degreasing (hand wiping) was responsible for important environmental and health effects as well as high operational costs. Envirowise (2003) states that replacement of hand-wiping processes with an automatic, fully enclosed, aqueous degreasing process yielded improved environmental performance in a company where organic solvents were in use. Moreover, replacing organic solvent degreasing (hand wiping) process with combined aqueous degreasing and surface coating enabled two different companies to save labor costs in addition to decreased VOC emissions (Envirowise, 2003). Based on this information, hand wiping process was replaced with an aqueous degreasing process in the company.

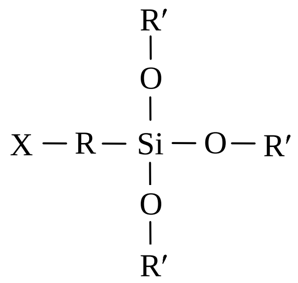
A 440-liter tank (length: 900 mm, wide: 700 mm, water height: 700 mm) made of American Iron and Steel Institute (AISI) 304 grade stainless steel (2 mm thick) was installed as the aqueous degreasing vat. The vat was equipped with electrical heaters of 36 kW total power capacity to keep process bath temperature constant at 55 ^{o}C. A liquid alkaline degreasing chemical (d = 1.39 g/cm^3) was diluted to 5% to be used as the degreasing aqueous medium. The reason behind the selection of an alkaline degreasing chemical was the fact that alkaline degreasers are less aggressive/corrosive to the equipment (vats, pumps, stirrers etc.) when compared to acidic degreasers (Envirowise, 2003). Workpieces are first immersed to the degreasing tank contained in a drum for 3 minutes during which air agitation is applied to increase the rate of mixing and contact. Then, degreased workpieces are rinsed in a stainless steel tank with the same dimensions as degreasing vat.

As a result of this change, degreasing solvent consumption (637 kg/month) was eliminated. Instead, the company started to use 45 kg aqueous alkaline degreasing chemical per month. In other words the degreasing chemical consumption of the company was reduced by 92.9% by weight. Before this application 764 man-hour was being spent monthly for hand wiping of workpieces one by one in solvent degreasing process. The required workforce was also reduced by 60.7% and became 300 man-hour/month. This achievement is mainly due to degreasing of several workpieces at once by dipping into the degreasing vat in a drum instead of processing one by one. As a result of this implementation, a total cost saving of

30,649 $/year was secured while working conditions of workers was improved by eliminating a major VOC source in the company.

8.3.3. Substituting Cadmium Plating Process with Silane-based Coating Process

"Environmental performance evaluation" indicated that cadmium plating line, relying primarily on the use of cadmium oxide (CdO) and sodium cyanide (NaCN), is the major source of hazardous waste generation in the company. Among the environmentally benign alternative coating/plating processes, silane based coating comes forefront as an emerging technology which offers high corrosion resistance and stable adhesion to a broad range of paints (Materne et al., 2006; Hu et al., 2007; Li et al., 2010; Jiang et al., 2012b). Accordingly, the cadmium plating line was replaced with organosilane (Figure 8.2) coating line in order to eliminate cadmium and cyanide consumption in the company. Implemented coating process composed of 3 consecutive operations: (i) silane based coating, (ii) rinsing and (iii) drying (Figure 8.3).



Where;
X = Organic (e.g., amino, vinyl, alkyl)
R' = e.g. methyl, ethyl, isopropyl
R = Aryl or alkyl $(CH_2)_n$ with n = 0, 1 or 3

Figure 8.2. Structure of the organosilane molecule (Materne et al., 2006)

A 440-liter tank (length: 900 mm, wide: 700 mm, water height: 700 mm) made of American Iron and Steel Institute (AISI) 304 grade stainless steel (2 mm thick) was installed as the organosilane coating vat. The organosilane polymer is diluted to 2.5% with deionized water in the coating vat. When the workpieces are dipped into the coating tank, a stable metal oxide film is formed between metal surface of the workpieces and the organosilane polymer. After coating, degreased workpieces are rinsed in a stainless steel tank with the same dimensions as coating vat. At the end of the operations rinsed workpieces are allowed to dry in a container equipped with 2 ventilators and a 16-kW electrical resistance heater.

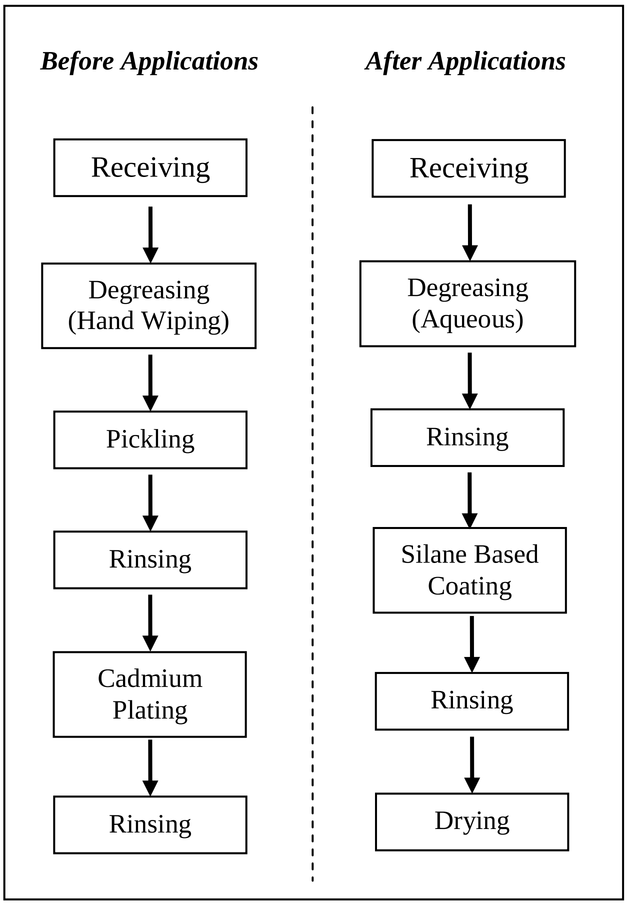


Figure 8.3. Coating process flow diagram before and after applications

As a result of this change, cadmium oxide (CdO) and sodium cyanide (NaCN) was removed from the operations of the company. So, 103 kg/month CdO was saved while NaCN saving was at a rate of 435 kg/month. Instead of consuming 538 kg/month hazardous chemical, it was possible to attain required corrosion resistance prior to the topcoat paints by using 6.3 kg/month organosilane polymer. In other words, coating chemical consumption was reduced by 98.8% on weight basis. In total, a monthly cost saving of 1,238 $ was achieved due to the phase out of CdO and NaCN from the process line. Moreover, the phase out of these hazardous chemicals enabled the company to start operating through an EU compliant surface coating process.

8.3.4. Economic Gains and Payback Calculations

In addition to various environmental and health benefits, the company acquired substantial economic gains as a result of resource efficiency applications. Before applications, cadmium plating chemicals (1,238 $/month) and degreasing solvent (1,105 $/month) were among the highest cost inputs of the company comprising 22.7% of total resource cost when they are combined. Since costly organic solvent based practice, as well as cadmium plating chemicals were replaced with economic alternatives 27,462 $ was saved annually, corresponding to a specific cost saving of 56.50 $/1.000 m^2 (Table 8.6). Replacement of labor intensive hand wiping (solvent degreasing) operation with automatic aqueous degreasing enabled the company to reduce the production cost by 17,386 $/year.

On the other hand, introduced automation and energy demanding drying requirements in aqueous degreasing increased the total energy consumption of the company by 9.8%. In other words energy costs of the company was increased by 3,510 $/year, which is still acceptable when other cost savings are considered. Water cost is also increased although at a considerably lower rate (1,125 $/year) due to deionized water requirement in silane-based coating process.

Table 8.6. Change in resource cost as a result of applications

Cost Item	Change in Specific Resource Cost ($/1.000 m^2)	Change in Annual Resource Cost ($/year)
Process chemicals	- 56.50	- 27,462
Water	+ 2.31	+ 1,125
Energy (electricity)	+ 7.22	+ 3,510
Manpower for surface coating	- 35.77	- 17,386
Total	- 82.74	- 43,372

Total annual cost saving was calculated to be 43,372 $/year by multiplying specific cost saving (82.74 $/1.000 m^2) with annual production of 486,000 m^2. It is remarkable that the annual cost saving (43,372 $/year) was as high as 8.4% of annual turnover (512.500 $) of the company. This analysis indicates that improved resource efficiency significantly enhanced the competitiveness of the company. During the implementation of resource efficiency measures 29.500 $ was spent for the equipments. So the payback period of the implementations was approximately 8.2 months.

8.4. Conclusions

In this study, the main objective was to investigate resource efficiency applications which could offer competitive advantage in terms of concrete economical gains as well as improved environmental performance in a Turkish SME in surface coating industry. "Environmental Performance Evaluation" was carried out, in order to determine areas/processes where significant improvement potential is present. As a result of the evaluation it was determined that major environmental issues are related with chemical intensive processes as it is the case for almost all surface finishing/coating enterprises.

Based on an opportunity assessment, below applications were realized in the cadmium plating line of the company:

- Replacing chemical/labor intensive solvent based degreasing (hand wiping) process with alternative degreasing practices.
- Substituting cadmium plating process with a less toxic and more environmentally friendly alternative coating process.

As a result of applications, degreasing chemical consumption of the company was reduced by 92.9% (Table 8.7). After the applications, required workforce was reduced by 60.7% in degreasing process and became 300 man-hour/month. Cadmium oxide (CdO) and sodium cyanide (NaCN) was removed from the operations of the company. Instead of consuming 538 kg/month hazardous chemical, it was possible to attain required corrosion resistance prior to the topcoat paints by using 6.3 kg/month organosilane polymer, an environmentally benign alternative. Owing to these improvements, the total specific chemical consumption of the company was reduced from 44.07 to 16.01 g/m^2, corresponding to a chemical saving of 63.7%. Total annual cost saving was calculated to be 43,372 $/year by multiplying specific cost saving (82.74 $/1.000 m^2) with annual production of 486,000 m^2. It is remarkable that the annual cost saving (43,372 $/year) was as high as 8.4% of annual turnover (512.500 $) of the company. The payback period of the implementations was approximately 8.2 months.

This study indicated that EU compliant and environmentally sustainable production can be realized in surface coating industry with tangible economic benefits. It is worth noting that the resource efficiency concept can be used as a key in Turkey, an EU accession country, to adopt norms and standards set by the European Commission (e.g. restrictions on the use of cadmium and cyanide in production processes).

Table 8.7. Summary of environmental performance of the company before and after applications

Resources/Wastes	Specific Consumption/Emission Values		
	Before Applications	After Applications	Change (%)
Chemical Consumption (g/m^2):			
- Degreasing Chemical	15.73	1.1	- 92.9
- Cadmium Oxide (CdO)	2.54	0.00	- 100.0
- Sodium Cyanide (NaCN)	10.74	0.00	- 100.0
- Silane Based Coating Chemical	0.00	0.15	+ 100.0
- Total chemical consumption	44.07	16.01	- 63.7
Water Consumption (L/m^2):			
- Mains Water	0.82	0.80	- 2.5
- Deionized Water	0.00	0.02	+ 100.0
- Total water consumption of the company	0.82	0.82	0.00
Energy Consumption (kWh/m^2):			
- Electricity	0.12	0.20	+ 62.4
- Total energy consumption	0.79	0.87	+ 9.8
CO_2 Emissions [a] (kg/m^2):			
- Indirect emissions (electricity)	0.073	0.118	+ 62.4
- Total emissions	0.207	0.252	+ 9.8
Human Resources (man-hour/m^2)			
- Surface Coating	0.019	0.007	- 60.7

a: 1 kWh Electricity = 590.0 g CO_2

CHAPTER 9

WATER RECYCLING AND REUSE IN SOFT DRINK/BEVERAGE INDUSTRY: A CASE STUDY FOR SUSTAINABLE INDUSTRIAL WATER MANAGEMENT IN TURKEY

9.1. Introduction

As an emerging economy, Turkey is currently witnessing a rapid industrial development and associated excessive resource consumption. Being among the essential natural resources as well as indispensible inputs of agricultural, industrial and domestic activities, water resources are under increasing pressure. According to “Turkey Water Report”, total water consumption in Turkey was increased 50.2% from 30.6 to 46.0 billion m^3 between 1990 and 2008 (MOEF, 2009d). Projections indicate that until 2030 total water consumption will increase almost threefold and become 112.0 billion m^3 (MOEF, 2008). During the same period, industrial water consumption is expected to increase tremendously or from 5 to 22 billion m^3. In other words, the share of the industrial water consumption will expected to increase from 10.9 to 19.6% among agricultural and domestic uses in Turkey (MOEF, 2009d). This trend reveals that although agricultural water use is by far the highest water consuming sector at present with a share of 70% of total water demand, industrial based development is subject to change it. Thus, serious measures should be taken in order to conserve water resources from depletion due to intensive industrial activities (Ulutaş et al., 2011). The drastic changes in water quality and increasing territorial reduction of ground water level in Ergene Basin (in Thrace Region) due to intensive textile manufacturing activities can be given as an example for mismanagement in this area (Kaykıoğlu and Ekmekyapar, 2005). In order to prevent similar cases to happen in other areas of Turkey, the water intensive sectors should be targeted for water conservation.

In Turkey, one of the core industrial sectors relying on continuous and high quality water supply is food/drink industry which has been experiencing a remarkable rate of economic growth. The Federation of Food and Drink Industry Associations of Turkey states that annual added-value created by food/drink companies increased by 53.3% from 7.7 to 11.8 billion Turkish Lira (TL) between 2004 and 2009 (TGDF, 2011). Turkish food/drink industry has continued to grow even with a higher rate after 2009. In 2009-2012 period employment was increased from 338,852 to 406,091, an increase of 19.8%. During the same period export of food/drink products increased 61.0% from 5.9 to 9.5 billion $. In 2010, food/drink industry achieved an annual turnover of 88.8 billion TL, which corresponds to 16.1% of total annual turnover (552.8 billion TL) generated in Turkish manufacturing industry (MOSIT, 2013).

Although food/drink industry is crucial for Turkish economy, its environmental impacts require particular attention. The primary impact of food/drink industry is on natural water resources. According to Turkish Statistical Institute, with a 131.2 million m^3/year it is responsible for 10.0% of total industrial water consumption (TSI, 2008c). Due to this high rate of water consumption food/drink industry placed in 3rd rank (after basic metals and textile products) among 23 manufacturing sectors in terms of water use. Furthermore, it exerts a great influence on receiving water bodies by discharging 76.3 million m^3 wastewater /year (TSI, 2008d). Besides water and wastewater issues, food/drink industry is among the highest solid and hazardous waste producer industries in Turkey. Producing 1.2 million ton/year of solid waste, it is responsible for 10.0% of total industrial solid waste generation which makes it 2nd biggest solid waste producer (TSI, 2008b). Based on hazardous waste generation quantity, food/drink industry is on 4th rank with a figure of 51.9 thousand tons/year (TSI, 2008a).

Since food/drink industry holds a water intensive and polluting character in Turkey, it was referred to in various policy and strategy documents to be treated as a priority sector for environmental protection (IDA, 2012; TTGV, 2010; Ulutaş et al., 2012b). The Ministry of Science Industry and Technology (MOSIT) underlined that steps are to be taken in the short-term to conserve natural resources and encourage waste recycling in the activities associated with the food/drink industry (MOSIT, 2013). Moreover, The Scientific and Technological Research Council of Turkey determined one of its targets as “protecting the environment by converting food/drink industry wastes into high added-value products” within the scope of “National R&D and Innovation Strategy: Food/Drink Sector” (TUBITAK, 2010).

In order to decrease water intensity and related environmental impacts as well as high costs associated with water/wastewater management in food/drink industry various water recycling and reuse techniques/technologies were developed. According to Haroon et al. (2013) wastewater of beverage/soft drink industry can be reused in bottle washing and as boiler make-up water after treatment through a combination of reverse osmosis and ion-exchange systems. Another water treatment technology which is gaining much interest is ozonation. Owing to its powerful oxidizing and disinfection properties, ozonation is becoming more popular in food/drink industry for treatment and consecutive recovery of wastewaters (Norton et al., 2012). In a mandarin orange canning company, a water reclamation system composed of chlorination, filtration by active carbon and UV-sterilization was installed. The treated water is reused for segmenting, transportation and washing of fruits which led to substantial water saving in the company (Wu et al., 2013). After a water audit, water pinch analysis was conducted in a non-alcoholic drink producer plant to identify water reuse opportunities. As a result of analyses recycling options were realized and this led to water saving of 83.2 m^3/day (Agana et al. 2013).

The aim of this study was to investigate water conservation and reuse opportunities in a soft drink/beverage manufacturing company. A walk-through audit was followed by analysis and benchmarking of water consumption of the company with the literature in order to determine processes/practices where significant improvement potential is present. After the diagnosis, the closed-loop water recycling systems were introduced to save water and associated costs in the company. This study is expected to be a model for food/drink industry as well as other manufacturing industries for sustainable industrial water management.

9.2. Methodology

9.2.1. General Information and Production Processes of the Company

The company was established in 1969 in Kayseri, Turkey. It operates on a covered area of 15,000 m^2 and employs 100–130 workers depending on the season. Located in Kayseri Organized Industrial Zone, it currently produces soft drinks/beverages (Nace code: C.11.0.7 - Manufacture of soft drinks; production of mineral waters and other bottled waters). Major products of the company can be listed as: (i) 100% fruit juice (no additives), (ii) fruit nectar (25–50% fruit juice) and (iii) fruit drink (3–30% fruit juice). The company holds several quality and management certificates including “ISO 9001:2000 - Quality Management System Certificate”, “ISO 22000 - Food Safety Management System Certificate” and “BRC - Certificate for Food Safety”. Annual fruit juice production capacity of the company is 50,000 m^3/year.

In 2008 and 2009 company processed 14,658 and 10,888 tons of fruits, respectively. In 2009, processed major fruit type was apple with 4,834 tons/year production. Grape, sour cherry and plum were other major types among 13 different types of fruits. On the other hand, the annual total soft drink/beverage production of the company was recorded as 36,009 and 38,761 m^3 for 2009 and 2010, respectively. In 2010, fruit nectars were the primary products of the company in terms of total production amount which was recorded as 30,795 m^3/year. Carbonated drinks and 100% fruit juice drinks were other major products with 4,335 and 2,218 m^3/year manufactured amounts respectively.

Although production procedures/practices of the company change according to type of the fruits to be processed and the products to be manufactured, a general process flow diagram could be developed as presented in Figure 9.1. In the company, fruits are processed into soft drinks/beverages through two consecutive processing lines: fruit concentrate production and fruit juice production.

The fruits are first conveyed from storage to sorting/grading unit. The fruits are sorted before being further processed in order to assure that fresh, mature and unspoiled fruits are to be used. In this step fruits that do not meet the required standards are rejected. After sorting, fruits are washed where debris and dirt are removed. Then, the washed fruits are crushed in special mills which creates a type of fruit pulp puree. Crushing is followed by pressing for extracting the juice from the fruit pulps. This is the major solid waste generating operation in the company since spent pulps are rejected at this point. Extracted juice is concentrated in the evaporation step where water is drawn out. Before being sorted as the intermediate product, the concentrated juice is sterilized and filled into barrels through the aseptic process.

Concentrated juice is first fed to the dilution unit (water addition) in the fruit juice production line. Then, the diluted juice is filtered for clarification. After clarification, pasteurization process takes place where juice is subjected to heat for keeping its temperature at 100 ± 2 ^oC for 30 seconds. Hot fruit juice is cooled during and after bottle filling. Eventually bottled products are labeled and stored before shipment.

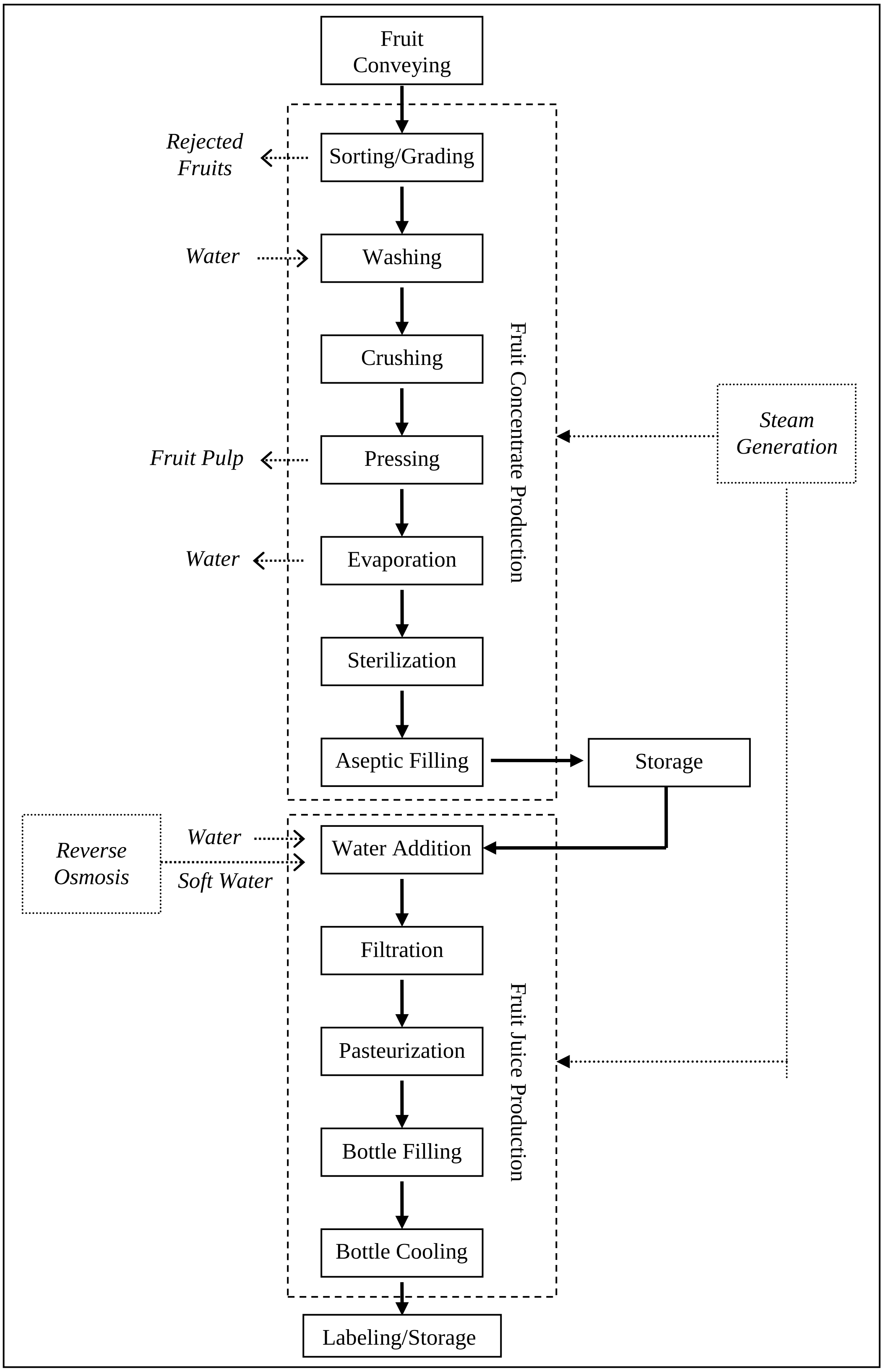


Figure 9.1. Process flow diagram of the company

9.2.2. Data Collection and Water Use Evaluation/Benchmarking

A walk-through audit was carried out together with company officials in order to develop the process flow diagram by getting information on inputs and outputs of major processes (Figure 9.1). After the walk-through audit, process-based numerical data were gathered about water consumption in the company. Since the objective of the study was to decrease water consumption and related wastewater generation, only the water consuming processes/practices were investigated in the company. Then, monthly water consumption figures were compiled from different sources provided by the staff of the company. For this purpose, information sources like process-based record sheets as well as water bills were analyzed.

In order to ensure a dependable baseline before water saving applications, the monthly water consumption data was averaged for 2009. Then, the average monthly water consumption in 2009 was regarded as the baseline situation throughout the study for comparison purposes. As part of the analyses, water use evaluation/benchmarking was carried out by using Environmental Performance Indicators (EPIs) (Alkaya and Demirer, 2013a) which are specific water consumption and wastewater generation data collected from relevant literature.

As described by the International Organization for Standardization (ISO) "environmental performance evaluation is a process to facilitate management decisions regarding an organization's environmental performance by selecting indicators, collecting and analyzing data and assessing information against environmental performance criteria" (Dias-Sardinha and Reijnders, 2001). Thus, in order to identify the processes/practices which need to be improved in manufacturing enterprises environmental performance evaluation methodologies are being developed and widely used in various sectors (Jiang et al., 2012a). According to Thoresen (1999) EPIs can be used by industrial enterprises to control performance of processes and set goals as well as benchmark with competitors' performance. In this study, EPIs were calculated by dividing water consumption data by 1 ton of manufactured product. Then, specific water consumption data (m^3/ m^3 product) was used for analysis/benchmarking of water consumption. In other words, the water intensive processes/practices were comparatively evaluated with environmentally friendly alternatives referred to in the literature including Best Available Techniques - BATs (European Commission 2001 and 2006b).

Based on the water use evaluation/benchmarking, processes/practices which need to be improved in terms of water consumption and wastewater generation were determined. Moreover, four objectives were set for improving water efficiency and decreasing production costs associated with determined processes/practices (Table 9.1). To achieve these objectives, 17 different techniques/measures were developed.

Table 9.1. Developed techniques/measures

Objectives	Techniques/Measures to Achieve the Objectives	Reference
Reducing, recycling and reusing cooling water	1. Replace once-through cooling with closed-circuit cooling system in fruit concentrate and fruit juice production lines	Casani and Knochel, 2002; European Commission, 2006b; WRAP, 2013
	2. Recycle bottle rinsing water to be used as cooling water	Envirowise, 2002
	3. Separate spent cooling water from waste water streams	IFC, 2007b
	4. Reuse cooling water blow-down in other processes including fruit washing and facility cleaning	Envirowise, 2002; European Commission, 2001; NCDENR, 2009c
Reducing, recycling and reusing washing/cleaning water	5. Segregate, treat and reuse wastewaters originating from filter cleaning operations through membrane processes	Oktay et al, 2007
	6. Recycle bottle rinsing water to be used as cleaning water	Casani and Knochel, 2002

Table 9.1. Developed techniques/measures (Continued)

	7.	Introduce automatic shut-off valves for water taps	IFC, 2007b
	8.	Introduce auto-cut off nozzles for the hoses used in facility cleaning	European Commission, 2006b; Pagan and Prasad 2007
	9.	Prevent water losses from hoses left turned on during non-production times	AFGC, 2006; Envirowise, 2002
	10.	Install high-pressure and low-volume jet/spray cleaning systems equipped with optimized nozzles	Envirowise, 2002; IFC, 2007b; NCDENR 2009c
Reducing unaccounted water losses	11.	Introduce regular maintenance programs for water transmission systems to check damages and prevent leaks	Envirowise, 2002; European Commission, 2006b; WRAP, 2013
Introducing water recycling and reuse between other processes	12.	Treat wastewater through a combination of reverse osmosis and ion-exchange systems to be used for washing/cleaning purposes	European Commission, 2006b; Haroon, 2013
	13.	Recycle and reuse bottle cleaning overflows after sedimentation and filtration	European Commission, 2006b
	14.	Recycle and reuse final rinses from tank cleaning operations	NCDENR, 2009c
	15.	Reincorporate product condensate into food product or reuse in other processes except disinfection purposes	Casani and Knochel, 2002
	16.	Reuse condensate water as the boiler make-up	IFC, 2007b
	17.	Install chlorination system for treatment and recycle of transport/flume water	NCDENR, 2009c

Among the techniques/measures listed in Table 9.1, based on evaluations carried out together with company officials two applications were proposed and implemented in 2010 to decrease water consumption and associated wastewater generation:

- Replace once-through cooling with closed-circuit cooling system in fruit concentrate and fruit juice production lines
- Reuse cooling water blow-down in fruit washing process

Applications of proposed techniques/measures were finalized in June 2010 (6^{th} month) after an implementation period of 90 days. Monitoring of the results of water saving techniques/measures lasted 9 months.

9.3. Results and Discussions

9.3.1. Water Use Evaluation/Benchmarking

The company is the single most water consuming plant within the Kayseri Organized Industrial Zone by consuming 70,959 m^3/month of water. There are five major areas where water is used extensively: (i) cooling, (ii) bottle preparation/filling, (iii) facility cleaning, (iv) utility operations and (v) fruit washing (Table 9.2). Apart from these water intensive areas, water is either consumed or lost during other activities including domestic use and transmission between processes. Groundwater is the major water source of the company. It is used in all processes except bottle preparation/filling where mains water is used either unprocessed or after softened by reverse osmosis (RO) system. Groundwater is withdrawn from two wells of the company by four pumps with 30 kW electrical powers each. Since company processes fresh fruits picked up in summer periods operational activities of the company increase during summer and autumn (6 months between June-November) so is the water demand.

As tabulated in Table 9.2, cooling is the largest water consuming activity with 43,251 m^3/month water demand. In other words, 61.0% of total water consumption is recorded for cooling purposes only. Cooling water is used in both fruit concentrate production and fruit juice production lines as once-through practice which relies on single use of water and discharge without any reuse or recycle. According to the calculations, 18.3% of total water consumption could not be attributed to any specific process and regarded as the domestic use and unaccounted losses (e.g. evaporation, leaks) by company officials.

Table 9.2. Breakdown of water consumption in production processes as the baseline situation

Processes	Water Consumption (m^3/month)	Specific Water Consumption (m^3/m^3 product)	Percent of Total Water Consumption (%)
Cooling	43,251	14.4	61.0
Bottle preparation/filling	6,583	2.2	9.3
Facility cleaning	6,000	2.0	8.4
Utility operations[a]	1,167	0.4	1.6
Fruit washing	959	0.3	1.4
Others[b]	13,000	4.3	18.3
Total	70,959	23.6	100.0

a: includes boilers and water softening

b: includes domestic use, unaccounted losses during transmission, evaporation etc.

In Table 9.3, water consumption breakdown of the company in comparison with the related literature was presented. According to the literature, in soft drink production, the major water consuming processes are washing/cleaning (25.0–55.0%) and bottle filling (23.0–60.0%). On the other hand, cooling practices are only responsible for 2.0–8.1% of total water consumption (ETBPP, 1998; Geçer, 2007; Pagan et al., 2004). However, in this company, cooling is the highest water consuming activity with a share of 61.0% while washing/cleaning and bottle filling account for 9.8 and 9.3% of total water consumption, respectively. This initial analysis indicates that cooling water consumption of the company is significantly higher than the reported values in the literature. Besides cooling water, percent sum (18.3%) of other uses (e.g. domestic use,) and unaccounted losses are also considerably higher than the reported values in the literature (3.7–13.0%). In addition to the benchmarking of water consumption breakdown of the company, the specific water consumption was comparatively evaluated by referring to the literature (Table 9.4). According to the literature it is possible to produce 1 m^3 of soft drink/beverage by consuming 2.3–6.5 m^3 of water. However, in this study specific water consumption of the company was calculated as 23.6 m^3/m^3 product. Based on this evaluation it can be claimed that between 72.5 and 90.2% of water saving potential is present in the company.

Table 9.3. Benchmarking of water consumption breakdown of the company

Processes	ETBPP, 1998 (%)	Geçer, 2007 (%)	Pagan et al., 2004 (%)	Seneviratne, 2007 (%)	This Study (%)
Cooling	2.0	8.1	2.0	4.0	61.0
Washing/cleaning	55.0	36.1	25.0	54.0[a]	9.8
Bottle filling[b]	23.0	35.1	60.0	27.0	9.3
Utility operations[c]	7.0	17.0	8.0	11.0	1.6
Others[d]	13.0	3.7	5.0	4.0	18.3
Total	100.0	100.0	100.0	100.0	100.0

a: includes equipment preparation

b: in product

c: includes boilers and water softening

d: includes domestic use, unaccounted losses etc.

Table 9.4. Benchmarking of specific water consumption of the company

Specific Water Consumption (m^3/ m^3 product)	Reference
1.5	AFGC, 2006
2.3	Binnie and Partners, 1987
2.3–6.1	ETBPP, 1998
3.5	Gumbo et al., 2003
3.0–4.0	Haroon, 2013
2.5–3.5	Ait Hsine et al., 2005
6.5	IFC, 2007b
23.6	This Study

9.3.2. Recycle and Reuse of Cooling Water

Based on Water Use Evaluation/Benchmarking, it was determined that cooling water consumption should be reduced in order to decrease overall water intensity of the company. It is stated in various studies that once-through cooling practice should be replaced by closed-circuit cooling in soft drink/beverage industry (Casani and Knochel, 2002; European Commission, 2006b; WRAP, 2013). According to European Commission (2006b), up to 80% of water can be saved by eliminating once-through cooling practice and introducing closed-circuit cooling. Moreover, cooling water blow-down can be reused in other processes including fruit washing and facility cleaning (Envirowise, 2002; European Commission, 2001; NCDENR, 2009c). Therefore, once-through cooling systems both in fruit concentrate and fruit juice production units were replaced in the company by separate closed-circuit cooling systems (Figure 9.2). Each closed-circuit cooling system composed of a cooling tower, stainless steel water pumps, stainless steel pipes/fittings, variable speed drivers (inverters) and a control panel. Technical specifications of the implemented systems are provided in Table 9.5.

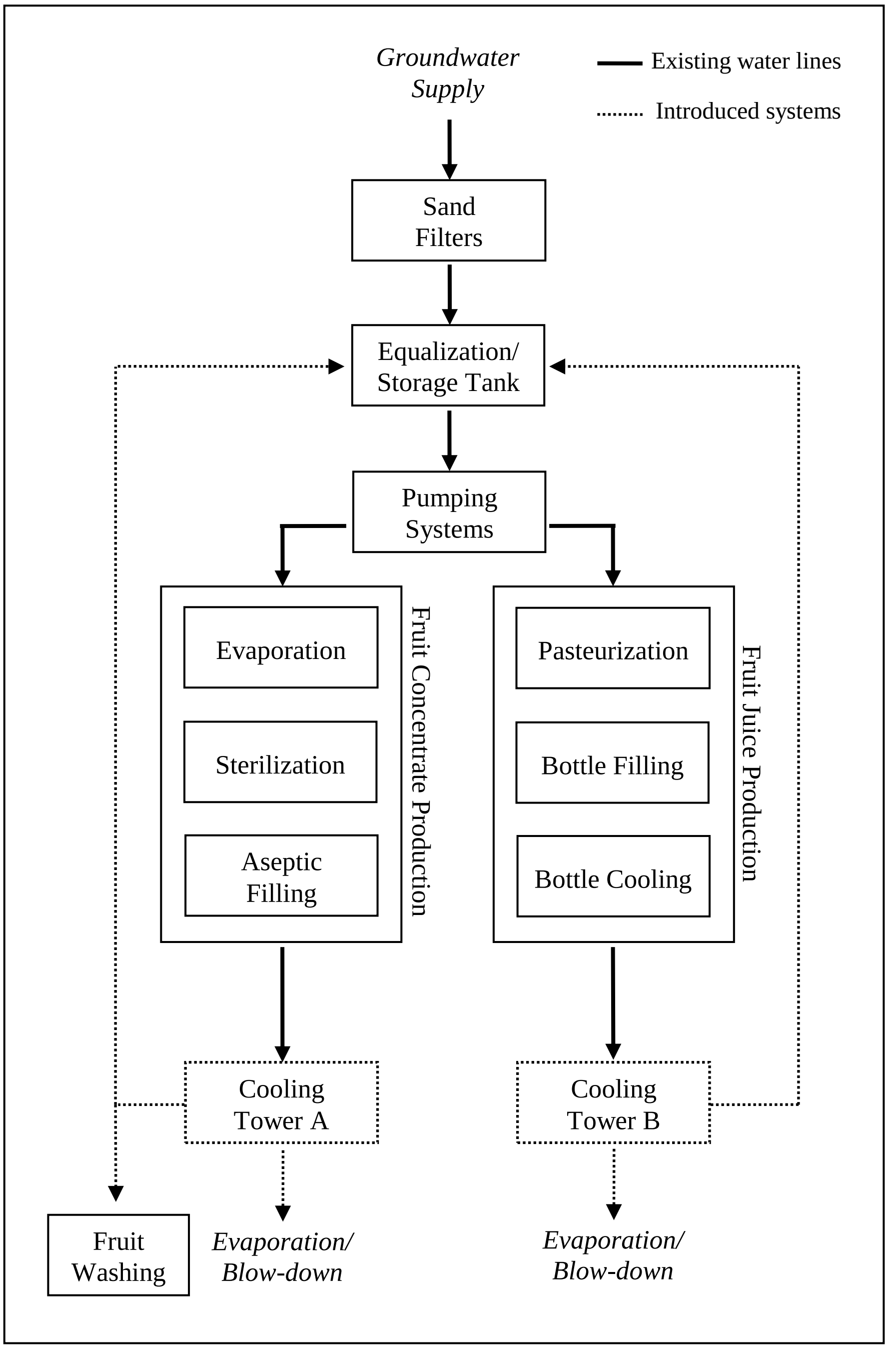


Figure 9.2. Recycle and reuse scheme of cooling water after applications

Table 9.5. Technical specifications of implemented cooling water recycle and reuse systems

Components of the System	Technical Specifications
Cooling Towers	Tower casings are made of stainless steel sheets. Connections between casing components are sealed with silicone. Polyvinyl chloride (PVC) filing materials are used to enable maximum contact surface between the air and water. The drift eliminators are manufactured from PVC and designed in a way that minimizes the water carried out with air flow. The fans, motors and belts are protected from the surroundings with wire mesh and sheet casing. Inspection doors are mounted on both of the cooling towers, which enable tower maintenance and floater adjustment. Designed inlet and outlet temperatures of cooling waters are 50 and 28 ^{o}C respectively.
Water pumps (for pumping to the cooling tower)	Six mechanical centrifugal pumps made of American Iron and Steel Institute (AISI) 304 grade stainless steel were installed. They are of a horizontal shaft monoblock type end suction pumps. By the help of these pumps cooling water (spent cooling water) is recirculated to the cooling tower. Electrical power of each pump is 7.5 kW while pumping capacity is 30–70 m^3/h. Working head of the pumps are 20–30 m and maximum allowable working pressures are 8 bars.
Water pumps (for pumping from the cooling tower)	Six mechanical centrifugal pumps made of AISI 304 grade stainless steel were installed. They are of a horizontal shaft monoblock type end suction pumps. By the help of these pumps cooling water (spent cooling water) is recirculated to the cooling tower. Electrical power of each pump is 3 kW while pumping capacity is 10–40 m^3/h. Working head of the pumps are 15–25 m and maximum allowable working pressures are 8 bars.
Pipes and fittings	AISI 304 stainless steel water pipes and connectors were installed for water transmission between cooling tower and process units.
Variable speed drivers (inverters)	Each pump is supplemented by an inverter for their speed control. Maximum applicable motor outputs of inverters are 7.5 kW.
Control panels	The installed control panels are in compliance with the standards set by Turkish Standards Institute (TSE). Panels are suitable for 3-7 kW pumps.

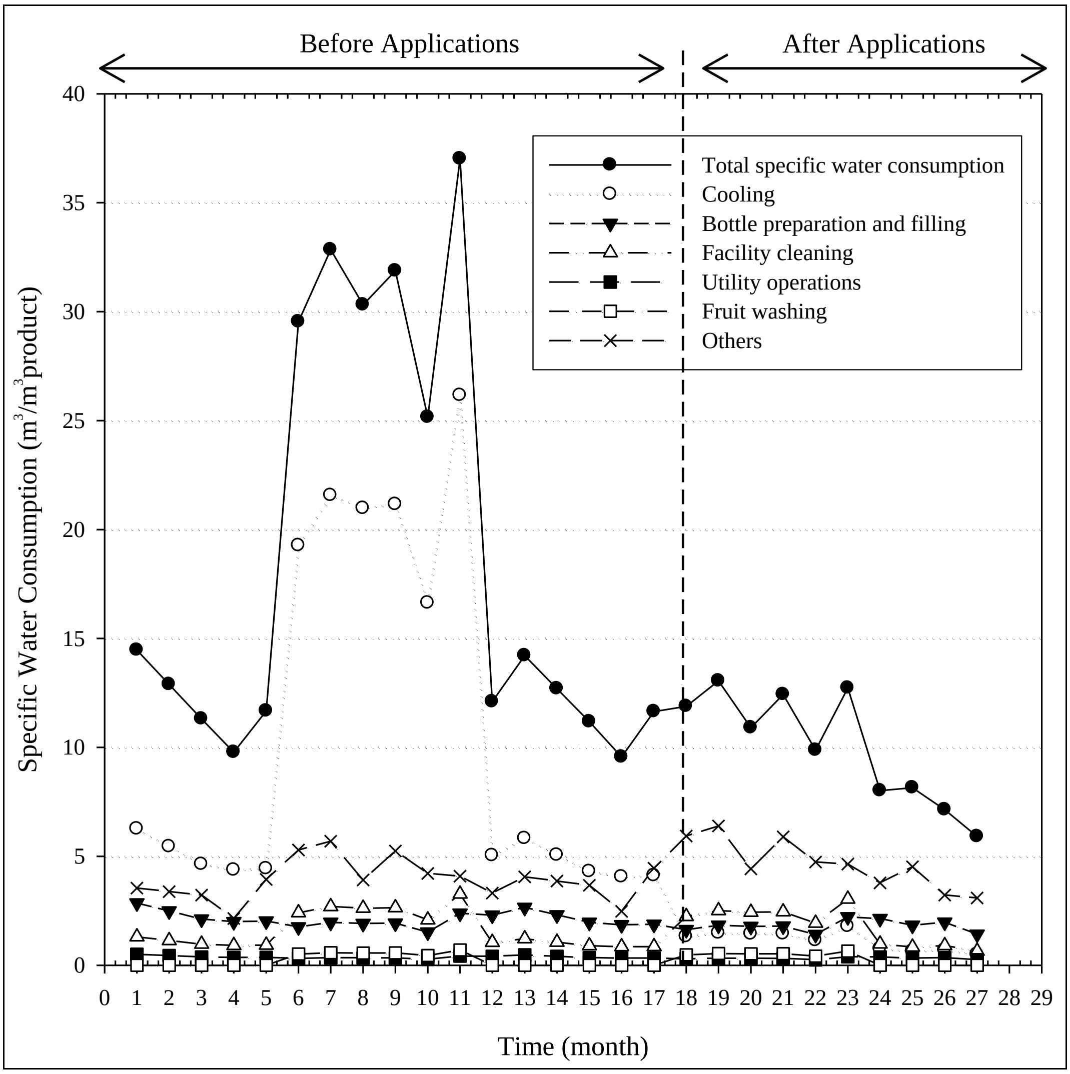


Figure 9.3. Specific water consumption before and after applications

Figure 9.3 shows the monthly specific water consumption of the company before and after the applications. It covers the period between January 2009 (1^{st} month) and March 2011 (27^{th} month). It is observed from the figure that specific cooling water consumption of the company increases during June-November 2009 (6^{th}–11^{th} month) and reaches 21.0 m^3/m^3 product. This observation can be explained with the fact that fruit concentrate production line of the company operates seasonally during June-November period when fruits are received. Thus, cooling water demand increases due to cooling needs of evaporation, sterilization and aseptic filling processes employed in fruit concentrate production line. Although fruit concentrate (intermediate product) is produced seasonally, fruit juice (final product) is produced all year long from the concentrate. In other words, monthly amount of product does not change considerably while water demand of the company increases during June-November period, which is reflected as an increase to specific cooling water consumption of the company. Before applications average cooling water consumption of the company was calculated as 14.4 m^3/m^3. After implementation of cooling water recycle and reuse systems, the total cooling water consumption of the company was decreased by 91.8% and became 1.2 m^3/m^3 product. In addition to this application a part of cooling water blow-down (959 m^3/month) is reused in fruit washing process which decreased fresh water withdrawal in washing/cleaning operations. During the same period water consumption in facility cleaning, utility operations, bottle preparation/filling, fruit washing and other processes did not change considerably. Owing to the decrease in cooling water consumption, the total specific water consumption of the company was decreased from 23.6 to 10.6 m^3/m^3 product a percent decrease of 55.0%.

European Commission (2006b) advocates that discharge of spent once-through cooling waters causes dilution and increase energy consumption in wastewater treatment pants thus should be avoided. Before applications, seasonal increase in total water consumption of the company due to increased cooling water demand was creating a hydraulic overload in wastewater treatment plant of the Kayseri organized industrial zone since the company was the major wastewater producer of the zone with 67.411 m^3/month of discharge. After applications specific wastewater generation of the company was reduced by 57.4% and hydraulic overload issues in wastewater treatment plant were resolved.

Major motivation of the company managers for taking part in this study was to secure economic benefits in addition to conservation of water resources. Since companies are not charged for groundwater use in Turkey, cost saving in the company was due to the reduced wastewater disposal cost which is paid to Kayseri organized industrial zone. The company is charged by 19.4 $-cent per m^3 of wastewater. So, annual cost saving of the company was calculated as 97,003 $. During the implementation of water saving measures/techniques 56,960 $ was spent for the equipments. The equipments were partly financed by UNIDO as a grant of 28,609 $ while the remaining share (28,351 $) was invested by the company. The payback period of the implementations was approximately 7 months.

9.4. Conclusions

The major objective of this study was to investigate measures/techniques that can substantially reduce water intensity of a manufacturing company in soft drink/beverage industry which rely on continuous supply of high quality water resources. Water use analysis/benchmarking was carried out, in order to determine areas/processes where significant water saving potential is present. Based on the evaluations, cooling water is targeted in the company for decreasing overall water demand. Below listed applications were realized in the company.

- Replace once-through cooling with closed-circuit cooling system in fruit concentrate and fruit juice production lines
- Reuse cooling water blow-down in fruit washing process

As a result of the applications specific cooling water consumption was reduced by 95.2% in fruit concentrate production line from 9.6 to 0.5 m^3/m^3 product (Table 9.6). Moreover specific cooling water consumption was reduced from 4.8 to 0.7 m^3/m^3 product which corresponds to a decrease of 85.2%. Therefore, the total cooling water demand of the company was reduced by 91.8%. Recycle and reuse of spent cooling water enabled the company to conserve 55.0% of total water consumption. Thus, the total annual water saving was calculated to be 503,893 m^3

by multiplying specific total water saving (13.0 m^3/m^3 product) with annual production of 38,761 m^3 product. After applications specific wastewater generation of the company was reduced by 57.4% and hydraulic overload issues in wastewater treatment plant of Kayseri organized industrial zone were resolved. During the implementation of water saving measures/techniques 56,960 $ was spent for the equipments while annual cost saving of the company was realized as 97,003 $. So the payback period of the implementations was approximately 7 months.

Çakmak (2007) states that measures should be taken for widespread uptake of effective and sustainable water resource utilization practices. According to "National R&D and Innovation Strategy for Water" prepared by The Scientific and Technological Research Council of Turkey prevention of water pollution, sustainable utilization of water resources and increased water recycling are among major objectives of Turkey government (TUBITAK, 2011). This study proved that water recycling and reuse can successfully be realized in soft drink/beverage industry as a sustainable industrial water management approach.

Table 9.6. Summary of water consumption and wastewater generation of the company before and after applications

Resources/Wastes	Specific Consumption/Emission Values		
	Before Applications	After Applications	Change (%)
Water Consumption (m^3/m^3 product):			
- Cooling water: concentrate production	9.6	0.5	– 95.2
- Cooling water: fruit juice production	4.8	0.7	– 85.2
- Total cooling water consumption	14.4	1.2	– 91.8
- Total water consumption	23.6	10.6	– 55.0
Wastewater Generation (m^3/m^3 product):			
- Total wastewater generation	22.5	9.6	– 57.4

Water cooling is a very common practice in many sectors and is by far the largest (59.5% of total) water consuming activity within whole manufacturing industry in Turkey (TSI, 2010). If successfully replicated in other manufacturing sectors apart from soft drink/beverage sector, outcomes of this study can be a solution for excessive cooling water consumption in Turkey as well as other parts of the world where similar processes are employed.

CHAPTER 10

SECTORAL ASSESSMENT OF THE TURKISH TEXTILE INDUSTRY FOR THE DIFFUSION OF SUSTAINABLE PRODUCTION APPROACH

10.1. Introduction

According to various studies from around the world, sector specific actions need to be taken in order to successfully diffuse sustainable production approach into manufacturing industries within a country (Asipjanov, 2004; Rogers and Banoo, 2004; TTGV, 2010; Sellahewa, 2011). United States Environmental Protection Agency - USEPA (2010) states that sector specific policies and recommendations need to be developed by means of detailed sectoral assessment studies. This approach is also in line with the policy development cycle proposed by The United Nations Industrial Development Organisation (UNIDO) and The United Nations Environment Programme (UNEP) which advocate that awareness creation and capacity building activities (from bottom to top) need to be supported by sectoral and macro level interventions (from top to bottom) (UNEP, 2002; UNIDO 2002). Supporting above arguments, the developed and industrialized countries analyze individual sectors so as to set up tailored sustainable production programmes for respective sectors.

In 2011, Australia's national science agency, The Commonwealth Scientific and Industrial Research Organisation (CSIRO), completed a sectoral assessment study on food manufacturing industry and developed a technology roadmap for achieving sustainable production. The study was based on a literature review and collection of information, from external stakeholders by forming a focus group, conducting telephone interviews and collecting responses via a questionnaire from food manufacturers, industry organisations, public research institutions, government organisations, consultants and retailers (Sellahewa, 2011). In 2010, USEPA adopted "The Pollution Prevention Program Strategic Plan (2010-2014)". The plan is supported by five sectoral strategies based on detailed sectoral analyses on (i) chemicals/manufacturing industries, (ii) hospitals, (iii) electronics, (iv) building/construction and (v) municipalities/institutions. The program issues grants annually to assist businesses in identifying better environmental strategies and solutions for reducing or eliminating waste at the source (USEPA, 2010). In the United Kingdom, Saritas and Aylen (2010) proposed a combined roadmap and scenario analysis for the dissemination of sustainable production, so called "breakthrough sustainability", into metal processing industry. Analyses were conducted on four levels including long run visions up to 2020, interim targets up to 2015, key R&D areas and specific project topics. The major aim of the study was to influence/shape public policy context towards sustainable production in the metal processing industry.

It is underlined in various studies and national policy/strategy documents that the sustainable production approaches should be adopted in Textile industry as a priority sector in Turkey (TTGV, 2010; MOIT, 2010; Ulutaş et al., 2011, IDA, 2012). Among all industrial sectors, textile industry is rated as one of the most polluting ones, considering both the volume discharged and effluent composition of the wastewater (Gümüş and Akbal, 2010, Alkaya et al., 2011). 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 2^{nd} largest industrial water consumer within the whole Turkish manufacturing sector after iron-steel production (TSI, 2008c). Öztürk (2005) states that 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

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

Since textile industry is an indispensible sector for Turkish economy in terms of macro-economic performances like export share and employment rate, it is crucial to sustain its competitive position and decrease environmental risks it generates. For the last 10 years, various studies have been conducted in Turkey to demonstrate that sustainable production approach can help textile industry to improve its environmental and economic performance (Kıran-Cılız 2003, Kocabaş et al., 2009; Ozturk et al., 2009; Alkaya and Demirer, 2013b). Moreover, "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 In December 2011 (TTGV, 2012). However a structural change could not be triggered towards sustainable production within Turkish textile industry beyond a few indivual cases yet.

These developments have brought about the necessity of a sectoral assessment for Turkish textile industry for generating recommendations for the successful diffusion of sustainable production approach within this sector. It is quite important that the "Communiqué of Integrated Pollution Prevention and Control in Textile Sector" is the first and only legal regulation on sustainable production in Turkey. This situation shows that textile industry has a big potential to act as a pioneering and a model sector for others for the dissemination of sustainable production applications in the future.

The results of this study were expected to reveal the gaps and deficiencies which prevent wide adoption of sustainable production applications. To the best of authors' knowledge, this study is the first ever activity in Turkey on sustainable production with a sector-specific dimension. With this perspective this study can be taken as an example and a model which can be replicated for other sectors in Turkey.

10.2. Methodology

The sectoral assessment framework developed consists of a three scale analysis (micro, meso and macro). Namely, (i) the textile producer firms' capacities and awareness, (ii) standards and demands of retailer companies and (iii) the existing institutional framework, strategies, supports and incentives. The assessment was conducted in a step-wise manner as depicted in Figure 10.1. The backbone of the study was the "Current Situation Analysis" on environmental management and sustainable production in textile industry. "Current Situation Analysis" was based on survey studies on producer firms, retailer companies and institutions. The survey studies were also supported by a literature survey which includes the review of relevant research studies and reports prepared for Turkish textile industry. After the analysis, results were discussed and recommendations were developed.

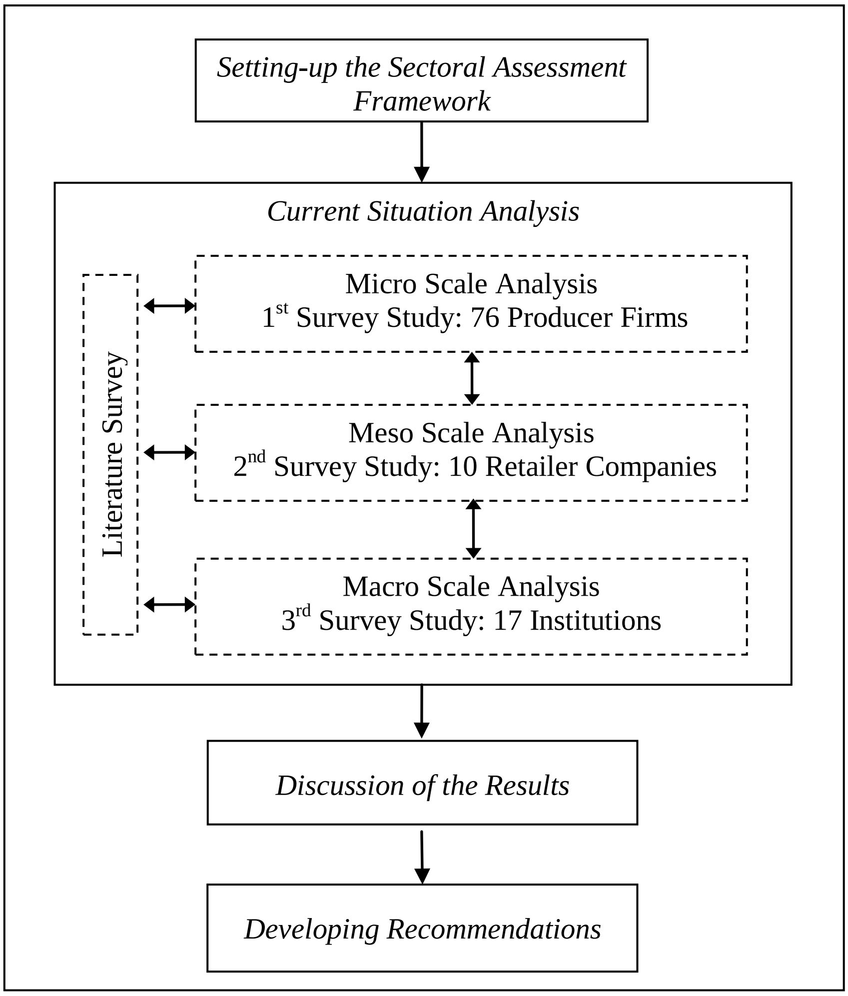


Figure 10.1. Schematic representation of the sectoral assessment methodology

10.2.1. Micro Scale Analysis: Textile Producer Firms

A questionnaire of 41 questions was used to obtain a better understanding on Turkish textile firms' perceptions, awareness and capacity on environmental management and sustainable production (Appendix C). Questions were grouped under six headings below:

1. General environmental policy and perspectives on the environmental legislation

2. The relationship between production processes/systems/technologies and environmental management
3. Measurement, implementation and monitoring activities realized in the context of environmental management
4. Effect of resource/waste management on company's production costs
5. Existing and planned activities for reducing the environmental impacts and associated costs
6. Impact of market conditions and customer relations on environmental performance and related costs

Questionnaires were distributed to the textile producer firms through various means including meetings with the local industrial organizations/associations and direct contacts mainly via e-mail/fax messages and telephone calls. In addition to e-mail/fax messages and telephone calls, site visits were carried out to 21 of the companies in order to get detailed information about their environmental situation/performance through face-to-face interviews. Since textile industry is growing towards developing regions within Turkey (MOIT, 2010), the majority of the firms was chosen accordingly from the areas where textile industry has a growing trend, namely Gaziantep, Kahramanmaraş, Malatya and Adıyaman.

As a result of meetings, email/fax/telephone communications and company visits, the questionnaires were filled by 116 companies. In order to assure the reliability of the survey study, the questionnaires in which less than 80% of the questions were answered were eliminated before the data analyses. In other words, only the questionnaires with at least 80% of answered questions were evaluated in the further analysis. By this way, 76 out of 116 questionnaires were evaluated in the micro scale analysis (Table 10.1). The list of all companies which were evaluated through survey study and/or site visits are provided in Appendix D.

Table 10.1. Distribution of the collected/evaluated questionnaires by cities

City	Evaluated Questionnaires (# of companies)
Gaziantep	26
Kahramanmaraş	18
Malatya	13
Adıyaman	7
Tekirdağ	5
Kayseri	2
Bursa	2
İstanbul	1
Adana	1
Afyonkarahisar	1
Total	76

Based on the answers, the companies were graded between 0–100% for each question. Level of environmental performance/competence of the company for associated area was determined by taking the average of the total grades of the relevant questions. Based on this method, the companies were ranked/scored as follows:

- Level 4 (Companies with 75–100% grade-level) *(The Desired Level)*
- Level 3 (Companies with 50–75% grade-level)
- Level 2 (Companies with 25–50% grade-level)
- Level 1 (Companies with 0–25% grade-level)

At the end of the micro scale analysis, the overall assessment of environmental performance of the companies was presented by using "clustering" analysis (Section 10.3.1.7). Clustering analysis is a statistical technique which enables grouping/categorizing multi-dimensional data sets in clusters based on similarities and dissimilarities (Pandit et al., 2011). In this study ”K-means” clustering algorithm was used by the help of Minitab® v.16 software (Minitab Inc.). ”K-means” algorithm is based on an iterative procedure which provides local solution, minimizing Euclidian distance between the observations and the cluster centers (Austin et al., 2013). In this study, the clustering analysis was used in order to categorize companies according to their environmental performances and perceptions in different areas (e.g. waste management, selection of production processes/technologies). So, the results were discussed by taking different company clusters and their member profiles (e.g. regions, subsectors) into account.

10.2.2. Meso Scale Analysis: Markets and Customer Relations

Since retailer companies (e.g. multinational corporations) are known to be highly influential on the economical, social and environmental performance of textile producers, it is of utmost importance to assess the mechanisms and means they intervene in environmental issues/concerns. A total of 10 retailer companies (4 multinational corporations and 6 large Turkish enterprises/retailers) contributed to the study. Multinational corporations were selected among the firms that have corporate social responsibility (CSR) policies and departments for social/ environmental compliance in Turkey. On the other hand, large Turkish enterprises/retailers were selected among important Turkish garment producers from around the country which cooperate with various textile producer companies from different textile sub-sectors.

A questionnaire with 14 open-ended survey questions (semi-structured interviews) were conducted in order to obtain a better understanding on the relevance of environmental management principles and standards for retailer companies when it comes to selecting their suppliers and auditing their performances (Appendix E). In the scope of meso scale analysis, survey study results were also supported by up-to-date information compiled from recent documents/reports.

Within the scope of "Meso Scale Analysis" below-listed retailer companies including multinational corporations responded to the survey through e-mail and telephone conversations. The contact details of representatives of each of the below companies are provided as Appendix F.

- Hennes and Mauritz AB (H&M)
- Marks and Spencer PLC
- Nike, Inc.
- Lee Cooper (Kipaş Group)
- Li & Fung Limited
- LC Waikiki (Tema Group)
- Cross Jeans (Şık Makas Giyim San. A.Ş.)
- Sunset (Günkar Tekstil Turizm İnş. San. ve Tic. Ltd. Şti)
- Hey Tekstil San. ve Tic. A.Ş.
- Yeşim Tekstil San. ve Tic. A.Ş.

10.2.3. Macro Scale Analysis: Institutional Set-up and Environmental Governance

Institutional set-up and environmental governance affecting textile industry were assessed by receiving information from the major stakeholder institutions in Turkey. The institutions were selected in such a way that information on all aspects of legislative framework, available financial support schemes, research/ development/ demonstration activities as well as informative and technical assistance for textile producers could be obtained. National, regional and sectoral institutions influential on textile industry were aimed to be covered. In this respect, ministries, umbrella organizations, regional development agencies, non-governmental organizations (NGOs), chambers of industry/ commerce and consultancy companies (totally 17 institutions) participated in the survey study from different regions of Turkey including, Ankara, İstanbul, İzmir, Bursa and Gaziantep.

A survey with 17 open-ended questions (semi-structured interviews) was elaborated to institutions of interest so as to obtain a better understanding on the current sectoral structure focusing on environmental management issues (Appendix G). In the scope of macro scale analysis, survey study results were also supported by up-to-date information compiled from recent documents/reports some of which were also referred to during interviews.

The below listed institutions were visited and questionnaires were filled during face-to-face interviews with the survey respondents:

- Ministry of Environment and Urbanization
- Ministry of Science, Industry and Technology
- Ministry of Economy
- Small and Medium Enterprises Development Organization (KOSGEB)
- The Union of Turkish Chambers of Commerce and Industry (TOBB)
- İzmir Development Agency (IDA)
- İpekyolu Development Agency
- Gaziantep Chamber of Commerce
- Gaziantep Chamber of Industry
- Technology Development Foundation of Turkey (TTGV)

The below listed institutions filled in the questionnaire and returned via fax/ e-mail messages:

- İstanbul Textile and Exporters' Associations (ITKIB)
- General Directorate of Electrical Power Resources Survey and Development Administration (EIE)
- TOBB National Council of Textile Organisations
- Bursa Demirtaş Organized Industrial Zone
- Eskon Energy Consultancy (Energy Service Company)
- Uenco Co. (Environmental Consultancy Company)
- Eko-tek Co. (Environmental Consultancy Company)

The contact details of the representatives (survey respondents) from each of the institutions are provided in Appendix H.

10.2.4. Development of Recommendations

The recommendations were developed according to four main headings which are defined as "the main phases for development of the sustainable production concept in a country" (UNEP, 2002):

- Policy and Strategy Reforms
- Financial Mechanisms
- Information Networks and Building Partnerships
- Capacity Building and Awareness Raising

While categorizing each recommendation based on the above listed headings, it has also been specified which scale(s) (micro, meso or macro) the recommendation is relevant to.

10.3. Results and Discussions

10.3.1. Micro Scale Analysis: Textile Producer Firms

10.3.1.1. Environmental Policies and Management Practices

General environmental policies and management approaches exist only in 40.8% of textile companies covered in the survey study. These companies are categorized as Level 4 companies (Figure 10.2). However, there are still 59.2% of companies (Level 1, 2 and 3) which need to integrate environmental concerns into their management perspectives. Most of the companies do not attempt to receive voluntary standards such as ISO 14001. Priority of the top management is generally given to short-term sustainability issues of the company by complying with the requirements of national legislations and customers. Energy management systems/energy managers as well as environmental engineers/responsible persons do not exist in the companies.

Since the scale of companies (e.g. production amount, production capacity, generated waste amounts) are not requested during survey studies, it was not possible to speculate on the scale of companies and its effect on Figure 10.2. However, the bigger companies (e.g. integrated textile producers) perform better when compared to the smaller scale companies (e.g. commissioners, subcontractors). This is mainly due to the fact that integrated companies are suppliers of multinational corporations which require rather established environmental management policies. So, if the scale of companies could be taken into consideration percentage of Level 4 would increase. This situation holds for the rest of this study since the better performer companies are comparatively bigger companies in scale.

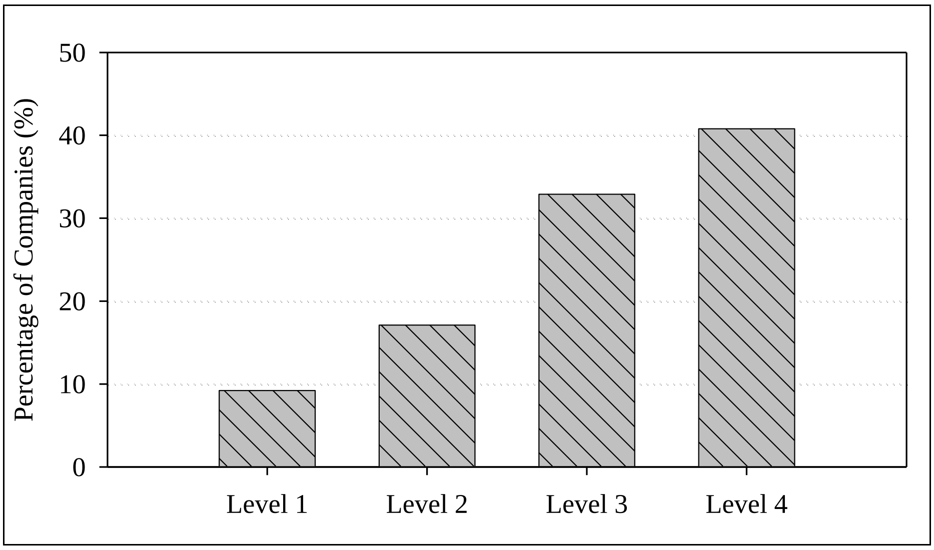


Figure 10.2. Environmental policies and management practices

10.3.1.2. Perspectives on the Environmental Legislations

Based on the analyses, only 39.5% of textile companies are at desired level in terms of their perspectives on environmental legislations (Figure 10.3). Meanwhile 64.0% of companies stated that only national norms are taken into consideration in their environmental investments. Although companies are aware of their liabilities and taking relevant precautions, their response to national regulations is still "reactive". In other words, companies are relatively sufficient in complying with mandatory national regulations; however they do not take "proactive" measures to adapt to potential regulations (e.g. EU harmonization process). Only 36.0% of all companies highlighted that they follow the EU harmonization process of Turkey in terms of new legislative development. Due to the huge difference between environmental issues associated with wet and dry processes, the national environmental norms and standards that regulate them are different. It is obvious that higher water, energy and chemical consumption as well as necessity of wastewater treatment bring a considerable pressure on wet processing companies. This situation makes it technically and economically more difficult for wet processing companies to comply with the regulations when compared to the rest of the companies (Alkaya et al., 2011).

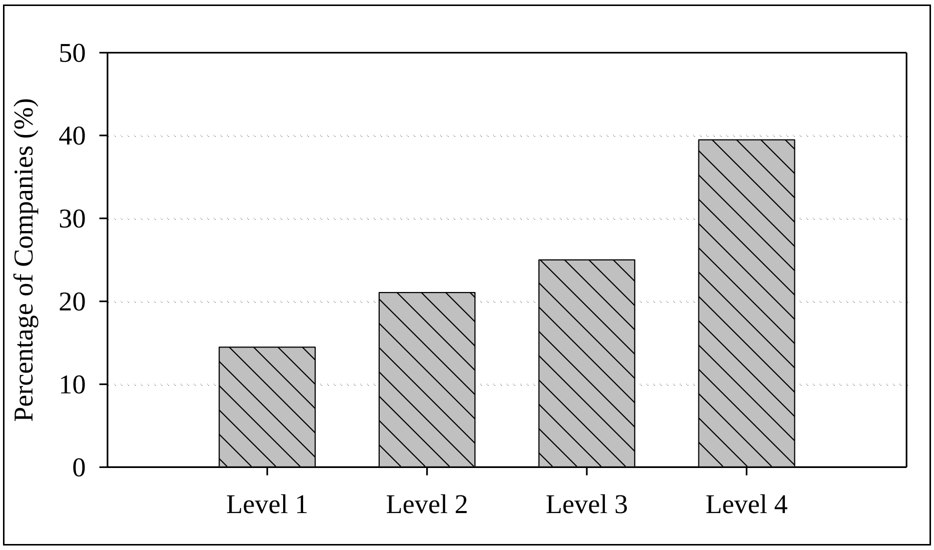


Figure 10.3. Perspectives on the environmental legislations

10.3.1.3. General Waste Management Activities

In the textile companies, general waste management practices such as wastewater treatment, solid waste disposal, and hazardous waste management are carried out based on the legislative requirements. External professional support and/or consultancy by private environmental consultancy firms are usually used. In terms of general waste management practices, 59.2% of all companies are at desired level (Figure 10.4). A high percentage (82.0%) of all companies has rather established systems for solid waste management. In these companies, solid wastes are disposed off after treatment or sent to the related plants/sites for disposal.

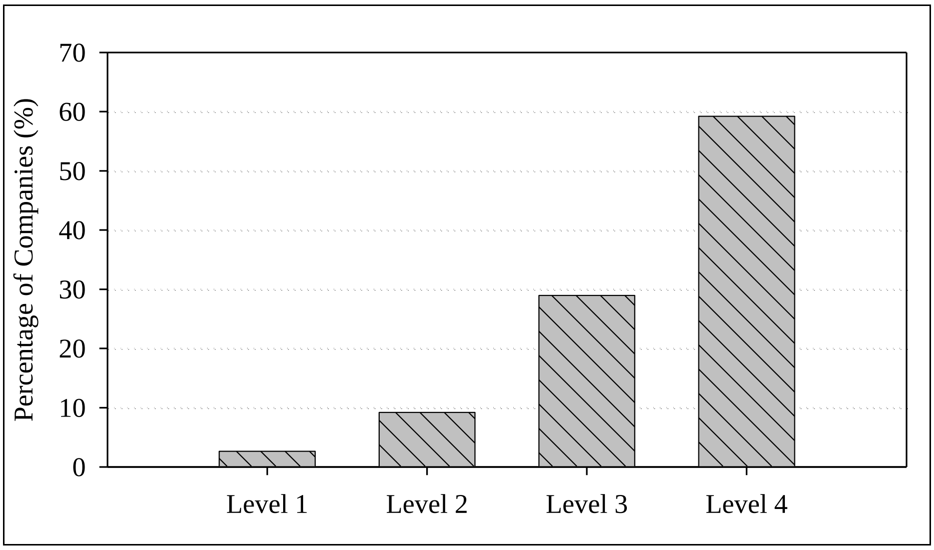


Figure 10.4. General waste management practices

10.3.1.4. Selection of Sustainable Production Processes/Technologies During New Investments or Capacity Increases

When the "selection of resource efficient and sustainable production processes/technologies during new investments or capacity increases" is of concern, only 27.6% of companies are at the desired level (Figure 10.5). Remaining companies have still problems with adapting/implementing the technologies due to various reasons including low level of technical knowledge, financial issues and gaps in environmental regulations. 51.3% of the companies are grouped as "Level 3". This means that most of the companies are "relatively close" to the desired level in terms of selection of sustainable production processes/technologies during new investments. Environmental investments which increase the production efficiency and provide economic savings are planned/implemented when short term economical return is expected. 66.2% of the companies are planning and implementing such kind of investments as long as they have short payback periods.

During the selection of raw materials and chemicals (dyes, enzymes, etc.) which affect the quality of product directly, those having less environmental impacts are preferred in 76.4% of wet processing companies. This means that, although environmentally friendly raw materials, technologies and processes are declared to be “expensive” by 53.1% of the companies, customer demands and internationally acceptable standards for products limit the use of environmentally harmful substances (Norris, 2013). This situation favors sustainable production from product development point of view.

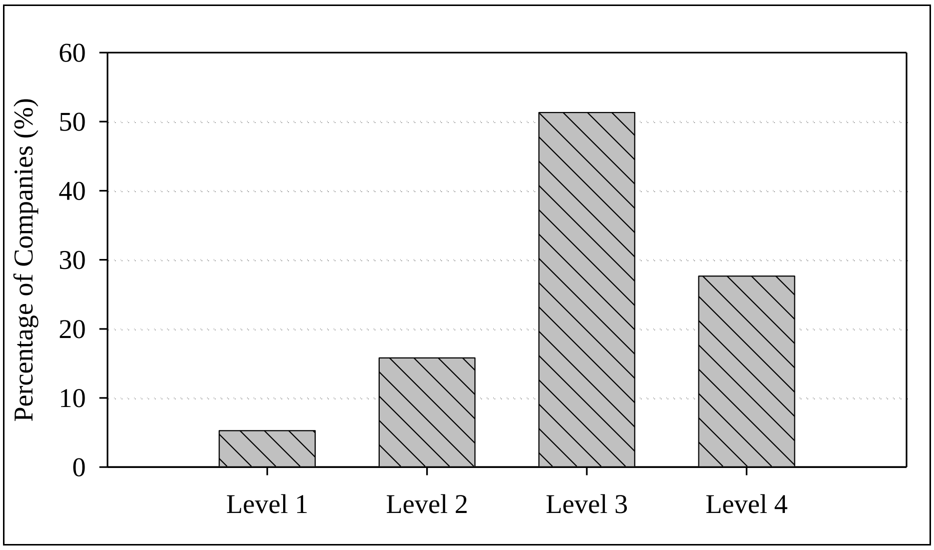


Figure 10.5. Selection of resource efficient and sustainable production processes/technologies during new investments or capacity increases

10.3.1.5. Monitoring and Management of Resources/Wastes

When it comes to monitoring and management of resources/wastes only 31.6% of companies are at the desired level (Figure 10.6). The common problem of all companies is to systematically monitor and record the amount of consumption/production of resources/wastes. Only a few companies tries to monitor their input/output on a regular basis, not to mention benchmarking with good practices in the sector and best available techniques referred to in various sectoral publications (Chougule and Sonaje, 2012). Only 38.7% of all companies are aware of internationally accepted “best practices” and/or “best available techniques” in the textile sector for “pollution prevention”. But adoption and implementation of those techniques/practices are very rare.

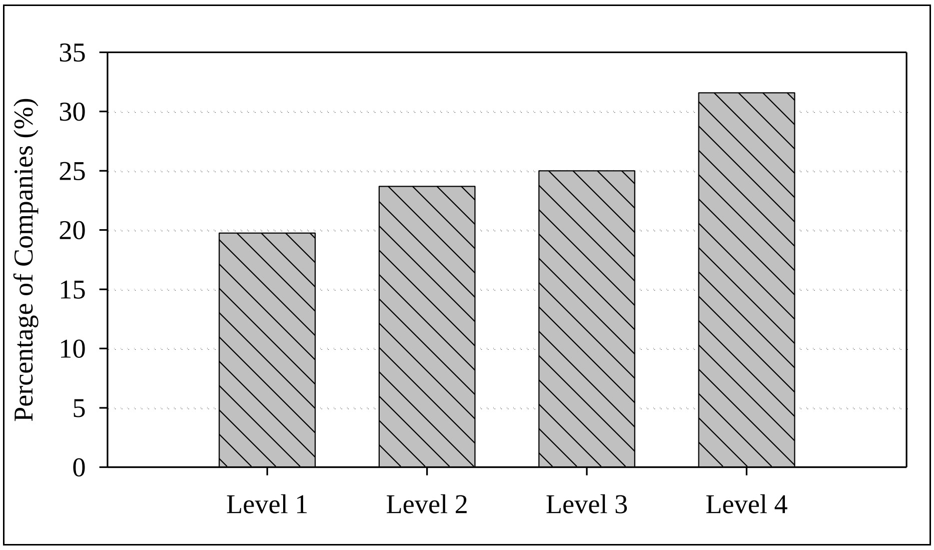


Figure 10.6. Monitoring and management of resources/wastes

Although above 90% of all companies stated that energy and raw materials are among the biggest cost items within their production costs (Figure 10.7), only 35.5% and 49.0% of them are taking measures and planning activities for efficient use of raw materials and energy, respectively (Figure 10.8). On the other hand solid waste, wastewater and air emissions management are found to be among the low priority areas in terms of their associated costs.

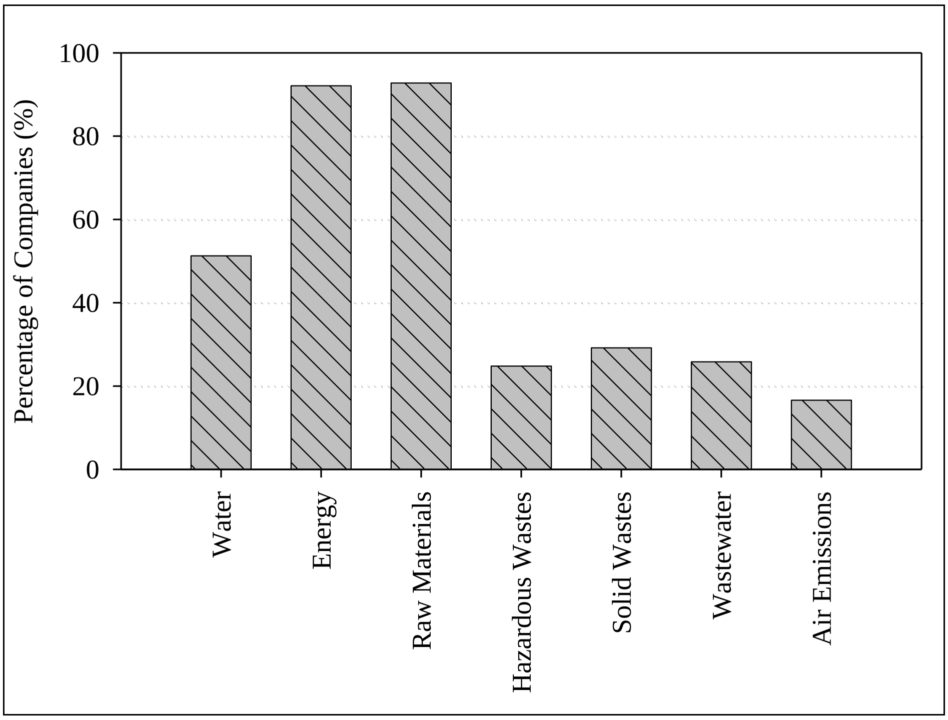


Figure 10.7. Priority of resource and waste management costs

Among ongoing/planned activities on resources and waste management, energy management/saving comes forefront in almost 49.0% of the companies. Water use is another issue for 44.1% of companies to be tackled through some management practices and new implementations. However, wastewater management is not seen as a cost item in majority of the companies mainly because the garment companies do not dispose wastewater (Halkbank, 2010) while some of the wet processing companies are discharging it into wastewater collection pipelines ending-up in central wastewater treatment plants of Organized Industrial Zones. When compared to other items, water management is still the second area after energy when ongoing/planned activities are of concern. The main reason of this situation is the embodied environmental impacts and economic concerns associated with water consumption indirectly (Jiang et al., 2010). In other words, although water is not seen as a cost item itself, its inseparable relation with energy and chemical consumption moves water oriented measures up in the activities list of companies.

To monitor and manage resources/wastes with sustainable production approach is far more important for wet processing companies since their resource use and waste generation is more intensive than the rest of the companies.

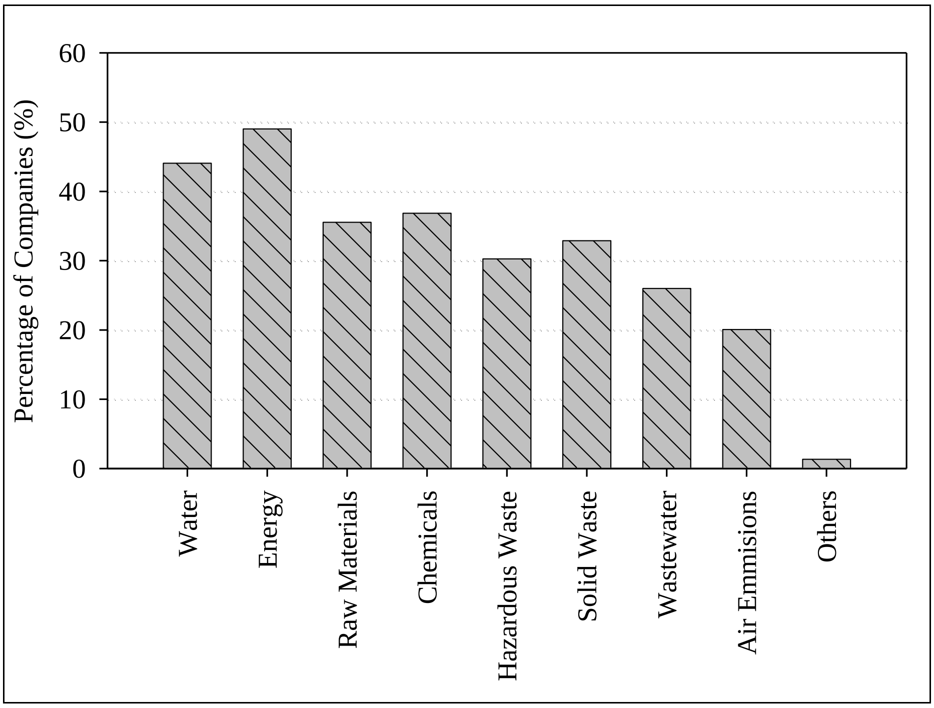


Figure 10.8. Ongoing/planned activities on resource/waste management

10.3.1.6. Effect of Markets and Customers on the Environmental Performance

As it was depicted in Figure 10.9, the answers of 47.4% of all companies indicate that the effect of markets and customer relations on the environmental performance (wastewater treatment, hazardous waste management, etc.) can be defined as "high". According to 76.3% of companies, demands of customers (e.g. corporate social responsibility standards) bring additional costs. Since companies are aware of the fact that their relationships between customers are very important, they are willing to meet the requirements of their customers. Moreover 81.0% of companies believe that environmentally friendly (organic, ecologic, etc.) textile products are an opportunity for the growth of the market and reduction of environmental impacts. This result indicates that product oriented approaches (organic textiles, environmentally friendly products, etc.) are more familiar to textile producers than the environmentally friendly production processes (Turkishtime, 2013).

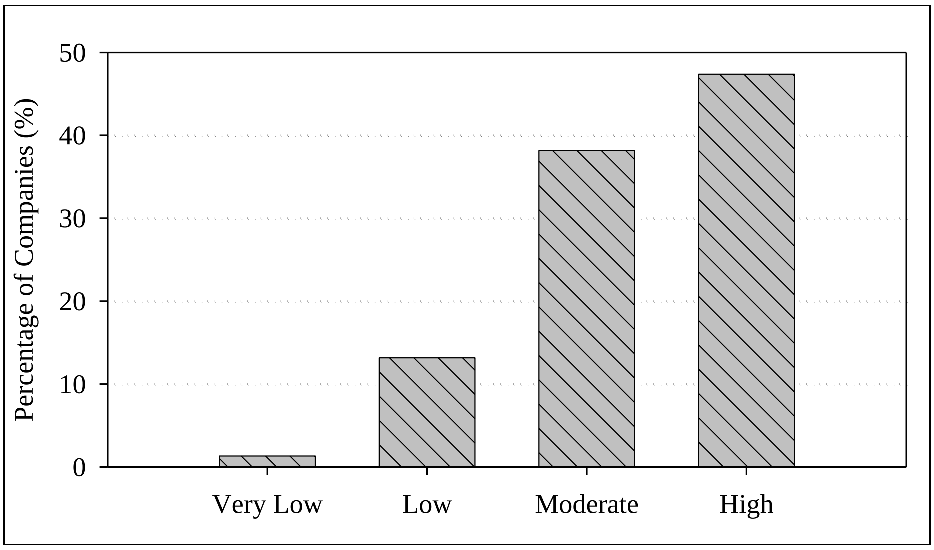


Figure 10.9. Effect of markets and customers on the environmental performance

10.3.1.7. Overall Assessment of Environmental Performance of the Companies

Based on above discussions it can be stated that although companies are rather "good" in general waste management practices (59.2% of the companies are at desired level), selection of resource efficient and sustainable production processes/technologies during new implementations are not at desired level

(27.6%). In addition to that there is still way to go in effective monitoring and management of resources. It is observed that systematic monitoring and benchmarking for continuous improvement is not practiced even in the technologically most developed companies. So, the results of survey analyses indicate that sustainable production approach is not adapted in the majority of the companies.

Clustering analysis indicates that there are three distinct clusters of companies according to overall environmental performance (Figure 10.10). According to the analysis it can be postulated that 29.2% of companies (Cluster-A2) performs well in all areas. This cluster includes the companies which are either important garment producers of multinational corporations or integrated facilities mostly based in Western and central regions (İstanbul, Bursa, Tekirdağ, Afyon etc.) of Turkey. Even these companies have some issues in integrating sustainable production into their production processes/technologies. On the other hand 41.6% of companies (Cluster-A3) performs considerably lower than the companies in Cluster-A2. These companies (29.2% of total) are mostly based in the Eastern parts of Turkey and include wide variety of sub-sectors namely spinning, knitting, weaving, garment production and wet processes. This cluster is below the desired level (75%) in terms of all of the areas. Finally Cluster-A1 is composed of the companies with very low environmental performance in all areas. These companies correspond to %29.2 of total number of companies. All of these companies are operational in the eastern parts of Turkey and mostly serve as commissioner (subcontractor) wet processing firms (dying, washing etc.) for other producers. They do not have direct relationships with retailers and generally do not follow nationally or internationally accepted standards.

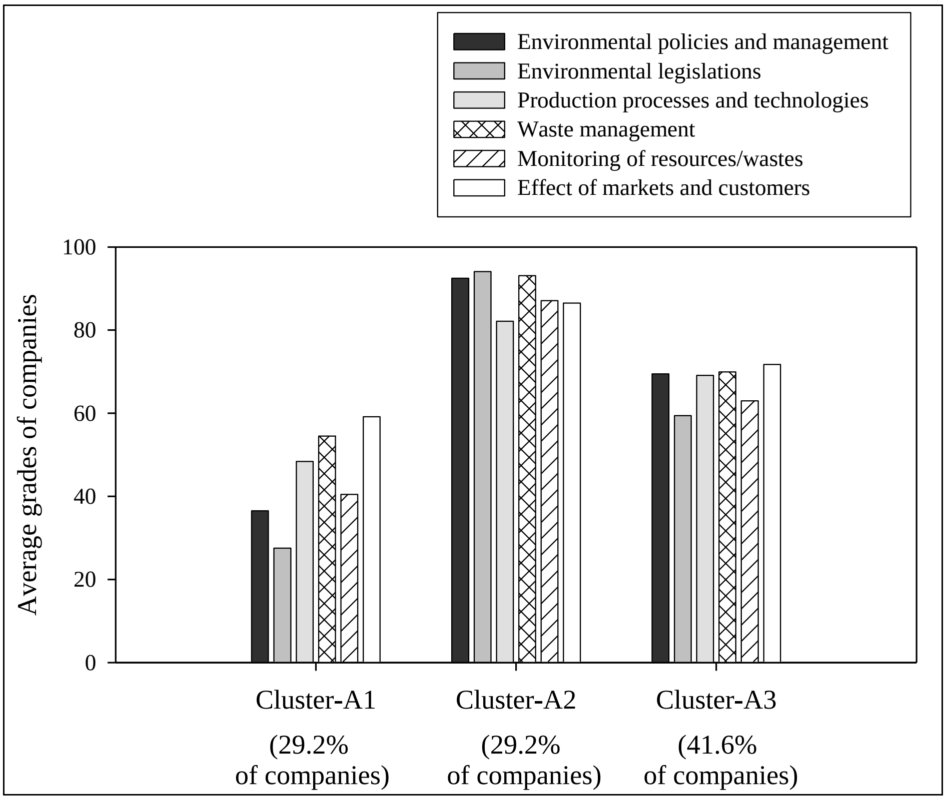


Figure 10.10. Results of clustering analysis for overall environmental performance of the companies

Based on the clustering analysis, companies were grouped under three clusters in terms of their perceptions on resource and waste management costs (Figure 10.11). One of the remarkable results is that regardless of their clusters all of the companies state that "energy" and "raw material" are the priority cost items. Besides these two major resources, "water" is an indispensible source for 34.2% of companies which belong to Cluster-B2. Since majority of Cluster-B2 companies are wet processing companies "wastewater management" is the 4th biggest cost item for these companies most of which operate their own wastewater treatment plants. Cluster-B1 companies composed of garment producers which require relatively small amounts of water. On the contrary these companies produce considerable amount of solid wastes mainly in the form of fabric trimmings. Since these garment producers are major suppliers of retailer companies (e.g. multinational corporations) they manage their solid and hazardous wastes via licensed waste management companies. So their solid and hazardous waste management costs are at considerable stage. On the other hand waste management is not a priority concern of Cluster-B3 companies although water management is. This situation is explained by the fact that these companies operate either in an organized industrial zone (OIZ) with established waste management facilities (e.g. Gaziantep OIZ) or dumping their wastes illegally. This cluster corresponds to 42.5% of all companies and includes companies from variety of subsectors.

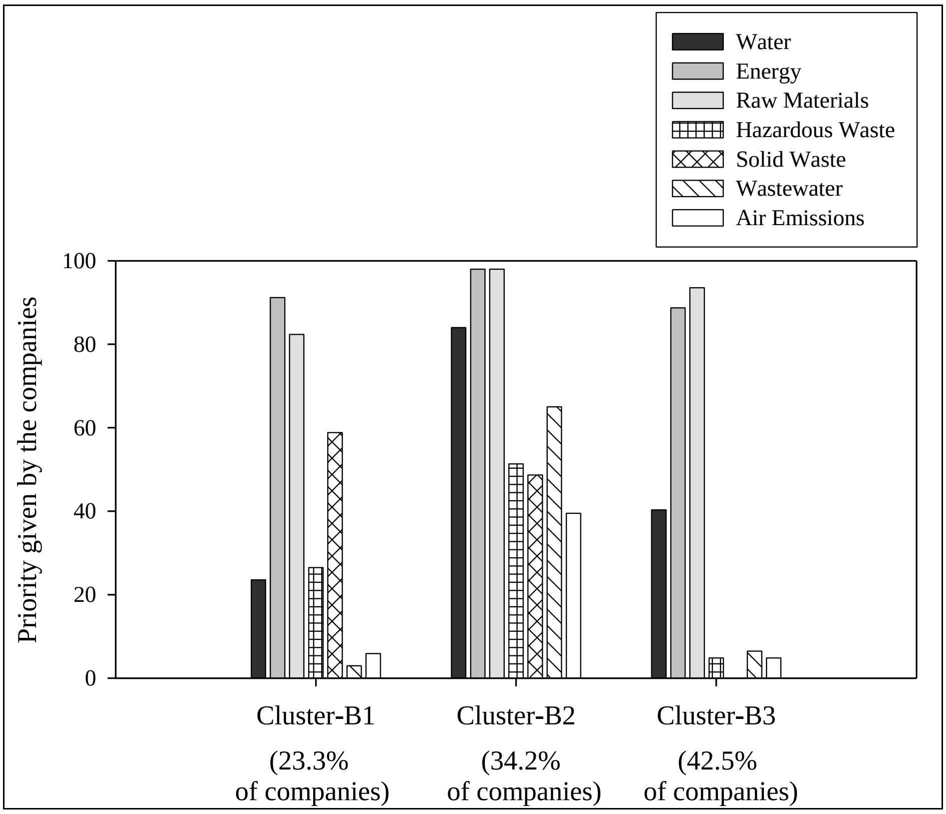


Figure 10.11. Results of clustering analysis for resource/waste management costs of the companies

Third and last clustering analysis was carried out to determine three major clusters of companies according to their ongoing/planned activities on resource/waste management (Figure 10.12). The results show that 49.3% of companies (both Cluster-C1 and C2 companies) have strong intention for energy management. Cluster-C1 companies (26.0% of total companies) carry out projects/activities considerably in all of the areas including carbon management as part of air emissions. Majority of these companies are also the members of Cluster-A2. These companies have established environmental management systems since they are directly in contact with important retailer companies which follow strict CSR policies. On the other hand, 23.3% of all companies (Cluster-C2) carry out project mainly on their important cost items namely energy, water, raw materials and chemicals. Most of the Cluster-C2 companies are operational in an OIZ. So they do not focus on waste management since OIZ is responsible for the management of their wastes. Maybe the most remarkable result of this clustering analysis is the finding that 50.7% of all companies (Cluster-C3) nearly does not have any action on resource/waste management. This result also reveals a serious problem that most of the companies lack awareness, technical capacity or financial resources to carry out activities even in the areas they underlined as important cost items like energy and raw materials.

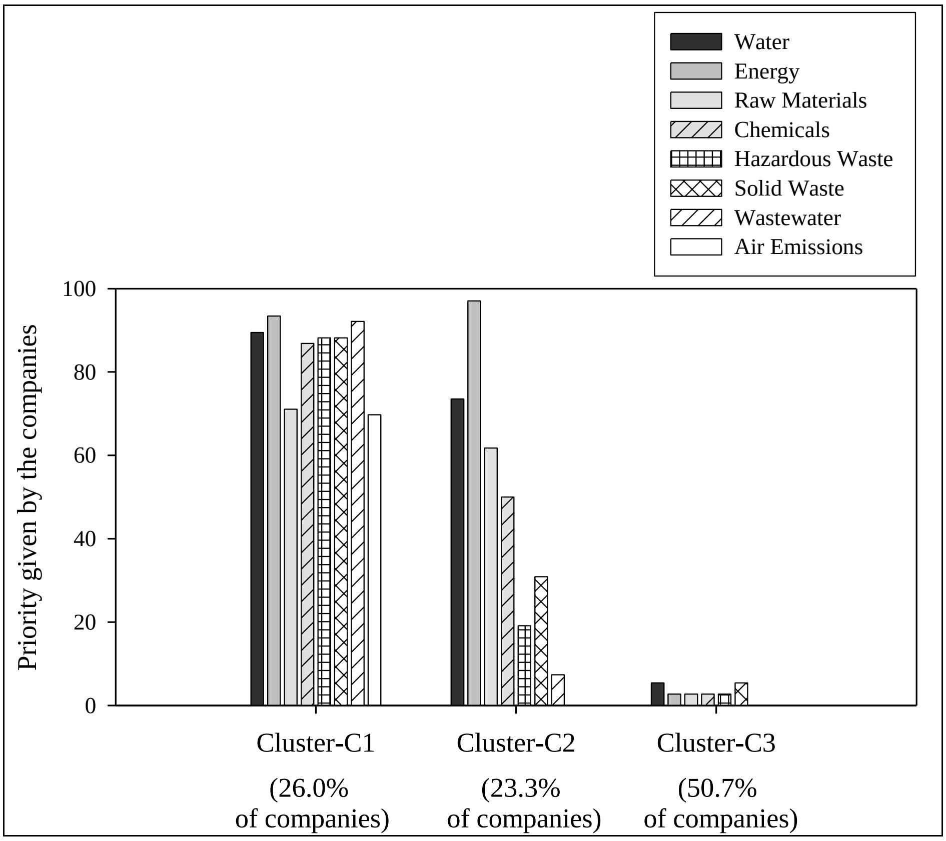


Figure 10.12. Results of clustering analysis for ongoing/planned activities on resource/waste management of the companies

10.3.2. Meso Scale Analysis: Markets and Customer Relations

10.3.2.1. General Corporate Social Responsibility Approach and Environmental Management

Retailer companies (e.g. multinational corporations) state that the environmental risks posed by the textile industry are high and a business action is crucial for decreasing the associated risks. Retailer companies reached through survey study have some efforts to integrate various actions that aim to improve the environmental sustainability of their operations and facilities as well as the work they carry out with their suppliers, customers and industry partners. Particularly multinational textile corporations request their suppliers to sign their Code of Conduct, which involves environmental standards (BlueSign®, Oeko-tex 100, Business for Social Responsibility-BSR, Business Social Compliance Initiative-BSH, etc.), before starting to place their orders (M. S. Kolyaei, personal communication, December 5, 2011). Environmental management is one of the three major pillars in these codes of conducts (Figure 10.13). The other pillars are economic sustainability and social compliance (Uzunoğlu, 2012).

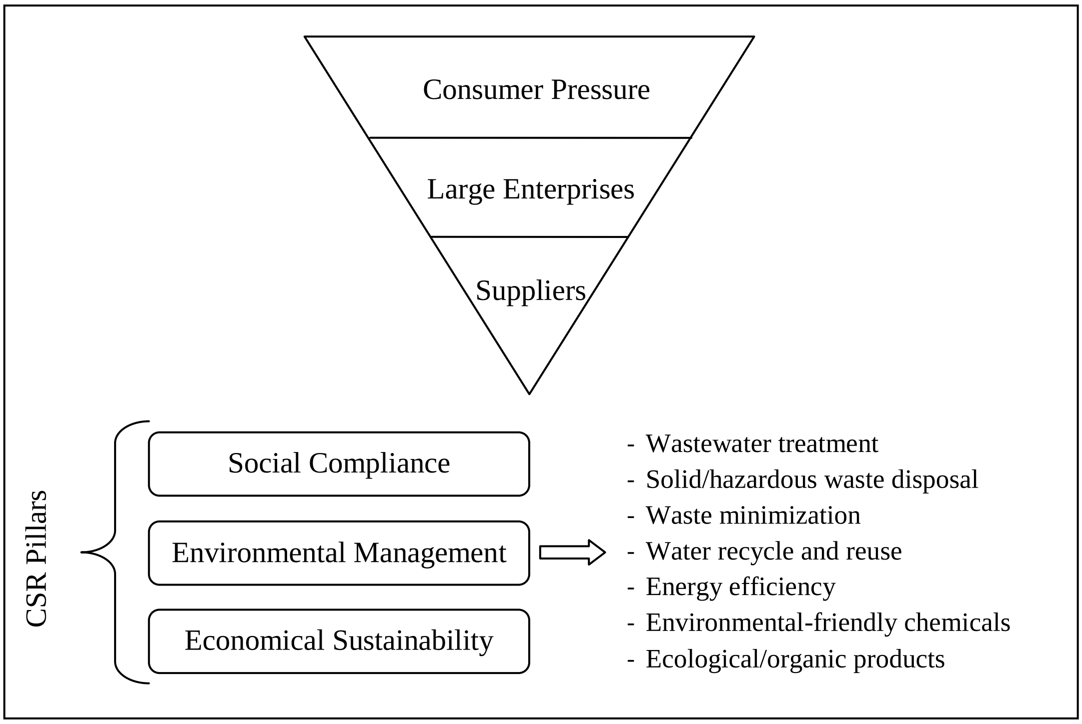


Figure 10.13. Pillars of corporate social responsibility

It is underlined by multinational corporations that in Turkey environment dimension of their CSR strategies started differentiating from sustainability and social compliance, parallel to the current trends in the global markets. The shift from a combined CSR approach to individualized perspectives to each pillar is due to the fact that each pillar has its own features, needs to be managed separately and requires different expertise (C. Soytaş, personal communication, December 9, 2011). Owing to that, some companies have recently started conducting their compliance audits separately for social, environmental and economic compliance. Although the viewpoints of multinational corporations are changing from combined to tailored approaches, large Turkish retailer companies even lack well-defined CSR policies. Although the export shares of the large Turkish retailer companies are high they do not feel considerable consumer pressure on social and environmental issues. Still their point of interest is quality, low price and timely delivery rather than environmental concerns (ITKIB, 2010).

In the supply chain performance of multinational corporations on the other hand, energy/carbon management, water use and associated wastewater treatment comes forefront, in addition to solid waste management within the scope of environmental management (Halkbank, 2010). Most of the corporations have some short and mid-term projects/ targets to reduce the energy and water consumption of their suppliers which are set as priority areas. Within the integrated CSR concept, environmental management is accepted as the most technical dimension among other dimensions namely economic and social compliance (M. Güner, personal communication, December 9, 2011). This is the main reason that corporations start getting either external technical support and/or employing professionals from environmental management field.

Environmental management is seen by multinational corporations as a driver for competitiveness of their suppliers, the textile producers. It is stated that compliance with national environmental legislations as well as resource efficiency, leading to economical savings are achieved, by CSR polices. However, the achievements of environmental activities/projects are limited to the approaches that multinational corporations follow as part of their own CSR policies. Issues like emerging environmental management practices, the state-of-art R&D activities diminishing environmental impacts and international best practices other than supplier companies are not covered in these CSR policies. This situation hinders the scaling-up of their environmental activities/projects.

10.3.2.2. Environmental Issues Addressed in their Corporate Social Responsibility Standards

Retailer companies request their suppliers to comply with their environmental standards although generally they do not require any generic environmental management system standards such as ISO 14001. The surveyed multinational corporations having CSR policies underline that most of the time their norms are stricter than any of the standards set out in the national rules or regulations (C. Soytaş, personal communication, December 9, 2011).Through regular audits, retailer companies evaluate environmental performance of the producer/supplier companies by following checklist-type procedures.

It is also clear that global environmental issues and trends dramatically influence the CSR approaches of multinational textile corporations. For the last 3–5 years energy efficiency and carbon management have become high priority concerns attributed to the climate change (Ö. Aksoy, personal communication, October 13, 2011). This can be regarded as a perfect example how consumer pressure and global market trends influence a market driven instrument like the CSR. In addition to the climate change, water scarcity is being referred in the survey results of retailer companies. In other words water efficiency is becoming more important in the scope of CSR policies.

Most of the surveyed retailer companies, especially multinational corporations tryies to develop methods and projects to decrease both negative environmental impacts and production costs of their suppliers. In other words, retailer companies are shifting their focus from checklist-type of evaluations, on which their suppliers have become quite competent, to an approach where resource efficient and sustainable production prevail (Figure 10.14). Retailer companies' representatives state that they receive positive responses from their suppliers since their new approaches bring both environmental and economic returns (N. Orday, personal communication, November 17, 2011).

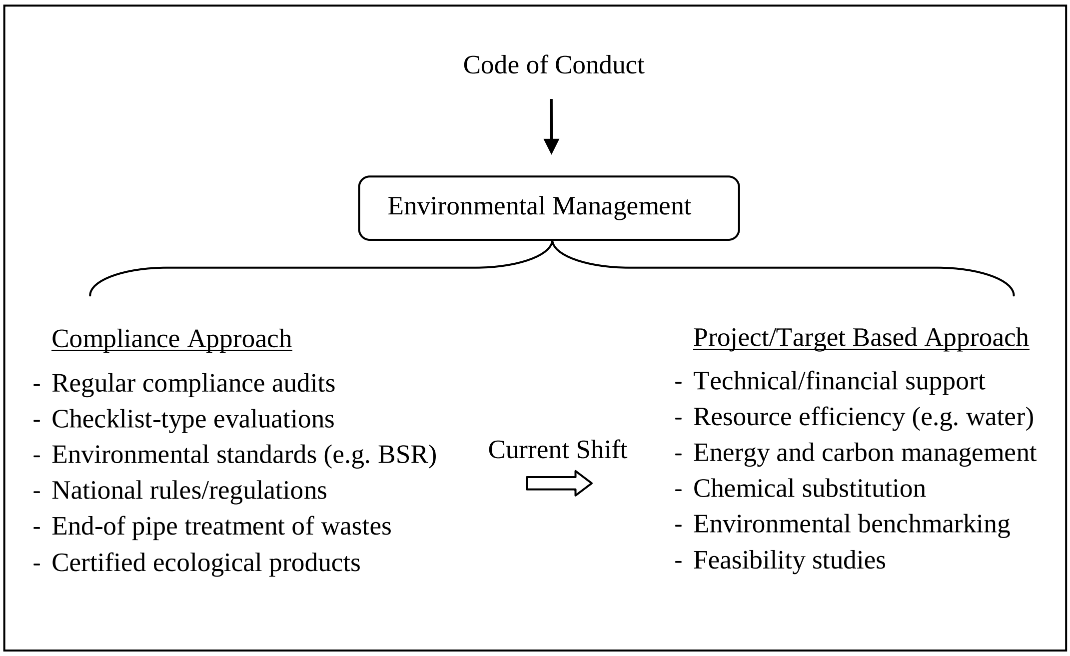


Figure 10.14. Environmental management approach in the context of Code of Conduct

10.3.2.3. Impact on the Environmental Performance of Suppliers

Even if the compliance audits and associated checklist-type environmental evaluations are conducted to all suppliers as part of the codes of conduct, project/target based activities (resource efficiency, developing ecological products, etc.) are carried out with selected major suppliers only. The reason behind is to use resources (financial, human, etc.) efficiently to achieve short- and mid-term targets with regard to environmental performance. This means only some of the major suppliers (garment producers) receive continuous support and encouragement, not to mention other producers or subcontractors when it comes to project/target based activities.

Abovementioned issues are the main barriers in front of real environmental achievements through the whole textile supply chain, which is referred in CSR policies of retailer companies, multinational corporations in particular. Some major suppliers (Turkish garment producers) started developing social and environmental compliance standards on their own, influenced by multinational corporations (D. Cesur, personal communication, December 27, 2011). Although being part of CSR approach, this development is a good indication that penetration of environmental consciousness is possible from the top of textile supply chain to producers (from top to the bottom). On the other hand, it is an obvious fact that from top to the bottom of the supply chain not only the scale of companies but also their awareness and capacity are decreased (Güleryüz, 2011). This situation also makes it difficult to reach quite a number of small scale companies including subcontractors.

10.3.2.4. Long-term Visions and Sustainability Measures

Retailer companies are striving to keep their competitive position through four important dimensions of their activities: (i) quality, (ii) cost, (iii) delivery time and (iv) corporate social responsibility (Turkishtime, 2013). It is stated that Turkish producers are relatively satisfactory competing with their competitors in Far East (China, India, etc.) in terms of both quality and delivery time since they are able to deliver relatively high quality products to European markets on time (F. Ak, personal communication, December 23, 2011).

So, in order to sustain long term cooperation with their suppliers in Turkey, multinational corporations aim at decreasing production costs without compromising high environmental performance as an integral part of CSR approaches. In their long-term visions, retailer companies see their major suppliers as strategic partners. Ensuring international technical/financial support to their strategic partners, retailer companies started focusing on sustainable production techniques/technologies including energy efficiency rather than end-of pipe approach in waste management (D. Kayama, personal communication, December 27, 2011). From that perspective areas that gain much attention are waste minimization at source, wastewater reuse, energy efficient technologies and environmentally friendly products.

Since the multinational corporations are operational in a number of countries (China, India, Indonesia, Turkey, etc.) through hundreds of producers, they have a high potential for environmental benchmarking among many different companies. Some corporations have started benefiting from this situation (M. Güner, personal communication, December 9, 2011). Best operational practices are selected among different producers with similar production processes through environmental performance indicators (energy consumption per unit product, wastewater generation per raw material, etc.). The environmental benchmarking enables multinational corporations to determine inefficiencies in production processes of some of their suppliers. By this way, knowledge transfer also becomes available from technically/technologically more developed producers to less developed ones. Multinational corporations consider this as a strategic approach for the sustainability of their activities.

10.3.3. Macro Scale Analysis: Institutional Set-up and Environmental Governance

10.3.3.1. Legislative Framework

The general outlook of the Turkish environmental legislation has been more "end of pipe" approach oriented, rather than a sustainable production or an integrated environmental management point of view. However, in recent years, particularly with the driving force of EU harmonization requirements, contemporary aspects of environmental management (MOEF, 2009c), namely sustainable production and resource efficiency related approaches, have started to be included (Z. Leblebici and O. Orhan, personal communication, September 12, 2011).

Water Pollution Control Regulation refers to resource efficiency and sustainable production approach by underlining the necessity of "water pollution prevention in a manner consistent with sustainable development objectives" as well as the importance of "production with technologies which prevent pollution at source by minimizing the concentration of pollution in the wastewater". As an important development relevant to this regulation, the "color parameter" (reducing the color of the wastewater before discharge to the receiving environment) was added into the sectoral tables of discharge standards as a new wastewater discharge parameter in April 2011 for related sectors including textile industry (Ciner et al., 2011). It is believed by Ministry of Environment and Urbanization (MOEU) representatives that textile companies may have difficulties in complying with this wastewater discharge parameter (Z. Leblebici and O. Orhan, personal communication, September 12, 2011).

The Registration, Evaluation and Authorization of Chemicals (REACH) Directive is among the EU directives for which a harmonization process is implemented in Turkey (TTGV, 2010). Due to the high amount and variety of chemicals and dyes used in textile sector, adaptation to REACH requirements is quite critical for the sector. Retailer companies (particularly multinational corporations) seek for their suppliers' compliance with the related principles set out by the REACH Directive, although Turkey has not fully adapted this Directive into its national legislation yet.

As far as the EU Harmonization Acquisition Programme of Turkey is considered, adaptation of IPPC Directive is included in the plan; however it is subject to the results of ongoing projects and is not expected to be realized in the near future. One of the industries subject to IPPC Directive is the textile industry. Hence, there is a comprehensive BREF for textile industry, which also includes pollution prevention (sustainable production) approaches and guides. Within this framework, representatives from MOEU have also underlined the need and significance of sectoral approach in understanding and disseminating BATs and BREFs (Z. Leblebici and O. Orhan, personal communication, September 12, 2011). For textile industry specifically, it is indicated that most of the enterprises operating in textile and garment sector in Turkey have begun to pay attention increasingly to the issues listed in the abovementioned reference document (MOIT, 2010).

In the Official Gazette dated 14.12.2011 and numbered 28142, the "Communiqué of Integrated Pollution Prevention and Control in Textile Sector" has been put into effect by MOEU. 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 textile plants having a capacity higher than 10 tonnes/day of washing, bleaching, mercerizing, sizing, printing, dyeing and finishing, are subject to this communiqué. The representatives of MOEU indicated the reason for the preparation of Integrated Pollution Prevention and Control Communiqué firstly for textile industry is the devastating environmental problems in Ergene River Basin where the textile industries are highly concentrated (Z. Leblebici and O. Orhan, personal communication, September 12, 2011).

As a matter of fact, it is quite interesting that a specific legislation has been developed which directly refers to IPPC as well as sustainable production for the first time in Turkey and the only target sector is specifically textile industry. This also shows that textile industry has a big potential to act as a pioneering and a model sector for others for the dissemination of sustainable production applications and that IPPC approach may potentially be applied for other sectors as well, in the future.

Regulation on Enhancement of Energy Efficiency in Energy Resources and Energy Use has been revised in October 2011. One of the most significant issues set by the revision is the requirement of TS EN ISO 50001 Energy Management System Certification as a prerequisite for benefitting from certain incentives and supports for energy efficiency. Since the regulation on energy efficiency was put into effect, there were considerable impacts observed in the market, including the industrial companies as well as the service providers, namely energy consultancy companies. Textile industry, as one of the major sectors in Turkey in terms of energy consumption, has been affected by these legislations and some initiatives have taken place. However, there is still room and potential for improving the energy efficiency capacity of this sector.

10.3.3.2. Financial Supports

TUBITAK provides support for sustainable production by means of two research groups. “Processes for the prevention of environmental pollution before it is created” and “clean technologies” are two of the priority areas of Environment, Atmosphere, Earth and Marine Research Group (CAYDAG) and “studies for identification, control, prevention and elimination of environmental pollution”.

These research groups (CAYDAG and TBAG) provide supports for sustainable production by means of various support programmes of TUBITAK targeting R&D activities.

TTGV started a financial support programme for environmental projects in 2006. Within the scope of the programme soft loan is provided for the "implementation projects" in the fields of environmental technologies (sustainable production), energy efficiency and renewable energy. Implementations have been realized in different sectors including, the textile, food, ceramic, plastic, steel, electricity production etc. Looking at the participation of the textile companies in these support programmes, the ratio of the textile companies among all companies is approximately 15%, which is relatively a good ratio (F. Ulutaş, personal communication, September 19, 2011).

Regional Development Agencies implement different support programmes at different periods, based on the regional plan and priorities defined. İzmir Development Agency (IDA) was the pioneer agency who has implemented a SME Financial Support Program in 2008–2009 with a target of "improving the competitiveness of enterprises and increasing employment as well as promoting the production and consumption of clean and alternative energy resources and innovative activities". "Promotion of utilizing environmentally sound technologies and energies and changeover to sustainable production processes" were among the priorities of the programme. Looking at the sectoral priorities for the period 2009–2013, agriculture and agro-industry which also includes textile industry are among the key sectors defined. Hence, textile industry was one of the focus sectors of the above mentioned SME Financial Support Programme of IDA. The participation ratio of textile industry within this programme is anticipated roughly to be around 10% (F. M. İneler, personal communication, September 16, 2011).

Within the framework of the energy related financial incentives, especially for energy efficiency, the grant programme implemented under Energy Efficiency Law should be considered as an important support for the relevant applications. All industrial sectors, including textile manufacturing, having an annual energy consumption of 1,000 toe or more, are eligible for the support programmes, namely the Efficiency Improvement Project Support (grant programme) and the Voluntary Agreements. The relevant procedures and principles are regulated by the Regulation on Enhancement of Energy Efficiency in Energy Resources and Energy Use.

Based on the figures provided by General Directorate of Electrical Power Resources and Development Administration (EIE), grant agreements were signed with 25 industrial companies (32 projects) for energy efficiency improvement projects between 2009–2010. Among these companies 7 of them are from textile industry; this figure corresponds to 8 projects. In the voluntary agreements, totally 22 agreements were made 3 of which were from textile industry. It is indicated that the majority of the textile companies are located in Marmara Region and their fields of manufacturing are manufacturing of various types of fibers, textile production and finishing, etc (E. Çalıkoğlu, personal communication, September 5, 2011). These figures also show that the textile industry has relatively a higher tendency towards investment type of projects and energy efficiency may be one of the priorities for the sector. However, Eastern or South-eastern regions seem to fall behind in this picture, when compared to Marmara Region which withholds the majority (Kunt and Zobu, 2011)

As an observation from the MOE representatives, the textile exporters are ready to align themselves towards environmentally friendly production in accordance with EU standards, and seek for a better coordination among all relevant public institutions which provide financial supports for such activities (Z. Leblebici and O. Orhan, personal communication, September 12, 2011).

10.3.3.3. Research, Development and Demonstration Activities

In 2009–2010, the Project “Determination of The Framework Conditions and Research-Development Needs for the Dissemination of Sustainable (Sustainable) Production Applications in Turkey” was implemented by TTGV, on behalf of Ministry of Environment and Forestry. In this project, the sub-sectors of the manufacturing industry in our country were subjected to a prioritization process for sustainable production practices. According to the results of this study, one of the five priority industrial sectors is “Manufacture of Textiles” (F. Ulutaş, personal communication, September 19, 2011).

According to the project “Determination of The Framework Conditions and Research-Development Needs for the Dissemination of Sustainable (Sustainable) Production Applications in Turkey” there are limited number of universities in our country which undertook important work on sustainable production (TTGV, 2010). Middle East Technical University, Bogazici University and İstanbul Technical University are the leading universities in Turkey. These universities carry out R&D activities on sustainable production. Moreover, many nationally (TUBITAK, State Planning Organization-SPO, Scientific Research Projects, MOEF) and internationally (EU FP 7, EU Marie Curie Actions IRSES, EU Leonardo da Vinci Multilateral Projects and German Federal Education and Research Ministry) supported research projects have been carried out in METU. In addition to these, several graduate dissertation studies, training activities, seminars, consulting services, invited talks, etc. have been carried out by METU and Bogazici University (TTGV, 2010). ITU has carried out projects on recycling and IPPC. ITU Department of Environmental Engineering has been conducting research projects on sustainable production technologies, increasing cooperation with industry and conducting sectoral training activities on the subject as the targets of its strategic plan. Even though they are at a limited extent, some studies on sustainable production are conducted in other universities (Uludag, Dokuz Eylül, İstanbul, Suleyman Demirel, Hacettepe, Zonguldak Karaelmas, Balıkesir, Ataturk, Aksaray, Harran Universities and Gebze Institute of Technology) (TTGV, 2010). However, the existing capacity based on quantitative performance criteria (publications in Citation Index journals, Research and Development, implementation and consulting projects, technology development and patent applications, etc.) is far from being sufficient to the needs of the country (TTGV, 2010).

Representatives of Ministry of Economy (MOE) underlined the importance of R&D and innovation for the textile industry, giving Germany as an example who produces advanced technology textile products. Particularly the fiber based solutions, such as increased flexibility of fibers and use of textile products in areas other than regular daily use are some of the developing R&D areas for the sector, in addition to the development of environmentally friendly textile products (M. A. Yurdupak, E. Açıkgöz and H. O. Korkmaz, personal communication, September 15, 2011).

Within the context of R&D, MOSIT representatives indicated the necessity of involving universities into the relevant activities, giving SANTEZ programme as an example of university – industry cooperation mechanism (S. Engin, T. Altınışık and S. Çotuk, personal communication, September 15, 2011).

Between 2008 and 2011, the UNIDO Eco-efficiency (Cleaner Production) Programme was implemented as a sub-programme of an MDGF funded UN Joint Programme called "Enhancing the Capacity of Turkey to Adapt to Climate Change". In this Programme, one of the major activities foreseen was the implementation of demonstration projects of sustainable production in the priority sectors (Alkaya and Demirer, 2013a). Again in this Programme, textile production was identified as one of the priority sectors and one of the six demonstration projects was applied in a textile company located in Bursa. Representatives of Ministry of Science, Industry and Technology emphasized the importance of demonstration projects of eco-efficiency (sustainable production), which is critically necessary for textile industry where use and management of chemicals is one of the problematic areas in addition to other major areas such as use of water and energy (S. Engin, T. Altınışık and S. Çotuk, personal communication, September 15, 2011).

10.3.3.4. Informative and Technical Assistance for Textile Producers and the Existing Capacity

Ministry of Environment and Urbanization implements training activities regarding different environmental issues such as training of the environment officers, trainings on water pollution, soil contamination and hazardous wastes. These training activities have been organized as a response to the requests from industries (mainly organized industrial zones) (Z. Leblebici and O. Orhan, personal communication, September 12, 2011).

Ministry of Economy deals with the export/ import, tax and similar problems of the textile sector and tries to provide solutions. Moreover, the Ministry carries out studies for the compilation of sector related statistics within the framework of their fields of activity (M. A. Yurdupak, E. Açıkgöz and H. O. Korkmaz, personal communication, September 15, 2011).

EIE has been delivering energy management trainings for years for the industry and providing the energy managers with the relevant certificates. It is reported that since 1997 trainings were given to the staff of totally 156 textile companies. The trainings are on-going (E. Çalıkoğlu, personal communication, September 5, 2011).

KOSGEB provides laboratory analysis services for SMEs. It is indicted that their laboratories have been renovated in 2009 and 2010 with new investments and addition of new equipment. The portfolio of analyses carried out by KOSGEB laboratories includes chemical analyses, mechanical tests, metrology services, technical assessment and monitoring. Moreover, KOSGEB operates a Textile Quality Control Testing Laboratory (TS EN ISO/ IEC 17025:2005 accredited) located in İkitelli, İstanbul, for providing the relevant laboratory services both for SMEs and large companies engaged in textile industry (V. Çelebi, personal communication, October 5, 2011).

Turkish Standards Institute (TSI) provides certification and training services in relation to Environmental Management System Standards (ISO 14000 series) as well as Energy Management System Standard (ISO 50001).

Regional Development Agencies carry out certain informative activities (meetings, seminars, etc.) in addition to analysis and reporting studies in relation to their financial support programmes. Additionally, they try to improve the cooperation opportunities among the relevant institutions such as chambers, universities and other public institutions in order to enhance the regional development activities desired and developing new projects. As an example İpekyolu Development Agency maintains its contacts with chambers of industry and trade for searching and discussing on the new markets available for the companies in the region. They search for financial resources for the companies and inform them accordingly. At the same time they prepare sectoral reports one of which is for textile industry. They also provide supports for technical and training related needs of the industry (V. Koca, personal communication, October 5, 2011).

Based on the sustainable production related capacities and activities of the universities some of the universities, starting with METU and Bogazici University, provide publications, trainings, seminars, consultancy services, etc. for different stakeholders such as industry, government, etc. Several related courses have been offered in METU.

Technology Development Foundation of Turkey (TTGV) provides several types of services related to environmental management and sustainable production, such as consultancy, sustainable production assessment, training and situation analysis (F. Ulutaş, personal communication, September 19, 2011).

The Union of Chambers and Commodity Exchanges of Turkey (TOBB) represents all the chambers and commodity exchanges as well as the sectoral assemblies. The environmental directorate of TOBB coordinates the communications between the sectoral institutions and the governmental institutions. In case comments are required for a draft environmental legislation from the sectors or other member associations, TOBB carries out all the necessary communications. There are 57 sectoral assemblies under TOBB one of which is Textile Sector Assembly.

Meanwhile, chambers of industry and commerce follow the environmental regulations and inform their members through various tools including meetings, seminars and announcements (DCCI, 2012). An example is the Gaziantep Chamber of Commerce which informs its members regularly on the changes taking place in environmental legislations. They organize meetings on environmental issues, carry out communications when needed (F. Tabur, personal communication, October 5, 2011).Gaziantep Chamber of Industry on the other hand, has the authority to issue incentive documents within the framework of investment incentive procedures. They also provide information and consultancy for their members related to financial supports available for R&D, environmental and other projects. Gaziantep Chamber of Industry also follows the environmental legislation and the EU harmonization process and informs and consults its members. It tries to advise companies about their waste management activities, etc (V. Çelebi, personal communication, October 5, 2011).

General Secretariat of ITKIB informs its member textile companies, related with the legislation revisions and makes announcements by bulletins and e-mails. For awareness raising purposes it organizes meetings and seminars on these topics for its members. In relation with support programmes, announcements and dissemination activities, it works in cooperation with the Ministry of Economy and collaborates with institutions such as Turkish Clothing Manufacturers Association (TGSD), Turkish Textile Dyeing and Finishing Industrialists' Association (TTTSD) and Tuzla Organized Industrial Zone (E. Açılan, personal communication, October 2, 2011).

Organized Industrial Zones in general, provide training and other awareness raising type of services as well as informing the companies about the opportunities relevant to consultancy, certification or capacity building activities. They also organize meetings and makes announcements to inform the companies on certain topics in cooperation with other regional institutions.

Energy efficiency consultancy companies provide the industrial companies including textile producers, with energy audit, consultancy and training services as well as feasibility studies and energy management practices. Similarly environmental consultancy companies provide environmental measurements and consultancy. Such a consultancy generally includes environmental management and legislative compliance related issues (Güleryüz, 2011).

10.4. Conclusions and Recommendations

It has been a priority issue for many developed/industrialize countries to develop sector specific policies/programmes to diffuse sustainable production within important sectors (Saritas and Aylen, 2010; USEPA, 2010; Sellahewa, 2011). Moreover there are some remarkable efforts in developing nations to integrate sustainable production approach into sectoral policies from different angles. Results of the study conducted by Abidin et al., (2010) indicate that technology characteristics, technology performances and communication networks significantly influence the adoption of cleaner production strategies in Malaysian food industry. So, recommendations were developed to effective use of those channels. On the other hand in South Africa, major barrier in front of the uptake of sustainable production approach in veichle industry was determined to be the lack of the legislative framework (Pandey, 2007). Pandey (2007) proposes that a number of policy initiatives need to be established in order to incorporate sustainable production into the legislative framework.

The major objective of this study was to conduct a sectoral assessment for the textile industry and develop recommendations in order to successfully diffuse sustainable production approach within this sector. Three scale analyses (micro, meso and macro) were conducted by means of survey studies taking into account (i) the textile producer firms' capacities and awareness, (ii) standards and demands of retailer companies as well as (iii) the existing institutional framework, strategies, supports and incentives. Survey study covered 76 textile producer firms, 10 retailer companies (e.g. multinational corporations) and 17 institutions.

The results of survey studies indicate that sustainable productions approach is not adapted in the majority of the producer firms. This situation corresponds to a big potential in terms of both economical and environmental performance when integrated environmental management and sustainable production is fully adapted in the textile producers. Meanwhile, retailer companies have recently started to focus on the supply management issues putting stress on resource efficiency and sustainable production approaches as integral parts of their CSR policies. Although currently there are serious gaps in terms of institutional capacities, financial supports and information networks there is a considerable movement and institutional intention in public and other relevant institutions in relation to the development of activities in line with the sustainable production approach.

Supporting above arguments, the developed and industrialized countries analyze individual sectors so as to set up tailored sustainable production programmes for respective sectors.

This study indicated that there is a strong need for a sector specific strategy document and/or action plan for the future. If serious steps could be taken through the recommendations provided below (Tables 10.2–10.5), Turkish textile industry would adopt sustainable production approach as a pioneering sector. To the best of authors' knowledge, this study is the first ever activity in Turkey on sustainable production with a sector-specific dimension. With this perspective this study can be taken as an example and a model which can be replicated for other sectors in Turkey.

Table 10.2. Recommendations on policy and strategy reforms

1.	Policy and Strategy Reforms	Relevant Scale	Reference
1.1	Framework legislation on sustainable production should be prepared and put into effect which also provide sectoral arrangements including textile industry.	Macro	Section 10.3.1.2 Section 10.3.3.1
1.2	Measures should be taken for successful implementation of the "Communiqué of Integrated Pollution Prevention and Control in Textile Sector".	Macro, Meso, Micro	Section 10.3.1.2 Section 10.3.3.1 Section 10.3.3.4 Section 10.3.1.7
1.3	Implementation of the "Communiqué of Integrated Pollution Prevention and Control in Textile Sector" should be followed closely and supported efficiently so as to obtain successful and tangible outcomes which act as a model for other sectors.	Macro	Section 10.3.3.1 Section 10.3.3.4
1.4	Regulatory arrangements for textile industry (e.g. Communiqué of Integrated Pollution Prevention and Control in Textile Sector) should be linked with financial instruments like government subsidies and incentives at both national and regional level.	Macro	Section 10.3.3.1 Section 10.3.3.2 Section 10.3.1.7
1.5	Retailer companies should shift their strategic focus from project-based sustainable production activities to integrated standards within their CSR policies.	Meso	Section 10.3.2.2 Section 10.3.2.4 Section 10.3.3.4

Table 10.3. Recommendations on Financial mechanisms

2.	Financial Mechanisms	Relevant Scale	Reference
2.1	Similar to the energy efficiency area, industry should be provided with a more comprehensive and integrated system of financial supports for all aspects of sustainable production including sustainable production audits.	Macro	Section 10.3.1.5 Section 10.3.3.2 Section 10.3.1.7
2.2	Measures should be taken for increasing the textile companies' benefitting from all existing financial supports in favor of sustainable production and resource efficiency.	Macro, Micro	Section 10.3.3.2
2.3	A mechanism which will provide information and guidance about the national and international funding opportunities on sustainable production should be formed.	Macro	Section 10.3.3.2 Section 10.3.3.4
2.4	New/innovative finance mechanisms should be developed for R&D, commercialization, demonstration and implementation projects of companies specifically in the field of environmental management and sustainable production. As a starting point, regional institutions/funds (e.g. regional development agencies) need to be restructured for this purpose, also aiming to facilitate companies' access to finance.	Macro	Section 10.3.3.2 Section 10.3.3.3 Section 10.3.1.5
2.5	Financial capacities/capabilities of institutions including environmental and energy consultancy firms, which are critical stakeholders giving services to textile companies, need to be developed. Preventive environmental management and sustainable production consultancy services should be promoted/ supported through legislative arrangements and financial tools.	Macro	Section 10.3.3.1 Section 10.3.3.2

Table 10.4. Recommendations on information networks and building partnerships

3.	Information Networks and Partnerships	Relevant Scale	Reference
3.1	In relevance to the sustainable production applications the Best Available Techniques (BATs) should be determined and made available on a sectoral basis through formation of a database for textile industry.	Macro	Section 10.3.3.3 Section 10.3.3.4 Section 10.3.3.5
3.2	Databases and an information exchange platform in relation to the applicability and benchmarking of specific sustainable production tools, case studies, best practices, etc., particularly for textile industry, should be formed.	Macro, Meso, Micro	Section 10.3.2.1 Section 10.3.3.3 Section 10.3.3.4
3.3	A continuous communication should be sustained between retailer companies which follow similar CSR policies, in order to develop collective projects/ activities (R&D, consultancy, finance, etc.) for common suppliers.	Meso, Micro	Section 10.3.2.3 Section 10.3.3.4
3.4	Relevant ministries and public institutions should establish coordination among themselves in order to achieve a well integrated and efficient system of services for environmental management and sustainable production, both at national and regional level.	Macro	Section 10.3.3.3 Section 10.3.3.4
3.5	A network of stakeholders from different institutions with varying expertise in textile industry and environmental management should be established. The existing platforms and associations can take the lead for such initiatives. Project based activities as well as specific programmes should be developed by means of this network in order to realize R&D, demonstration and implementation projects in the field of environmental management and sustainable production.	Macro, Meso, Micro	Section 10.3.3.3 Section 10.3.3.4 Section 10.3.1.7
3.6	Sectoral associations in collaboration with related committees, working groups, etc. should take the issue into their agenda and carry out studies to determine the present situation, awareness, capacity, required actions, etc. with their sector through benchmarking studies.	Macro, Meso, Micro	Section 10.3.3.3 Section 10.3.3.4
3.7	Measures should be taken to enhance the university-industry cooperation in textile industry for sustainable production activities.	Macro, Meso, Micro	Section 10.3.3.4

Table 10.5. Recommendations on capacity building and awareness raising

4.	Capacity Building and Awareness Raising	Relevant Scale	Reference
4.1	Capacity building and awareness raising activities should be carried out for all stakeholders starting with the public institutions at national, regional and sectoral levels, in relation to the sustainable production in the textile industry.	Macro, Meso, Micro	Section 10.3.2.4 Section 10.3.3.4 Section 10.3.1.7
4.2	Specific training programmes should be organized and carried out for relevant national and sectoral experts, retailer companies and textile producers on environmental management, sustainable production and other relevant concepts.	Macro, Meso, Micro	Section 10.3.2.1 Section 10.3.3.4 Section 10.3.1.7
4.3	Awareness should be created on resource efficiency and sustainable production approaches among executives of textile producer companies. The importance of environmental policies and management practices should be communicated with them through reliable channels (governmental institutions, universities, NGOs, etc.).	Macro, Meso, Micro	Section 10.3.1.1 Section 10.3.3.4
44	Retailer companies should develop their capacities (technical, human resource, etc.) in order to shift their focus on sustainable production from project based activities to the integration of the sustainable production and other emerging concepts and standards into their CSR policies in the long-term.	Meso	Section 10.3.2.1 Section 10.3.2.2 Section 10.3.2.3
4.5	Retailer companies should take measures in order to encourage their suppliers for using their current know-how, experiences and opportunities of benchmarking on environmentally-friendly products to develop wider environmentally-friendly production perspectives.	Meso, Micro	Section 10.3.2.1 Section 10.3.2.2 Section 10.3.2.3
4.6	A specific capacity building effort on Best Available Techniques (BATs) and the related Reference Document (BREF) including the information sharing and technical infrastructure development should be conducted for textile industry.	Macro, Micro	Section 10.3.1.5 Section 10.3.3.4
4.7	Demonstration and eco-innovation projects as well as feasibility studies with different tools and strategies of sustainable production in textile companies should be carried out and communicated.	Macro, Meso, Micro	Section 10.3.3.3 Section 10.3.3.4

Table 10.5. Recommendations on capacity building and awareness raising (Continued)

4.8	The current and potential legislative developments which indicate a planned shift from end-of-pipe approach to sustainable production should be shared with textile companies by various means like trainings, campaigns and seminars organized by public authorities and other relevant institutions.	Macro, Meso, Micro	Section 10.3.3.1 Section 10.3.3.4
4.9	Technical capacities/capabilities of institutions including environmental and energy consultancy firms, which are critical stakeholders giving services to textile companies, need to be developed, including sustainable production audits.	Macro	Section 10.3.3.4
4.10	In parallel and integration with energy efficiency campaigns and activities carried out for textile industry, other sustainable production aspects such as water efficiency and chemical use should also be taken into consideration and companies' attention should be drawn to these aspects as well.	Macro, Micro	Section 10.3.1.7 Section 10.3.3.4

CHAPTER 11

OVERVIEW AND REMARKS

In this study, the main objective was to investigate the applicability of sustainable production opportunities in six companies from six different sectors as well as providing a sectoral assessment study in textile industry as an example for the diffusion of sustainable production approach in Turkish manufacturing industry.

As part of the sustainable production pilot applications "Environmental Performance Evaluation" was carried out in each of the companies in order to determine areas/processes where significant improvement potential is present. As a result of the environmental performance evaluation, objectives were set for each company to decrease the negative environmental impacts and production costs associated with the high impact processes/practices. To achieve these objectives, 77 options were developed for six companies in total. Based on the opportunity assessment, 19 options were selected and implemented in the companies.

In the companies, significant water saving (849,668 m^3/year) was achieved as a result of applications targeting reduction of water use (Table 11.1). In addition to water, 3,607 MWh of total energy was saved by decreasing natural gas and electricity consumption associated with water heating/pumping. Due to energy saving, CO_2 emissions of companies were reduced considerably by 904.1 tons/year. Chemical saving was also achieved by process and technology changes in metal processing, textile and surface coating/painting companies. In total 278.4 tons/year of chemicals (e.g. NaCl, CdO, NaCN) were prevented from being used and end-up in the wastewater. By this way pollutant load in generated wastewaters were decreased substantially.

Table 11.1. Environmental gains achieved in the companies as a result of applications

Sector of the Company	Water Saving (m^3/year)	Natural Gas Saving (MWh/ year)	Electricity Saving (MWh/ year)	Total Energy Saving (MWh/ year)	CO_2 Reduction (tons/ year)	Chemical Saving (tons/ year)
Metal Processing	18,831	-	32.6	32.6	19.2	1.4
Chemical	151,428	-	117.8	117.8	69.5	-
Food	29,002	-	15.2	15.2	9.0	-
Textile	146,514	3,441	-	3,441	825.6	263.4
Surface Coating	-	-	-	-	-	13.6
Soft Drink	503,893	-	-	-	-	-
Total	849,668	3,441	165,6	3,607	904.1	278.4

Energy is indispensible for almost all of the industrial sectors. Moreover energy consumption is one of the major cost items in many sectors including iron-steel, cement, textile, chemicals industries. On the other hand water is one of the cheapest resources owing to the groundwater management policies of Turkey. If water is not associated with major cost items of the companies (e.g. chemicals, energy) water saving cannot bring economic returns to the companies. However, when water consumption is associated with energy and chemical consumption as it is the case in some industries (e.g. textile, metal processing), increased water efficiency enable companies save energy and chemicals which increase economic viability of the implementations.

Besides all these tangible improvements following gains were achieved as a result of pilot applications:

- improved product quality
- generation of valuable by-product
- resolved issues in wastewater treatment plant
- reduced amount of wastewater treatment sludge
- reduced VOC emissions
- improved health and safety conditions
- reduced auxilary cost
- reduced maintenance requirements
- ensured compliance with the national regulations
- ensured compliance with the EU regulations
- reduced workforce and production time

During the implementation of sustainable production measures 269,611 $ was spent for the equipments (Table 11.2). Total annual cost saving was calculated to be 479,083 $/year. So the payback period of the implementations was approximately 6.8 months.

Table 11.2. Implementation costs and payback periods of applications

Sector of the Company	Implementation Cost ($)	Annual Cost Saving ($/year)	Payback Period (months)
Metal Processing	34,233	14,760	27.8
Chemical	50,082	104,905	5.7
Seafood	76,900	48,175	19.2
Textile	21,936	170,868	1.5
Surface Coating	29,500	43,372	8.2
Soft Drink	56,960	97,003	7.0
Total	269,611	479,083	6.8

Within the scope of the sectoral assessment of Turkish textile industry, a three scale analysis (micro, meso and macro) was conducted by means of survey studies taking into account (i) the textile producer firms' capacities and awareness, (ii) standards and demands of retailer companies as well as (iii) the existing institutional framework, strategies, supports and incentives. Survey study covered 76 textile producer firms, 10 retailer companies (e.g. multinational corporations) and 17 institutions.

The results of survey studies indicate that sustainable production approach is not yet adopted in the majority of the textile producer firms. This situation corresponds to a big potential in terms of both economical and environmental performance when sustainable production approach is fully adapted in the textile producers. Meanwhile, retailer companies have recently started to focus on the supply chain management issues putting stress on resource efficiency and sustainable production approaches as integral parts of their CSR policies. Although currently there are serious gaps in terms of institutional capacities, financial supports and information networks there is a considerable movement and institutional intention in public and other relevant institutions in relation to the development of activities in line with the sustainable production approach. If serious steps could be taken through the recommendations (provided in Section 10.4) Turkish textile industry would adopt sustainable production approach as a pioneering sector. To the best of authors' knowledge, this study is the first ever activity in Turkey on sustainable production with a sector-specific dimension on situation analysis and policy recommendations. With this perspective this study can be taken as an example and a model which can be replicated for other sectoral assessment studies in Turkey.

CHAPTER 12

RECOMMENDATIONS

“Sustainable production” which is based on the concept of creating more goods and services while using fewer resources and creating less waste and pollution is one of the options that Turkish manufacturing industry can apply for sustainable industrial development. The results of the study show that the wide-spread uptake of proposed sustainable production measures would generate a tremendous change in the Turkish manufacturing industry even without heavy investments for technology changes. Moreover, the economic returns would help Turkish manufacturing industry to sustain its competitive position in the global markets which faces a pressing challenge of low cost, high quality and environmentally benign production.

Based on the discussions and conclusions drawn within this study following recommendations were developed in order to diffuse sustainable production approach into Turkish manufacturing industry:

- The companies should carry out environmental performance evaluation and benchmark their performances in order to determine the processes/practices where there is improvement potential.
- The governmental organizations should integrate sustainable production approach into their policy agendas as one of the major tools to adopt environmental norms and standards set by the European Commission for manufacturing industry.

- Since the environmental performance evaluation and benchmarking was carried out specifically for six industrial sectors in this study, generated results can effectively be used for comparison/benchmarking in the same sector. Although sustainable production applications realized in the companies can be replicated in various other sectors employing similar processes (e.g. cooling water recycling, water softening), first conducting a detailed environmental performance evaluation based on specific data for the corresponding sector would be needed.
- Future research is needed for developing successful demonstration projects in different sectors within manufacturing industry.
- Further, demonstration projects should be supported by policy-level studies (sectoral assessments, roadmaps etc.) in order to stimulate the dissemination of sustainable production approach in Turkish manufacturing industry.

REFERENCES

Abidin, R., Abdullah, C. S., & Osman, W. N. (2010). Clean production strategies adoption: a survey on food and beverage manufacturing sector. *Communications of the IBIMA*, *2010*, 1–10.

Abou-Elela, S. I., Haleem, H. A., Abou-Taleb, E., & Ibrahim, H. S. (2007). Application of cleaner production technology in chemical industry: a near zero emission. *Journal of Cleaner Production*, *15*(18), 1852–1858. doi:10.1016/j.jclepro.2006.10.005

Agana, B. A., Reeve, D., & Orbell, J. D. (2013). An approach to industrial water conservation--a case study involving two large manufacturing companies based in Australia. *Journal of environmental management*, *114*, 445–460. doi:10.1016/j.jenvman.2012.10.047

Ait Hsine, E., Benhammou, A., & Pons, M.-N. (2005). Water Resources Management in Soft Drink Industry-Water Use and Wastewater Generation. *Environmental Technology*, *26*(12), 1309–1316. doi:10.1080/09593332608618605

Alkaya, E., Böğürcü, M., Ulutaş, F., & Demirer, G. N. (2011). Cleaner (sustainable) production in textile wet processing. In N. Ahmed El (Ed.), *Non-Conventional Textile Waste Water Treatment*. New York, USA: Nova Science Publishers Inc.

Alkaya, E., & Demirer, G. N. (2013a). Greening of production in metal processing industry through process modifications and improved management practices. *Resources, Conservation and Recycling*, *77*, 89–96. doi:10.1016/j.resconrec.2013.06.004

Alkaya, E., & Demirer, G. N. (2013b). Sustainable textile production: A case study from a woven fabric manufacturing mill in Turkey. *Journal of Cleaner Production*. doi:10.1016/j.jclepro.2013.07.008

Anh, P. T., My Dieu, T. T., Mol, A. P. J., Kroeze, C., & Bush, S. R. (2011). Towards eco-agro industrial clusters in aquatic production: the case of shrimp processing industry in Vietnam. *Journal of Cleaner Production, 19*(17–18), 2107–2118. doi:10.1016/j.jclepro.2011.06.002

Ankara Development Agency - ADA. (2013). Ankara bölge planı (taslak): 2014-2023. Ankara, Turkey. Retrieved from http://belge.ankaraka.org.tr/tr/bolge-plani/ankara-bolge-plani-2014-2023-taslak.pdf, last visited on November, 2013.

Archer, M., Mark, E., & George, M. (2008). *Thawing seafood* (No. SR598). Retrieved from www.seafoodacademy.org/Documents/SR598%20thawing.pdf, last visited on September, 2013.

Arneth, H., & Dötsch, S. (2006). Pumps for heat transfer applications. *World Pumps*, *2006*(482), 22 – 27. doi:http://dx.doi.org/10.1016/S0262-1762(06)71143-9

Asipjanov, A. A. (2004). *Development of cleaner production strategies for the Kyrgyz Republic*. Asian Institute of Technology. Retrieved from http://www.faculty.ait.asia/visu/Data/AIT-Thesis/Master%20Thesis%20final/almaz%2004r.pdf, last visited on October, 2013.

August Kumar Pandey. (2007). *Identification and assessment of cleaner production technologies and appropriate technology management strategies and methods in South African vehicle industry* (Masters of Engineering (Technology Management)). University of Pretoria, Pretoria, South Africa. Retrieved from http://upetd.up.ac.za/thesis/available/etd-12202007-155142/unrestricted/dissertation.pdf, last visited on October, 2013.

Austin, E., Coull, B. A., Zanobetti, A., & Koutrakis, P. (2013). A framework to spatially cluster air pollution monitoring sites in US based on the PM2.5 composition. *Environment International*, *59*, 244–254. doi:10.1016/j.envint.2013.06.003

Australian Environment Protection Agency - EPA. (2001). *Cleaner production case study: Tony's Tuna International*. Adelaide, Australia. Retrieved from www.epa.sa.gov.au/xstd_files/Industry/Report/cptony.pdf, last visited on October, 2013.

Australian Food and Grocery Council - AFGC. (2006). *Environment Report 2005*. Kingston, Australia. Retrieved from http://globaldocuments.morningstar.com/documentlibrary/document/4ee22a2c93ede24e.msdoc/original, last visited on October, 2013.

Babu, B. R., Bhanu, S. U., & Meera, K. S. (2009). Waste minimization in electroplating industries: A review. *Journal of Environmental Science and Health, Part C*, *27*(3), 155–177. doi:10.1080/10590500903124158,

Bagajewicz, M. J., & Faria, D. C. (2009). On the appropriate architecture of the water/wastewater allocation problem in process plants. In Jacek Jeżowski and Jan Thullie (Ed.), *Computer Aided Chemical Engineering* (Vol. Volume 26, pp. 1–20). Elsevier.

Baral, A., & Engelken, R. D. (2002). Chromium-based regulations and greening in metal finishing industries in the USA. *Environmental Science & Policy*, *5*(2), 121–133. doi:10.1016/S1462-9011(02)00028-X

Barros, M. C., Magán, A., Valiño, S., Bello, P. M., Casares, J. J., & Blanco, J. M. (2009). Identification of best available techniques in the seafood industry: a case study. *Journal of Cleaner Production*, *17*(3), 391–399. doi:10.1016/j.jclepro.2008.08.012

Barros, M. C., Torres, M. T., Bello, P. M., Roca, E., & Casares, J. J. (2008). Integrated pollution prevention and control in the surface treatment industries in Galicia (NW Spain). *Clean Technologies and Environmental Policy*, *10*(2), 175–188.

Bates, B., Kundzewicz, Z. W., Wu, S., & Palutikof, J. (2008). *Climate change and water. in: technical paper of the intergovernmental panel on climate change*. Geneva, Switzerland: Intergovernmental Panel on Climate Change - IPCC. Retrieved from http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf, last visited on November, 2013.

Baum, T., & Schiffrin, D. J. (1997). AFM study of surface finish improvement by ultrasound in the anisotropic etching of Si in KOH for micromachining applications. *Journal of Micromechanics and Microengineering*, *7*(4), 338–342.

Beermann, M. (2011). Linking corporate climate adaptation strategies with resilience thinking. *Journal of Cleaner Production*, *19*(8), 836–842. doi:10.1016/j.jclepro.2010.10.017

Bello Bugallo, P.M., Cristóbal Andrade, L., Magán Iglesias, A., & Torres López, R. (2013). Integrated environmental permit through Best Available Techniques: evaluation of the fish and seafood canning industry. *Journal of Cleaner Production*, *47*, 253–264. doi:10.1016/j.jclepro.2012.12.022

Bello Bugallo, Pastora Ma., Stupak, A., Cristóbal Andrade, L., & Torres López, R. (2012). Material Flow Analysis in a cooked mussel processing industry. *Journal of Food Engineering*, *113*(1), 100–117. doi:10.1016/j.jfoodeng.2012.05.014

Bezama, A., Valeria, H., Correa, M., & Szarka, N. (2012). Evaluation of the environmental impacts of a Cleaner Production Agreement by frozen fish facilities in the Biobío Region, Chile. *Journal of Cleaner Production*, *26*, 95–100. doi:10.1016/j.jclepro.2011.12.029

Binnie and Partners. (1987). *Water and wastewater management in the soft drink industry*. *prepared for the* (No. NATSURV 3). Pretoria, South Africa. Retrieved from http://books.google.com.tr/books/about/Water_and_Waste_water_Management_in_the.html?id=D_BaAAAACAAJ&redir_esc=y, last visited on August, 2013.

Bloemkolk, J. W. (1997). *Industrial cooling water discharge: Cooling systems and emissions.* (No. 95.050).

Böğürcü, M. (2012). *Investigation of sectoral priorities for cleaner (sustainable) production at regional and national level* (Master of Science). Middle East Technical University, Ankara, Turkey. Retrieved from http://etd.lib.metu.edu.tr/upload/12614218/index.pdf, last visited on November, 2013.

Busch, T. (2011). Organizational adaptation to disruptions in the natural environment: The case of climate change. *Scandinavian Journal of Management*, *27*(4), 389–404. doi:10.1016/j.scaman.2010.12.010

Cagno, E., & Trucco, P. (2008). Cleaner technology transfer in the Italian galvanic industry: economic and know-how issues. *Journal of Cleaner Production*, *16*(1), 32–36. doi:10.1016/j.jclepro.2007.10.021

Cagno, Enrico, Trucco, P., & Tardini, L. (2005). Cleaner production and profitability: analysis of 134 industrial pollution prevention (P2) project reports. *Journal of Cleaner Production*, *13*(6), 593–605. doi:10.1016/j.jclepro.2003.12.025

Cakmak, B., Ucar, Y., & Akuzum, T. (2007). Water resources management, problems and solutions for Turkey. In *International Congress on River Basin Management* (pp. 22–24). Retrieved from http://www2.dsi.gov.tr/english/congress2007/chapter_2/69.pdf, last visited on August, 2013.

Campbell, B., & Pauly, D. (2013). Mariculture: A global analysis of production trends since 1950. *Marine Policy*, *39*, 94–100. doi:10.1016/j.marpol.2012.10.009

Cappell, R., Wright, S., & Nimmo, F. (2007). *Sustainable production and consumption of fish and shellfish: Environmental impact analysis*. Edinburgh, United Kingdom. Retrieved from http://archive.defra.gov.uk/environment/business/products/roadmaps/documents/seafood-scp-haskoning.pdf, last visited on September, 2013.

Casani, S., & Knøchel, S. (2002). Application of HACCP to water reuse in the food industry. *Food Control*, *13*(4–5), 315–327. doi:10.1016/S0956-7135(02)00037-3

Casani, S., Leth, T., & Knøchel, S. (2006). Water reuse in a shrimp processing line: Safety considerations using a HACCP approach. *Food Control*, *17*(7), 540–550. doi:10.1016/j.foodcont.2005.03.002

Center for Industrial Research and Service - CIRAS. (2005). *Energy-related best practices: A sourcebook for the chemical industry*. Iowa, USA. Retrieved from http://www.ciras.iastate.edu/publications/EnergyBP-ChemicalIndustry/EnergyBestPractices-ChemicalIndustry-Sourcebook.pdf, last visited on July, 2013.

Chougule, M. B., & Sonaje, N. P. (2012). Novel techniques of water recycling in textile wet processing through best management practices (BMP's). *International Journal of Applied Science and Advance Technology*, *1*(1), 29–33.

Clarens, A. F., Zimmerman, J. B., Keoleian, G. A., Hayes, K. F., & Skerlos, S. J. (2008). Comparison of life cycle emissions and energy consumption for environmentally adapted metalworking fluid systems. *Environmental Science & Technology*, *42*(22), 8534–8540.

Çiner, F., Solmaz, S., & Üstün, G. (2011). *Havza yönetiminde renk parametresinin önemi ve kazanımları: Büyük Menderes örneği*. Retrieved from http://kckk2011.nku.edu.tr/doc/sunumlar/1.oturum/FEH%C4%B0MAN%20%C3%87%C4%B0NER.pdf, last visited on October, 2013.

Dahab, M. F., & Lund, J. (1994). A demonstration project of pollution prevention in the metal finishing industry. *National Conference on Promoting Pollution Prevention by Voluntary Initiatives*. Retrieved from http://infohouse.p2ric.org/ref/05/04862.pdf, last visited on January, 2013.

Dias-Sardinha, I., & Reijnders, L. (2001). Environmental performance evaluation and sustainability performance evaluation of organizations: an evolutionary framework. *Eco-Management and Auditing*, *8*(2), 71–79. doi:10.1002/ema.152

Diyarbakır Chamber of Commerce and Industry - DCCI. (2012). *Tekstil, hazır giyim ve deri sektörü strateji eylem planı*. Diyarbakır, Turkey. Retrieved from http://www.dtso.org.tr/2013/dosya/rapor/Tekstil-Eylem-plani-ozeti.pdf, last visited on October, 2013.

Enderle, P., Nowak, O., & Kvas, J. (2012). Potential alternative for water and energy savings in the automotive industry: case study for an Austrian automotive supplier. *Journal of Cleaner Production, 34*, 146–152. doi:10.1016/j.jclepro.2011.11.013

Environment Agency. (2003). *Guidance for the large volume organic chemicals sector* (No. Sector Guidance Note IPPC S4.01). Retrieved from http://www.sepa.org.uk/air/process_industry_regulation/pollution_prevention__control/uk_technical_guidance/s4_chemical.aspx, last visited on July, 2013.

Environmental Technology Best Practice Programme – ETBPP. (1997). *Water and chemical use in textile dyeing and finishing* (No. GG62). Retrieved from http://www.wrap.org.uk/sites/files/wrap/GG062.pdf, last visited on July, 2012.

Environmental Technology Best Practice Programme – ETBPP. (1998). *Water use in the soft drinks industry* (No. EG 126). Retrieved from http://infohouse.p2ric.org/ref/23/22794.pdf, last visited on August, 2013.

Environmental Technology Best Practice Programme – ETBPP. (1999). *Reducing water and effluent costs in fish processing* (No. GG187). Retrieved from http://infohouse.p2ric.org/ref/23/22896.pdf

Envirowise. (2002). *Water minimisation in the food and drink industry* (No. GG349). Oxfordshire, The United Kingdom. Retrieved from http://infohouse.p2ric.org/ref/23/22916.pdf, last visited on September, 2013.

Envirowise. (2003). *Cost-effective paint and powder coating: application technology* (No. GG387). Oxfordshire, The United Kingdom. Retrieved from http://ec.europa.eu/environment/air/pollutants/stationary/solvents/activities/pdf/d029_paint_and_powder_coating.pdf, last visited on April, 2013.

Ernst & Young. (2013). *Ernst & Young's attractiveness survey: Turkey 2013 The shift, the growth and the promise*. Retrieved from http://www.ey.com/Publication/vwLUAssets/Turkey_attractiveness_survey_2013/$FILE/turkey_attractiveness_2013.pdf, last visited on November, 2013.

European Commission. (2001). *Reference document on the application of best available techniques to industrial cooling systems (BREF)*. Brussels, Belgium. Retrieved from http://eippcb.jrc.ec.europa.eu/reference/BREF/cvs_bref_1201.pdf, last visited on July, 2013.

European Commission. (2003). *Reference document on best available techniques for the textiles industry (BREF)*. Brussels, Belgium. Retrieved from http://eippcb.jrc.es/reference/BREF/txt_bref_0703.pdf, last visited on July, 2012.

European Commission. (2006a). *Reference document on best available techniques for surface treatment of metals and plastics (BREF)*. Brussels, Belgium. Retrieved from http://eippcb.jrc.es/reference/BREF/stm_bref_0806.pdf, last visited on April, 2013.

European Commission. (2006b). *Reference document on best available techniques in the food, drink and milk industries (BREF)*. Brussels, Belgium. Retrieved from http://eippcb.jrc.ec.europa.eu/reference/BREF/fdm_bref_0806.pdf, last visited on September, 2013.

European Commission. (2007a). *Reference document on best available techniques in the production of polymers (BREF)*. Brussels, Belgium. Retrieved from http://eippcb.jrc.ec.europa.eu/reference/BREF/pol_bref_0807.pdf, last visited on July, 2013.

European Commission. (2007b). *Reference document on best available techniques on surface treatment using organic solvents (BREF)*. Brussels, Belgium. Retrieved from http://eippcb.jrc.es/reference/BREF/sts_bref_0807.pdf, last visited on April, 2013.

European Commission. (2008). *Directive 2008/105/EC of the European Parliament and of the council: Directive on environmental quality standards*. Brussels, Belgium. Retrieved from http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:348:0084:0097:EN:PDF, last visited on April, 2013.

European Commission. (2010). *Europe 2020: A strategy for smart, sustainable and inclusive growth*. Brussels, Belgium. Retrieved from http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF, last visited on April, 2013.

European Commission. (2011a). *A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy*. Brussels, Belgium. Retrieved from http://ec.europa.eu/resource-efficient-europe/pdf/resource_efficient_europe_en.pdf, last visited on April, 2013.

European Commission. (2011b). *Roadmap to a resource efficient Europe*. Brussels, Belgium. Retrieved from http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf, last visited on April, 2013.

European Commission. (2011c). *Directive 2011/65/EU of the European Parliament and of the council: On the restriction of the use of certain hazardous substances in electrical and electronic equipment*. Brussels, Belgium. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:174:0088:0110:en:PDF, last visited on April, 2013.

European Environment Agency - EEA. (2011). *2011 Survey of resource efficiency policies in EEA member and cooperating countries: Country profile Turkey*. Copenhagen, Denmark. Retrieved from http://www.eea.europa.eu/themes/economy/resource-efficiency/turkey-2014-resource-efficiency-policies, last visited on November, 2013.

European Technology Platform for Sustainable Chemistry - SUSCHEM. (2012). *Position document of Innovation Partnership on Water Efficient Europe: Every drops counts*. Retrieved from http://www.water-europe.eu/documents/Position%20document%20on%20Water%20Innovation.pdf, last visited on July, 2013.

Eurostat. (2012). *Environment and energy statistics*. Retrieved from http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-12-023/EN/KS-SF-12-023-EN.PDF, last visited on November, 2013.

Faria, D. C., & Bagajewicz, M. J. (2011). Novel bound contraction procedure for global optimization of bilinear MINLP problems with applications to water management problems. *Computers & Chemical Engineering*, *35*(3), 446–455. doi:10.1016/j.compchemeng.2010.04.010

Ferrero, F., Periolatto, M., Rovero, G., & Giansetti, M. (2011). Alcohol-assisted dyeing processes: a chemical substitution study. *Journal of Cleaner Production*, *19*(12), 1377–1384. doi:10.1016/j.jclepro.2011.04.008

Florida Department of Environmental Protection - FDOEP. (2006). *Electroplating tip sheet: Drag-out reduction*. Florida, USA. Retrieved from http://infohouse.p2ric.org/ref/04/03983.pdf, last visited on January, 2013.

Freibauer, A., Mathijs, E., Brunori, G., Damianova, Z., Faroult, E., Gomis, J. G., … Treyer, S. (2011). *Sustainable food consumption and production in a resource-constrained world*. Retrieved from http://ec.europa.eu/research/agriculture/scar/pdf/scar_feg3_final_report_01_02_2011.pdf, last visited on September, 2013.

Fresner, J., Schnitzer, H., Gwehenberger, G., Planasch, M., Brunner, C., Taferner, K., & Mair, J. (2007). Practical experiences with the implementation of the concept of zero emissions in the surface treatment industry in Austria. *Journal of Cleaner Production*, *15*(13), 1228–1239.

Galitsky, C., & Worrell, E. (2008). Energy efficiency improvement and cost saving opportunities for the vehicle assembly industry: An energy star guide for energy and plant managers. Retrieved from http://escholarship.org/uc/item/33x4p6p9#page-1, last visited on January, 2013.

García, V., Pongrácz, E., Phillips, P. S., & Keiski, R. L. (2013). From waste treatment to resource efficiency in the chemical industry: recovery of organic solvents from waters containing electrolytes by pervaporation. *Journal of Cleaner Production*, *39*, 146–153. doi:10.1016/j.jclepro.2012.08.020

Geçer, F. (2007). Analysis of beverage industry wastewater and recommendations. Presented at the University Students II Environmental Problems Congress, Fatih University, İstanbul. Retrieved from http://cevre.club.fatih.edu.tr/webyeni/konfreweb/kongre_kitabi.pdf, last visited on August, 2013.

Goldblatt, A., Lee, J., Şahin, K., & Sieber, M. (2012). *Country report Turkey* (No. GR 522). USA: McCallum Graduate School of Business, Bentley University. Retrieved from http://aarongoldblatt.files.wordpress.com/2012/01/econ-report1.pdf, last visited on November, 2013.

Greer, L., Keane, E. K., & Lin, Z. (2010). *NRDC's ten best practices for textile mills to save money and reduce pollution: A practical guide for responsible sourcing*. Natural Resources Defense Council (NRDC). Retrieved from http://www.nrdc.org/international/cleanbydesign/files/rsifullguide.pdf, last visited on July, 2012.

Gumbo, B., Mlilo, S., Broome, J., & Lumbroso, D. (2003). Industrial water demand management and cleaner production potential: a case of three industries in Bulawayo, Zimbabwe. *Physics and Chemistry of the Earth, Parts A/B/C*, *28*(20–27), 797–804. doi:10.1016/j.pce.2003.08.026

Güleryüz, Ö. (2011). *Küresel gelişmeler ışığında Türkiye'de tekstil sektörü ve geleceği* (Master of Science). Süleyman Demirel University, Isparta, Turkey. Retrieved from eprints.sdu.edu.tr/879/1/TS00936.pdf, last visited on October, 2013.

Gümüş, D., & Akbal, F. (2010). Photocatalytic degradation of textile dye and wastewater. *Water, Air, & Soil Pollution*, *216*(1-4), 117–124. doi:10.1007/s11270-010-0520-z

Halkbank. (2010). *Halkbank kurumsal sosyal sorumluluk projesi: Tekstil ve hazır giyim sektör raporu*. Ankara, Turkey. Retrieved from http://www.riskmedakademi.com.tr/images/stories/dokumanlar/tekstil_sektor_raporu.pdf, last visited on October, 2013.

Hall, G. M. (2010). Introduction: Challenges to the Fish-Processing Industry in a Resource-Starved World. In G. M. H. R. Fellow (Ed.), *Fish Processing* (pp. 1–29). Wiley-Blackwell. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/9781444328585.ch1/summary, last visited on September, 2013.

Haroon, H., Waseem, A., & Mahmood, Q. (2013). Treatment and reuse of wastewater from beverage industry. *J. Chem. Soc. Pak*, *35*(1), 5.

Hasanbeigi, A. (2010). *Energy-Efficiency Improvement Opportunities for the Textile Industry*. China Energy Group, Energy Analysis Department Environmental Energy Technologies Division Lawrence Berkeley National Laboratory.

Hasanbeigi, A., Hasanabadi, A., & Abdorrazaghi, M. (2012). Comparison analysis of energy intensity for five major sub-sectors of the Textile Industry in Iran. *Journal of Cleaner Production*, *23*(1), 186–194. doi:10.1016/j.jclepro.2011.10.037

Hasanbeigi, A., & Price, L. (2012). A review of energy use and energy efficiency technologies for the textile industry. *Renewable and Sustainable Energy Reviews*, *16*(6), 3648–3665. doi:10.1016/j.rser.2012.03.029

Heimann, N., & Simpson, G. T. (2005). Surface mineralization as an alternative to cadmium plating and hexavalent chromate treatment for corrosion protection. In *Navy ISA RUST Conference, Louisville, KY*. Retrieved from http://www.elisha.com/docs/, last visited on April, 2013.

Hekimoğlu, B., & Altındeger, M. (2012). *Current situation, problems and solutions for seafood sector in Turkey and Samsun*. Retrieved from http://www.samsuntarim.gov.tr/yayinlar/tarimsal_strateji/tarimsal_strateji_pdf/turkiye_ve_samsun_ilinde_su_urunleri_sektorunun_mevcut_durumu_sorunlari_ve_cozum_onerileri.pdf, last visited on September, 2013.

Hoque, A., & Clarke, A. (2013). Greening of industries in Bangladesh: pollution prevention practices. *Journal of Cleaner Production*, *51*, 47–56. doi:10.1016/j.jclepro.2012.09.008

Hu, J.-M., Liu, L., Zhang, J.-Q., & Cao, C.-N. (2007). Electrodeposition of silane films on aluminum alloys for corrosion protection. *Progress in Organic Coatings*, *58*(4), 265–271. doi:10.1016/j.porgcoat.2006.11.008

Hunt, G. E. (1988). Hazardous waste minimization: Part IV waste reduction in the metal finishing industry. *JAPCA*, *38*(5), 672–680.

Intergovernmental Panel on Climate Change - IPCC. (2007). *Climate change 2007: impacts, adaptation and vulnerability*. Cambridge, United Kingdom and New York, NY, USA. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf, last visited on November, 2013.

Intergovernmental Panel on Climate Change - IPCC. (2013). *Working group I contribution to the IPCC fifth assessment report, climate change 2013: the physical science basis - final draft underlying scientific technical assessment* (No. 12.VIII.2013). Geneva, Switzerland. Retrieved from http://www.climatechange2013.org/images/uploads/WGIAR5_WGI-12Doc2b_FinalDraft_TechnicalSummary.pdf, last visited on September, 2013.

International Finance Corporation - IFC. (2007a). *Environmental, health, and safety guidelines for fish processing*. Retrieved from http://www.ifc.org/wps/wcm/connect/c7d2710048855d048d9cdf6a6515bb18/Final%2B-%2BFish%2BProcessing.pdf?MOD=AJPERES, last visited on September, 2013.

International Finance Corporation - IFC. (2007b). *Environmental, health, and safety guidelines for food and beverages*. Retrieved from http://www.ifc.org/wps/wcm/connect/c7bfaf0048855482b314f36a6515bb18/Final%2B-%2BFood%2Band%2BBeverage%2BProcessing.pdf?MOD=AJPERES, last visited on September, 2013.

İstanbul Development Agency - ISDA. (2013). *İstanbul bölge planı (taslak): 2014-2023*. İstanbul, Turkey. Retrieved from http://www.istka.org.tr/content/pdf/2014-2023-istanbul-Bolge-Plani-n.pdf, last visited on November, 2013

İstanbul Textile and Apparel Exporters' Associations - ITKIB. (2010). *Turkish textile industry*. İstanbul, Turkey. Retrieved from http://www.itkib.org.tr/english/about/sectors/textile/textile_info.pdf, last visited on October, 2013.

İzmir Development Agency - IDA. (2012). *Strategy report on the dissemination of eco-efficiency (cleaner production) applications in İzmir* (No. ISBN: 978-605-5826-08-6). İzmir. Retrieved from www.izka.org.tr/files/eko_verimlilik_sonuc_raporu.pdf, last visited on November, 2013.

İzmir Development Agency - IDA. (2013a). *İzmir bölge planı (ikinci taslak): 2014-2023*. İzmir, Turkey. Retrieved from http://www.izmiriplanliyorum.org/static/upload/file/2014-2023_izmir_bolge_plani_%28taslak%29_22082013.pdf, last visited on November, 2013.

İzmir Development Agency - IDA. (2013b). *İzmir Seafood Sector Strategy*. Retrieved from http://www.izmiriplanliyorum.org/static/upload/file/izmir_su_urunleri_sektoru_stratejisi.pdf, last visited on September, 2013.

Jiang, Z., Zhang, H., & Sutherland, J. W. (2012a). Development of an environmental performance assessment method for manufacturing process plans. *The International Journal of Advanced Manufacturing Technology*, *58*(5-8), 783–790. doi:10.1007/s00170-011-3410-7

Jiang, L.-L., Wu, L.-K., Hu, J.-M., Zhang, J.-Q., & Cao, C.-N. (2012b). Electrodeposition of protective organosilane films from a thin layer of precursor solution. *Corrosion Science*, *60*, 309–313. doi:10.1016/j.corsci.2012.03.042

Jiang, W., Yuan, Z., Bi, J., & Sun, L. (2010). Conserving water by optimizing production schedules in the dyeing industry. *Journal of Cleaner Production*, *18*(16–17), 1696–1702. doi:10.1016/j.jclepro.2010.07.004

Kalliala, E., & Talvenmaa, P. (2000). Environmental profile of textile wet processing in Finland. *Journal of Cleaner Production*, *8*(2), 143–154. doi:10.1016/S0959-6526(99)00313-3

Kaykıoğlu, G., & Ekmekyapar, F. (2005). Ergene havzasında endüstriyel işlem suyu olarak kullanılan yer altı sularının özellikleri üzerine araştırma. *Trakya University Journal of Science*, *6*(1), 85–91.

Kıran-Cılız, N. (2003). Reduction in resource consumption by process modifications in cotton wet processes. *Journal of Cleaner Production*, *11*(4), 481–486. doi:10.1016/S0959-6526(02)00069-0

Kliopova, I., & Bagdonas, A. (2003). Optimization of electroplating processes in Lithuanian machine and instrument industry. *Environmental Research, Engineering and Management*, *3*(25), 29–37.

Knuckey, I., Sinclair, C., Surapaneni, A., & Ashcroft, W. (2004). Utilisation of seafood processing waste-challenges and opportunities. *SuperSoil*, *2004*, 3rd.

Kocabaş, A. M., Yükseler, H., Dilek, F. B., & Yetiş, Ü. (2009). Adoption of European Union's IPPC Directive to a textile mill: Analysis of water and energy consumption. *Journal of Environmental Management*, *91*(1), 102–113. doi:10.1016/j.jenvman.2009.07.012

Koefoed, M., & Buckley, C. (2008). Clean technology transfer: a case study from the South African metal finishing industry, 2000–2005. *Journal of Cleaner Production*, *16*(1, Supplement 1), S78–S84. doi:10.1016/j.jclepro.2007.10.023

Koeller and Company. (2006). *A report on potential best management practices*. Sacramento, USA. Retrieved from www.cuwcc.org/WorkArea/downloadasset.aspx?id=797, last visited on November, 2013.

Kong, G., & White, R. (2010). Toward cleaner production of hot dip galvanizing industry in China. *Journal of Cleaner Production*, *18*(10), 1092–1099.

Kunt, V., & Zobu, H. (2011). *Harnessing sustainable linkages for SMEs in Turkey's textile sector: Diagnostic study report*. Ankara, Turkey. Retrieved from www.undp.org.tr/Gozlem2.aspx?WebSayfaNo=2275, last visited on October, 2013.

Li, M., Yang, Y.-Q., Liu, L., Hu, J.-M., & Zhang, J.-Q. (2010). Electro-assisted preparation of dodecyltrimethoxysilane/TiO2 composite films for corrosion protection of AA2024-T3 (aluminum alloy). *Electrochimica Acta*, *55*(8), 3008–3014. doi:10.1016/j.electacta.2009.12.081

Li, R., Yu, Q., Yang, C., Chen, H., Xie, G., & Guo, J. (2010). Innovative cleaner production for steel phosphorization using Zn–Mn phosphating solution. *Journal of Cleaner Production*, *18*(10), 1040–1044.

Liu, L., & Ma, X. (2010). Technology-based industrial environmental management: a case study of electroplating in Shenzhen, China. *Journal of Cleaner Production*, *18*(16–17), 1731–1739. doi:10.1016/j.jclepro.2010.06.026

Ludwig, F., Kabat, P., Henk, van S., & van der Valk, M. (2009). *Climate change adaptation in the water sector*. Earthscan, London. Retrieved from www.newater.uni-osnabrueck.de/intern/sendfile.php?id=74, last visited on October, 2013.

Magalhães, J. M., Silva, J. E., Castro, F. P., & Labrincha, J. A. (2005). Physical and chemical characterisation of metal finishing industrial wastes. *Journal of Environmental Management*, *75*(2), 157–166. doi:10.1016/j.jenvman.2004.09.011

Materne, T., Buyl, F. ois de, & Witucki, G. L. (2006). *Organosilane technology in coating applications: Review and perspectives* (No. 26-1402A-01). USA: Dow Corning Corporation. Retrieved from http://www.dowcorning.com/content/publishedlit/26-1402-01.pdf, last visited on April, 2013.

Ministry of Development - MOD. (2013). *Onuncu kalkınma planı: 2014-2018*. Ankara, Turkey. Retrieved from http://www.dpt.gov.tr/DocObjects/view/15089/Onuncu_Kalk%C4%B1nma_Plan%C4%B1.pdf, last visited on October, 2013.

Ministry of Economy - MOE. (2013a). *Turkey's general economic outlook*. Ankara, Turkey. Retrieved from http://www.herrick.com/siteFiles/News/9640C015DDEA21A128D04F68182DF041.pdf, last visited on November, 2013.

Ministry of Economy - MOE. (2013b). *Chemical industry in Turkey*. Ankara, Turkey. Retrieved from http://www.tcp.gov.tr/english/sectors/sectoringpdf/chemical_industry.pdf, last visited on July, 2013.

Ministry of Environment and Forestry - MOEF. (2004). *Environmental atlas of Turkey*. Ankara, Turkey. Retrieved from http://www2.cedgm.gov.tr/dosya/cevreatlasi.htm, last visited on July, 2013.

Ministry of Environment and Forestry - MOEF. (2006a). *AB entegre çevre uyum stratejisi: 2007 - 2023*. Ankara, Turkey. Retrieved from http://www.abgs.gov.tr/files/SEPB/cevrefaslidokumanlar/uces.pdf, last visited on June, 2013.

Ministry of Environment and Forestry - MOEF. (2006b). *Türkiye kamu çevre ve ormancılık araştırma programı*. Ankara, Turkey. Retrieved from http://www.tubitak.gov.tr/tubitak_content_files/ARDEB/kamag/Turkiye_Kamu_Cevre_ve_Orman_Arastirma_Programi.pdf, last visited on October, 2013.

Ministry of Environment and Forestry - MOEF. (2008). *Wastewater treatment action plan*. Ankara, Turkey. Retrieved from http://www.styd-cevreorman.gov.tr/DATA/aat_eylem_plani.pdf, last visited on October, 2013.

Ministry of Environment and Forestry - MOEF. (2009a). *Hazardous waste management concept for Turkey* (No. LIFE06/TCY/TR/000292). Ankara, Turkey. Retrieved from http://www.lifetcy06.cevreorman.gov.tr/, last visited on April, 2013.

Ministry of Environment and Forestry - MOEF. (2009b). *Paint/varnish: Guidance document* (No. LIFE06/TCY/TR/000292). Retrieved from http://www.iso.org.tr/tr/documents/cevre/boya_vernik.pdf?redirected=1, last visited on April, 2013.

Ministry of Environment and Forestry - MOEF. (2009c). *Turkey water report* (No. DSI Archive). Ankara, Turkey. Retrieved from http://www2.dsi.gov.tr/english/pdf_files/TurkeyWaterReport.pdf, last visited on August, 2013.

Ministry of Environment and Forestry - MOEF. (2009d). *Çevresel etki değerlendirmesi sektörel rehberleri: Tekstil fabrikaları*. Ankara, Turkey. Retrieved from http://www.csb.gov.tr/gm/dosyalar/belgeler/belge395/Sektorel_rehber_tekstil_yeni.pdf, last visited on September, 2013.

Ministry of Environment and Urbanization - MOEU. (2012). *The Republic of Turkey: Climate Change Strategy for 2010 – 2020*. Ankara, Turkey. Retrieved from http://iklim.cob.gov.tr/iklim/Files/Stratejiler/%C4%B0DES_ENG.pdf, last visited on September, 2013.

Ministry of Industry and Trade - MOIT. (2010). *Turkish industrial strategy document: Towards EU membership*. Ankara. Retrieved from http://www.sanayi.gov.tr/Files/Documents/TurkiyeSanayiStratejisiIngilizce.pdf, last visited on November, 2013.

Ministry of Industry and Trade - MOIT. (2012). *Textile, garment, leather and leather products sectors report*. Ankara. Retrieved from http://www.sanayi.gov.tr/DocumentList.aspx?catID=1435&lng=tr, last visited on July, 2012.

Ministry of Science Industry and Technology - MOSIT. (2011). *Turkish machinery industry sectoral strategy document and action plan (2011-2014)*. Ankara, Turkey. Retrieved from http://www.sanayi.gov.tr/Files/Documents/makine_sektoru_strateji_b23052011142400.pdf, last visited on January, 2013.

Ministry of Science Industry and Technology - MOSIT. (2012a). *Strategic plan: 2013-2017*. Ankara, Turkey. Retrieved from http://www.sanayi.gov.tr/Files/Documents/bilim-sanayi-ve-teknoloji-31122012154058.pdf, last visited on October, 2013.

Ministry of Science Industry and Technology - MOSIT. (2012b). *Macihnery sector report*. Ankara, Turkey. Retrieved from http://sgm.sanayi.gov.tr/DocumentList.aspx?catID=1020&lng=tr, last visited on April, 2013.

Ministry of Science Industry and Technology - MOSIT. (2012c). *Automotive sector report*. Ankara, Turkey. Retrieved from http://sgm.sanayi.gov.tr/DocumentList.aspx?catID=1020&lng=tr, last visited on April, 2013.

Ministry of Science Industry and Technology - MOSIT. (2012d). *Turkish chemical industry strategy document and action plan*. Ankara, Turkey. Retrieved from http://www.sanayi.gov.tr/Files/Documents/kimya-sektoru-strateji-be-16012013111910.pdf, last visited on July, 2013.

Ministry of Science Industry and Technology - MOSIT. (2013). *Food and drink sector report*. Ankara, Turkey. Retrieved from http://sgm.sanayi.gov.tr/DocumentList.aspx?catID=1020&lng=tr, last visited on August, 2013.

Morry, C. J., Brideau, A., Chadwick, E. M. P., Giddens, D., Lindsay, C., Mallet, P., & Woyewoda, A. (2006). *Practical best management practices for reduction of effluent from seafood processing in Atlantic Canada*. Retrieved from www.dfo-mpo.gc.ca/Library/324972.pdf, last visited on September, 2013.

Nair, C. (1990). Pollution control through water conservation and wastewater reuse in the fish processing industry. *Water Science & Technology*, *22*(9), 113–121.

Neelis, M., Patel, M., Blok, K., Haije, W., & Bach, P. (2007). Approximation of theoretical energy-saving potentials for the petrochemical industry using energy balances for 68 key processes. *Energy*, *32*(7), 1104–1123. doi:10.1016/j.energy.2006.08.005

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to environmental change: contributions of a resilience framework. *Annual review of Environment and Resources, 32*(1), 395.

Nimnu, N. (1998). *Waste Minimization of Cold Storage Factory Case Study: Freezing Fish Factory*. King Mongkuts University of Technology Thonburi. Bangkok (Thailand). Graduate School. Retrieved from http://www.thaithesis.org\/detail.php?id=973&language=eng, last visited on September, 2013.

Nishitani, K., Kaneko, S., Fujii, H., & Komatsu, S. (2011). Effects of the reduction of pollution emissions on the economic performance of firms: an empirical analysis focusing on demand and productivity. *Journal of Cleaner Production*, *19*(17–18), 1956–1964. doi:10.1016/j.jclepro.2011.06.021

Norris, L. (2013). Aesthetics and ethics: Upgrading textile production in northern Kerala. *Geoforum*, *50*, 221–231. doi:10.1016/j.geoforum.2013.09.006

North Carolina Division of Pollution Prevention and Environmental Assistance - NCDENR. (2009a). *Water efficiency industry specific processes: Metal finishing*. North Carolina, USA. Retrieved from http://infohouse.p2ric.org/ref/01/0069209.pdf, last visited on April, 2013.

North Carolina Division of Pollution Prevention and Environmental Assistance - NCDENR. (2009b). *Water efficiency industry specific processes: Textiles*. North Carolina, USA. Retrieved from http://infohouse.p2ric.org/ref/01/0069203.pdf, last visited on July, 2012.

North Carolina Division of Pollution Prevention and Environmental Assistance - NCDENR. (2009c). *Water efficiency industry specific processes: Food Processing*. North Carolina, USA. Retrieved from faculty.mu.edu.sa/download.php?fid=24296, last visited on September, 2013.

Norton, T., Misiewicz, P., O'Donnell, C., Tiwari, B. K., Cullen, P. J., & Rice, R. G. (2012). Ozone for water treatment and its potential for process water reuse in the food industry. *Ozone in Food Processing*, 177–199.

Oktay, S., Iskender, G., Germirli Babuna, F., Kutluay, G., & Orhon, D. (2007). Improving the wastewater management for a beverage industry with in-plant control. *Desalination*, *211*(1–3), 138–143. doi:10.1016/j.desal.2006.02.088

Organisation for Economic Co-operation and Development - OECD. (2011). *Private sector engagement in adaptation to climate change: approaches to managing climate risks* (No. ENV/WKP(2011)9). Retrieved from http://dx.doi.org/10.1787/5kg221jkf1g7-en, last visited on October, 2013.

Organisation for Economic Co-operation and Development - OECD. (2012). *SME policy index Western Balkans and Turkey: Progress in the implementation of the small business act for Europe*. Retrieved from http://www.oecd.org/daf/psd/smepolicyindexwesternbalkansandturkey2012.htm, last visited on November, 2013.

Organisation for Economic Co-operation and Development - OECD. (2013a). *Better life index: Country reports*. Paris, France. Retrieved from http://www.oecd.org/newsroom/BLI2013-Country-Notes.pdf, last visited on November, 2013.

Organisation for Economic Co-operation and Development - OECD. (2013b). *Agricultural Outlook 2013-2022: Highlights*. Retrieved from www.oecd.org/site/oecd-faoagriculturaloutlook/highlights-2013-EN.pdf, last visited on September, 2013.

Öztürk, E., Yetiş, Ü., Dilek, F. B., & Demirer, G. N. (2009). A chemical substitution study for a wet processing textile mill in Turkey. *Journal of Cleaner Production*, *17*(2), 239–247. doi:10.1016/j.jclepro.2008.05.001

Öztürk, H. K. (2005). Energy usage and cost in textile industry: A case study for Turkey. *Energy*, *30*(13), 2424–2446. doi:10.1016/j.energy.2004.11.014

Öner, E., & Şahinbaşkan, B. Y. (2011). A new process of combined pretreatment and dyeing: REST. *Journal of Cleaner Production*, *19*(14), 1668–1675. doi:10.1016/j.jclepro.2011.05.008

Pagan, B., & Prasad, P. (2007). The Queensland food eco-efficiency project: reducing risk and improving competitiveness. *Journal of Cleaner Production*, *15*(8–9), 764–771. doi:10.1016/j.jclepro.2006.06.014

Pagan, R., Prasad, P., Price, N., & Kemp, E. (2004). *Eco-efficiency toolkit for the Queensland food processing industry* (No. ISBN: 0 9752100 2 5). Queensland, Australia. Retrieved from http://www.ecoefficiencygroup.com.au/Portals/0/Eco-efficiency%20Toolkit%20for%20the%20Queensland%20Food%20Processing%20Industry.pdf, last visited on August, 2013.

Palamutçu, S. (2010). Electric energy consumption in the cotton textile processing stages. *Energy*, *35*(7), 2945–2952. doi:10.1016/j.energy.2010.03.029

Pandit, Y. P., Badhe, Y. P., Sharma, B. K., Tambe, S. S., & Kulkarni, B. D. (2011). Classification of Indian power coals using K-means clustering and Self Organizing Map neural network. *Fuel*, *90*(1), 339–347. doi:10.1016/j.fuel.2010.09.012

Panjeshahi, M. H., Ataei, A., Gharaie, M., & Parand, R. (2009). Optimum design of cooling water systems for energy and water conservation. *Chemical Engineering Research and Design*, *87*(2), 200–209. doi:10.1016/j.cherd.2008.08.004

Place, F., & Meybeck, A. (2013). *Food security and sustainable resource use – what are the resource challenges to food security? A Report for the Food Security Futures conference, 11-12 April 2013, Dublin, Ireland*. Retrieved from http://www.pim.cgiar.org/files/2013/01/FoodSecurityFuturesSustainableResourceUseExSum.pdf, last visited on September, 2013.

Proenca, A. C., Nunes, M. L., & Barata, F. (2000). Clean technologies in sardine canning industry. In *Proceedings of 30th WEFTA Plenary Meeting on the Faroe Islands* (pp. 145–9).

Pusavec, F., Krajnik, P., & Kopac, J. (2010). Transitioning to sustainable production – Part I: application on machining technologies. *Journal of Cleaner Production*, *18*(2), 174–184. doi:10.1016/j.jclepro.2009.08.010

Randall, P. M. (1992). Pollution prevention methods in the surface coating industry. *Journal of Hazardous Materials*, *29*(2), 275–295. doi:10.1016/0304-3894(92)85073-A

Reeve, D. J. (2007). Environmental improvements in the metal finishing industry in Australasia. *Journal of Cleaner Production*, *15*(8), 756–763.

Regional Activity Centre for Cleaner Production - RAC/CP. (2001). *Pollution prevention in food canning processes*. Barcelona, Spain. Retrieved from http://www.industry.org.il/_UploadsCl/dbsAttachedFiles/foodcanningprocesses%281%29.pdf, last visited on September, 2013.

Regional Activity Centre for Cleaner Production (RAC/CP). (2002). *Alternatives for pollution prevention in the surface treatment sector*. Barcelona, Spain. Retrieved from www.cprac.org/docs/tsu_eng.pdf, last visited on April, 2013.

Ren, X. (2000). Development of environmental performance indicators for textile process and product. *Journal of Cleaner Production*, *8*(6), 473–481. doi:10.1016/S0959-6526(00)00017-2

Republic of Turkey Small and Medium Enterprises Development Organization - KOSGEB. (2012). *Enhancing the competitiveness of SMEs in Turkey: Country Report*. Retrieved from http://www.comcec.org/UserFiles/File/%C3%BClkeraporlar%C4%B1/28_isedak_%C3%BClke_rap/T%C3%BCrkiye.pdf, last visited on April, 2013.

Regers, D. E. C., & Banoo, I. (2004). *National cleaner production strategy of South Africa*. Pretoria, South Africa: The Government of the Republic of South Africa. Retrieved from http://sawic.environment.gov.za/documents/307.pdf, last visited on October, 2013.

Roberts, L. (1996). Improving the environmental performance of firms: the experience of two metal working companies. *Journal of Cleaner Production*, *4*(3), 175–187.

Rosi, O. L., Casarci, M., Mattioli, D., & De Florio, L. (2007). Best available technique for water reuse in textile SMEs (BATTLE LIFE Project). *Desalination*, *206*(1–3), 614–619. doi:10.1016/j.desal.2006.06.010

Salihoğlu, G. (2010). Industrial hazardous waste management in Turkey: current state of the field and primary challenges. *Journal of hazardous materials*, *177*(1-3), 42–56. doi:10.1016/j.jhazmat.2009.11.096

Saritas, O., & Aylen, J. (2010). Using scenarios for roadmapping: The case of clean production. *Technological Forecasting and Social Change*, *77*(7), 1061–1075. doi:10.1016/j.techfore.2010.03.003

Saygın, D., Patel, M. K., Worrell, E., Tam, C., & Gielen, D. J. (2011). Potential of best practice technology to improve energy efficiency in the global chemical and petrochemical sector. *Energy*, *36*(9), 5779–5790. doi:10.1016/j.energy.2011.05.019

Sellahewa, J., Trujillo, F., Sanguansri, P., & Simons, L. (2011). *Technology roadmap for environmentally sustainable food manufacturing*. Commonwealth Scientific and Industrial Research Organisation - CSIRO. Retrieved from http://www.csiro.au/~/media/CSIROau/Divisions/CSIRO%20Food%20and%20Nutritional%20Sciences/2011Roadmap-workshop/Technology%20roadmap%20by%20CSIRO.pdf, last visited on October, 2013.

Schmidt, M. (2010). Approaches towards the Efficient Use of Resources in the Industry. *Chemical Engineering & Technology*, *33*(4), 552–558. doi:10.1002/ceat.201000043

Scottish Climate Change Impacts Partnership - SCCIP. (2010). *Adapting to climate change: A guide for businesses in Scotland*. Retrieved from http://www.adaptationscotland.org.uk/Upload/Documents/AdaptingtoClimateChangeScreenFINAL2.pdf, last visited on August, 2013.

Seneviratne, M. (2007). *A Practical Approach to Water Conservation for Commercial and Industrial Facilities*. Elsevier. Retrieved from http://www.sciencedirect.com/science/book/9781856174893, last visited on April, 2013.

Shaikh, M. A. (2009). Water conservation in textile industry. *PTJ*, *9*, 48–51.

Shen, L., Worrell, E., & Patel, M. K. (2010). Environmental impact assessment of man-made cellulose fibres. *Resources, Conservation and Recycling*, *55*(2), 260–274. doi:10.1016/j.resconrec.2010.10.001

State Planning Organization - SPO. (2000). *Uzun vadeli strateji ve sekizinci beş yıllık kalkınma planı: 2001-2005*. Ankara, Turkey. Retrieved from http://ekutup.dpt.gov.tr/plan/viii/plan8.pdf, last visited on September, 2013.

State Planning Organization - SPO. (2006). *Dokuzuncu kalkınma planı: 2007-2013*. Ankara, Turkey. Retrieved from http://ekutup.dpt.gov.tr/plan/plan9.pdf, last visited on September, 2013.

State Planning Organization - SPO. (2007). *Report of export commission on chemical sector*. Ankara, Turkey. Retrieved from www.kalkinma.gov.tr/DocObjects/Download/3457/oik580.pdf, last visited on July, 2013.

Sthiannopkao, S., & Sreesai, S. (2009). Utilization of pulp and paper industrial wastes to remove heavy metals from metal finishing wastewater. *Journal of Environmental Management*, *90*(11), 3283–3289.

Tanapongpipat, A., Khamman, C., Pruksathorm, K., & Hunsom, M. (2008). Process modification in the scouring process of textile industry. *Journal of Cleaner Production*, *16*(1), 152–158. doi:10.1016/j.jclepro.2006.06.016

Technology Development Foundation of Turkey – TTGV. (2010). *Identification of framework conditions and R&D requirements for dissemination of cleaner production practices in Turkey*. Ankara, Turkey. Retrieved from http://www.ttgv.org.tr/content/docs/cleaner-production-final-report.pdf, last visited on November, 2013.

Technology Development Foundation of Turkey – TTGV. (2011). *Sanayide eko-verimlilik (temiz üretim) kılavuzu: yöntemler ve uygulamalar*. Ankara, Turkey. Retrieved from http://www.ekoverimlilik.org/wp-content/uploads/2011/11/Sanayide_Eko-verimlilik_Temiz-Uretim_Kilavuzu-Yontemler-ve-Uygulamalar.pdf, last visited on November, 2013.

Technology Development Foundation of Turkey – TTGV. (2012). *Analysis of environmental situation in Turkish textile industry with a special focus on target region.* Retrieved from http://www.ttgv.org.tr/tr/kurumsal-sosyal-sorumluluk-ve-cevre, last visited on September, 2013.

Telukdarie, A., Buckley, C., & Koefoed, M. (2006). The importance of assessment tools in promoting cleaner production in the metal finishing industry. *Journal of Cleaner Production*, *14*(18), 1612–1621.

The Federation of Food and Drink Industry Associations of Turkey - TGDF. (2011). *Food and drink industry inventory*. Ankara, Turkey. Retrieved from http://www.gidahatti.com/resimler/gununhaberleri/16052013/2012_envanteri_son.pdf, last visited on August, 2013.

The Food and Agriculture Organization of the United Nations - FAO. (2013). *Food Outlook: Biannual report on global food markets*. Retrieved from www.fao.org/docrep/018/al999e/al999e.pdf, last visited on August, 2013.

The German Federal Government. (2008). *German strategy for adaptation to climate change*. Retrieved from http://www.bmu.de/fileadmin/bmuimport/files/english/pdf/application/pdf/das_gesamt_en_bf.pdf, last visited on September, 2013.

The Scientific and Technological Research Council of Turkey - TUBITAK and Technology Development Foundation of Turkey - TTGV. (1999). *Bilim-teknoloji-sanayi tartışmaları platformu*. Ankara, Turkey. Retrieved from http://kutuphane.tbmm.gov.tr:8088/2000/200004030.pdf, last visited on October, 2013.

The Scientific and Technological Research Council of Turkey - TUBITAK. (2003a). *Vizyon 2023: Bilim ve teknoloji stratejileri teknoloji öngörü pojesi: Çevre ve sürdürülebilir kalkınma tematik paneli*. Ankara, Turkey. Retrieved from http://www.tubitak.gov.tr/tubitak_content_files/vizyon2023/csk/CSK_son_surum.pdf, last visited on October, 2013.

The Scientific and Technological Research Council of Turkey - TUBITAK. (2003b). *Vision 2023 technology foresight project: Chemicals panel report*. Ankara, Turkey. Retrieved from http://www.tubitak.gov.tr/tubitak_content_files/vizyon2023/kimya/kimya_son_surum.pdf, last visited on October, 2013.

The Scientific and Technological Research Council of Turkey - TUBITAK. (2010). *National R&D and innovation strategy: food/drink sector*. Ankara, Turkey. Retrieved from http://www.tubitak.gov.tr/tubitak_content_files/BTYPD/btyk/22/BTYK22_Ek7_Gida_Bilgi_Notu.pdf, last visited on April, 2013.

The Scientific and Technological Research Council of Turkey - TUBITAK. (2011). *National R&D and innovation strategy for water*. Ankara, Turkey. Retrieved from http://www.tubitak.gov.tr/sites/default/files/ek2_ulusal_su_arge_yenilik_stratejisi.pdf, last visited on April, 2013.

Thiede, S., Posselt, G., & Herrmann, C. (2013). SME appropriate concept for continuously improving the energy and resource efficiency in manufacturing companies. *CIRP Journal of Manufacturing Science and Technology*, *6*(3), 204–211. doi:10.1016/j.cirpj.2013.02.006

Thoresen, J. (1999). Environmental performance evaluation — a tool for industrial improvement. *Journal of Cleaner Production*, *7*(5), 365–370. doi:10.1016/S0959-6526(99)00154-7

Thrane, M., Nielsen, E. H., & Christensen, P. (2009). Cleaner production in Danish fish processing – experiences, status and possible future strategies. *Journal of Cleaner Production*, *17*(3), 380–390. doi:10.1016/j.jclepro.2008.08.006

Tol, R. S. J. (2005). Adaptation and mitigation: trade-offs in substance and methods. *Environmental Science & Policy*, *8*(6), 572–578. doi:10.1016/j.envsci.2005.06.011

Turkish Statistical Institute - TSI. (2008a). *Hazardous waste generation breakdown in Turkish manufacturing industry*. Ankara, Turkey. Retrieved from http://www.tuik.gov.tr/PreHaberBultenleri.do?id=10824, last visited on May, 2013.

Turkish Statistical Institute - TSI. (2008b). *Solid waste generation breakdown in Turkish manufacturing industry*. Ankara, Turkey.
Retrieved from http://www.tuik.gov.tr/PreHaberBultenleri.do?id=10824, last visited on May, 2013.

Turkish Statistical Institute - TSI. (2008c). *Water consumption breakdown in Turkish manufacturing industry*. Ankara, Turkey.
Retrieved from http://www.tuik.gov.tr/PreHaberBultenleri.do?id=10824, last visited on May, 2013.

Turkish Statistical Institute - TSI. (2008d). *Wastewater generation breakdown in Turkish manufacturing industry*. Ankara, Turkey.
Retrieved from http://www.tuik.gov.tr/PreHaberBultenleri.do?id=10824, last visited on May, 2013.

Turkish Statistical Institute - TSI. (2010). *Manufacturing industry water indicators*. Ankara, Turkey. Retrieved from http://www.tuik.gov.tr/PreTablo.do?alt_id=1019, last visited on May, 2013.

Turkishtime. (2013). *İhracat stratejileri: 2023 hedeflerine güçlü ilerleyen sektör*. İstanbul, Turkey. Retrieved from
http://www.timakademi2023.org/wp-content/themes/a23/docs/tekstil-hazir-giyim.pdf, last visited on August, 2013.

Uçaroğlu, S., & Talinli, İ. (2012). Recovery and safer disposal of phosphate coating sludge by solidification/stabilization. *Journal of Environmental Management*, *105*(0), 131–137. doi:10.1016/j.jenvman.2012.03.029

Ulson de Souza, A. A., Melo, A. R., Pessoa, F. L. P., & Guelli Ulson de Souza, S. M. de A. (2010). The modified water source diagram method applied to reuse of textile industry continuous washing water. *Resources, Conservation and Recycling*, *54*(12), 1405–1411. doi:10.1016/j.resconrec.2010.06.001

Ulutaş, F., Alkaya, E., Böğürcü, M., & Demirer, G. N. (2011). A comparative analysis of Turkish and European Union environmental legislation regarding cleaner (sustainable) production concept. *International Journal of Environment and Sustainable Development*, *10*(3), 246–266. doi:10.1504/IJESD.2011.045366

Ulutaş, F., Alkaya, E., Bogurcu, M., & Demirer, G. N. (2012a). The national capacity assessment on cleaner (sustainable) production in Turkey. *Sustainable Cities and Society*, *5*, 30–36. doi:10.1016/j.scs.2012.05.006

Ulutaş, F., Alkaya, E., Bogurcu, M., & Demirer, G. N. (2012b). Determination of the framework conditions and research–development needs for the dissemination of cleaner (sustainable) production applications in Turkey. *International Journal of Sustainable Development & World Ecology*, *19*(3), 203–209. doi:10.1080/13504509.2011.606550

Undersecretariat of Treasury. (2013). *Turkish economy*. Ankara, Turkey. Retrieved from http://www.treasury.gov.tr/File/?path=ROOT/Documents/General%20Content/Ekonomi_Sunumu_ENG.pdf, last visited on November, 2013.

United Nations Development Programme - UNDP. (2008). *Turkey corporate social responsibility baseline report*. Ankara, Turkey. Retrieved from www.undp.org.tr/publicationsDocuments/CSR_Report_en.pdf, last visited on April, 2013.

United Nations Environment Programme - UNEP. (1994). *Government strategies and policies for cleaner production*. Paris, France. Retrieved from http://dspace.mit.edu/bitstream/handle/1721.1/1560/%252327.PDF?sequence=1, last visited on October, 2013.

United Nations Environment Programme - UNEP. (2000). *Cleaner production assessment in fish processing*. Paris, France.
Retrieved from www.uneptie.org/shared/publications/pdf/2481-CPfish.pdf, last visited on September, 2013.

United Nations Environment Programme - UNEP. (2002). *Sustainable consumption and cleaner production global status 2002*. Paris, France. Retrieved from http://www.unep.fr/shared/publications/pdf/3211-GlobalStatus02.pdf, last visited on November, 2013.

United Nations Environment Programme - UNEP. (2004). *Guidelines for the application of best available techniques (BATs) and best environmental practices (BEPs) in industrial sources of BOD, nutrients and suspended solids for the Mediterranean region* (No. MAP Technical Reports Series No. 142). Athens, Greece.

United States Environmental Protection Agency - USEPA. (2010). *2010-2014 pollution prevention (P2) program strategic plan*. Retrieved from www.epa.gov/p2/pubs/docs/P2StrategicPlan2010-14.pdf, last visited on November, 2013.

United Nations Framework Convention on Climate Change - UNFCCC. (2013). *National adaptation programmes of action*. Retrieved from http://unfccc.int/files/cooperation_support/least_developed_countries_portal/napa_project_database/application/pdf/napa_index_by_country.pdf, last visited on October, 2013.

United Nations Industrial Development Organisation - UNIDO. (2002). *Manual on the development of cleaner production policies: approaches and instruments*. Vienna, Austria. Retrieved from www.unido.org/fileadmin/import/9750_0256406e.pdf, last visited on November, 2013.

United States Agency for International Development - USAID. (2009a). *Metal finishing: Cleaner production fact sheet and resource guide*. Washington DC, USA. Retrieved from http://www.encapafrica.org/EGSSAA/metalfinish.pdf, last visited on April, 2013.

United States Agency for International Development - USAID. (2009b). *Food processing: Cleaner production fact sheet and resource guide*. Washington DC, USA. Retrieved from www.encapafrica.org/EGSSAA/foodprocessing.pdf, last visited on August, 2013.

Uttamangkabovorn, M., Prasertsan, P., & Kittikun, A. H. (2005). Water conservation in canned tuna (pet food) plant in Thailand. *Journal of Cleaner Production*, *13*(6), 547–555. doi:10.1016/j.jclepro.2003.12.003

Uzunoğlu, H. (2010). *Tekstil sektöründe çevre akımı: Ekolojik tekstil*. Retrieved from http://www.izto.org.tr/portals/0/iztogenel/dokumanlar/tekstil_sektorunde_cevre_akimi_h_uzunoglu_25.04.2012%2010-40-12.pdf, last visited on October, 2013.

Van Berkel, R. (2007). Cleaner production and eco-efficiency in Australian small firms. *International Journal of Environmental Technology and Management*, *7*(5), 672–693.

Van Hoof, B., & Lyon, T. P. (2013). Cleaner production in small firms taking part in Mexico's Sustainable Supplier Program. *Journal of Cleaner Production*, *41*, 270–282. doi:10.1016/j.jclepro.2012.09.023

Videira, N., Antunes, P., Scholl, G., Gaetaniello, A., & Reisch, L. (2012). *Background paper on Sustainable Food Consumption and Growth 1st Multinational knowledge brokerage event on Sustainable Food Consumption*. Retrieved from http://www.scp-responder.eu/pdf/knowledge/papers/RESPONDER%20Food1%20-%20Background%20Paper.pdf, last visited on August, 2013.

Visvanathan, C. (2007). *Seafood processing* (No. ED78.20). Pathumthani, Thailand. Retrieved from http://www.fpeac.org/seafood/IndustrialWasteAbatement-Seafood.pdf, last visited on September, 2013.

Wang, J., Qu, D., Tie, M., Ren, H., Peng, X., & Luan, Z. (2008). Effect of coagulation pretreatment on membrane distillation process for desalination of recirculating cooling water. *Separation and Purification Technology*, *64*(1), 108–115. doi:10.1016/j.seppur.2008.07.022

Waste and Resources Action Programme - WRAP. (2013). *Water minimisation in the food and drink industry*. Oxon, The United Kingdom. Retrieved from http://www.wrap.org.uk/sites/files/wrap/Water%20Minimisation%20in%20FD%20 Industry.pdf, last visited on August, 2013.

Werner, S. (2006). Heat-transfer pumps for processing synthetic oils. *World Pumps*, *2006*(475), 38–40. doi:10.1016/S0262-1762(07)70056-1

Willumeit, T. (2010). *Caterpillar: OXSILAN - Update*. France: Chemetall Group. Retrieved from http://docs7.chomikuj.pl/1584148356,PL,0,0,CAT-OXSILAN-internet.pdf, last visited on April, 2013.

Wu, D., Chu, Y., Chen, J.-C., Hong, J.-G., Gao, H.-F., Fang, Z., … Ye, X.-Q. (2013). Quality monitoring for a water reclamation system in a mandarin orange canning factory. *Desalination and Water Treatment*, *51*(16-18), 3138–3144. doi:10.1080/19443994.2012.749007

Wymenga, P., Spanikova, V., Barker, A., Konings, J., & Canton, E. (2012). *EU SMEs in 2012: at the crossroads*. Rotterdam, The Nederlands. Retrieved from http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/performance-review/files/supporting-documents/2012/annual-report_en.pdf, last visited on April, 2013.

Yale University. (2012). *Environmental performance index: Summary for policy makers*. USA. Retrieved from http://epi.yale.edu/sites/default/files/downloads/Summary_Final-%20OnlineV3_1.pdf, last visited on November, 2013.

You, S.-H., Tseng, D.-H., & Guo, G.-L. (2001). A case study on the wastewater reclamation and reuse in the semiconductor industry. *Resources, Conservation and Recycling*, *32*(1), 73–81. doi:10.1016/S0921-3449(00)00096-3

You, S.-H., Tseng, D.-H., Guo, G.-L., & Yang, J.-J. (1999). The potential for the recovery and reuse of cooling water in Taiwan. *Resources, Conservation and Recycling*, *26*(1), 53–70. doi:10.1016/S0921-3449(98)00075-5

Zeng, S. X., Meng, X. H., Yin, H. T., Tam, C. M., & Sun, L. (2010). Impact of cleaner production on business performance. *Journal of Cleaner Production*, *18*(10–11), 975–983. doi:10.1016/j.jclepro.2010.02.019

Zhai, H., & Rubin, E. S. (2010). Performance and cost of wet and dry cooling systems for pulverized coal power plants with and without carbon capture and storage. *Energy Policy*, *38*(10), 5653–5660. doi:10.1016/j.enpol.2010.05.013

Zhang, C., Chen, J., & Wen, Z. (2012). Assessment of policy alternatives and key technologies for energy conservation and water pollution reduction in China's synthetic ammonia industry. *Journal of Cleaner Production*, *25*, 96–105. doi:10.1016/j.jclepro.2011.11.056

Zheng, P., Feng, X., Qian, F., & Cao, D. (2006). Water system integration of a chemical plant. *Energy Conversion and Management*, *47*(15–16), 2470–2478. doi:10.1016/j.enconman.2005.11.001

Zimmer, M.-M., König, U., Galant, S., Severin, A., & Sessler, B. (2011). *Recommendation for an efficient contribution of SME companies to greater resource efficiency within the supply chain of metal finishing by focusing on interdisciplinary branches like surface finishing*. Retrieved from http://ec.europa.eu/environment/resource_efficiency/pdf/Galvano.pdf, last visited on April, 2013.

APPENDIX A

INITIAL DATA COLLECTION FORM FOR PILOT APPLICATIONS

FİRMA VE PİLOT UYGULAMA (PROJE) BİLGİLERİ		
Firma Bilgileri	Firma Adı	
	Adres	
	E-posta	
	Web Adresi	
	Telefon	
	Faks	
	Faaliyet Konusu	
	NACE Kodu	
	Toplam Personel Sayısı	
	Firma Yetkilisi (Adı Soyadı ve Ünvanı)	
Proje Bilgileri	Proje No	
	Proje Adı	
	Proje Bütçesi	
	Proje Süresi	
	Proje Başlama Tarihi	
	Proje Bitiş Tarihi	

1. EKONOMİK GÖSTERGELER

1.1. Ürün

- Firma bünyesinde üretilen ürünleri ve üretim miktarlarını belirtiniz.

Ürün	Miktar (ton,m^3/yıl)	
	2008	2009

- 2010 yılı üretim miktarlarını aylık bazda belirtiniz.

Ürün/Hizmet	Miktarı (ton,m^3/ay)						
	Ocak	Şubat	Mart	Nisan	Mayıs	Haziran	Temmuz
TOPLAM							

1.2. Gelir/ Gider

		ABD Doları		Oran* (%)	
		2008	2009	2008	2009
Gelirler	I. Yurtiçi satışlar				
	II. Yurtdışı satışlar				
	Satışlar				
Giderler	I. İşletme maliyetleri a. Hammadde b. Enerji c. Su d. Atık/atıksu bertarafı e. Diğer				
	II. Personel				
	III. Vergiler				
	IV. Diğer				
	Toplam Giderler				

***Toplam gelir ya da gidere oranın belirtiniz.

- 2010 yılı için gelir ve giderleri aylık bazda belirtiniz

		ABD Doları							
		Ocak	Şubat	Mart	Nisan	May	Haz	Tem	Ağu
Gelirler	III. Yurtiçi satışlar								
	IV. Yurtdışı satışlar								
	Net satışlar								
Giderler	V. İşletme maliyetleri f. Hammadde g. Enerji h. Su i. Atıksu arıtımı j. Diğer								
	VI. Personel								
	VII. Vergiler								
	VIII. Diğer								
	Toplam Giderler								

2. ÇEVRESEL GÖSTERGELER

2.1. Hammadde Kullanımı

- Firma genelinde üretimde kullanılan ana hammaddeleri, tüketim miktarlarını, hammadde kayıp/firelerini, hammadde türünü/kaynağını ve tehlikeli madde içerip içermediklerini ve belirtiniz.

Tüketilen hammadde	**Tüketim miktarı (ton,m^3/yıl)**		**Hammadde Kayıp/Fire Miktarı (ton,m^3/yıl)**		**Türü/Kaynağı (geri-dönüştürülmüş vb.)**	**Özelliği (tehlikeli /değil)**
	2008	**2009**	**2008**	**2009**		

- 2010 yılı ana hammadde tüketim miktarlarını aylık bazda belirtiniz.

Tüketilen hammadde	Tüketim miktarı (ton, m^3/ay)							
	Ocak	Şubat	Mart	Nisan	Mayıs	Haz	Tem	Ağu

- 2010 yılı hammadde kayıp/fire miktarlarını aylık bazda belirtiniz.

Tüketilen hammadde	Kayıp/ Fire miktarı (ton, m^3/ay)							
	Ocak	Şubat	Mart	Nisan	Mayıs	Haz	Tem	Ağu

- Belirtilen hammadde tüketimi ve kayıp/fire verilerinin kaynağını (fatura, firma kaydı, sözlü beyan vb.) belirtiniz.

2.2. Enerji Kullanımı

- Tesiste kullanılan yıllık toplam enerji miktarını ve enerji tüketim maliyetlerini belirtiniz.

Tüketilen enerji türü	Tüketim miktarı		Tüketim maliyeti ($/yıl)	
	2008	2009	2008	2009
Kömür (ton)				
Doğalgaz (Nm^3)				
Fuel-oil (ton) (Cinsi:............)				
Elektrik (kWh)				
LPG (ton/yıl)				
Yenilenebilir (Belirtiniz)				
Diğer				
TOPLAM* (kWh)				

*Toplam enerji tüketim miktarını firmanın kullandığı enerji kaynağının kalorifik değerinden yola çıkarak kWh cinsinden hesaplayınız.

Aşağıda GRI "Sustainable Reporting" dokümanından alınan örnek dönüşüm tablosu verilmiştir.

Enerji Türü	**kWh Dönüşümü**
Kömür	$7{,}2 \times 10^3$ kWh/ton
Doğal gaz	10,84 kWh/Nm^3
Fuel-oil	$2{,}83 \times 10^3$ kWh/ton
LPG	$13{,}80 \times 10^3$ kWh/ton

- 2010 yılı enerji tüketim miktarlarını aylık bazda belirtiniz.

Tüketilen enerji türü	**Tüketim miktarı**							
	Ocak	Şubat	Mart	Nisan	Mayıs	Haz	Tem	Ağu
Kömür (ton)								
Doğalgaz (Nm^3)								
Fuel-oil (ton) (Cinsi:.........)								
Elektrik (kWh)								
LPG (ton)								
Yenilenebilir (Belirtiniz)								
Diğer								
TOPLAM* (kWh)								

*Toplam enerji tüketim miktarını firmanın kullandığı enerji kaynağının kalorifik değerinden yola çıkarak kWh cinsinden hesaplayınız.

- Belirtilen enerji tüketim verilerinin kaynağını (fatura, sayaç, firma kaydı, sözlü beyan vb.) belirtiniz

2.3. Su Kullanımı

- Tesiste kullanılan yılık toplam su miktarı, tüketim maliyetlerini ve kayıp kaçakları belirtiniz.

Su Kaynağı	Tüketim miktarı (m^3/yıl)		Tüketim maliyeti ($/yıl)*		Kayıp/Kaçak Miktarı (m^3/yıl)	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**
Şebeke suyu						
Yeraltı suyu						
Diğer						
TOPLAM						

*Tüketim maliyetlerine pompa maliyetlerini de dahil ediniz.

- 2010 yılı su tüketim miktarlarını aylık bazda belirtiniz.

Su kaynağı	Tüketim miktarı (m^3/ay)							
	Ocak	Şubat	Mart	Nisan	Mayıs	Haz	Tem	Ağu
Şebeke								
Yeraltı								
Diğer								
TOPLAM								

- 2010 yılı su kayıp/kaçak miktarlarını belirtiniz.

Su kaynağı	Kayıp/kaçak miktarı (m^3/ay)							
	Ocak	Şubat	Mart	Nisan	Mayıs	Haz	Tem	Ağu
Şebeke								
Yeraltı								
Diğer								
TOPLAM								

- Tesiste kullanılan su işleniyorsa, işlenen suyun kaynağını, işlenen yıllık su miktarını, işleme maliyetini, işleme yöntemini (yumuşatma, deiyonizasyon, vb.) ve bu suyun kullanım alanlarını belirtiniz.

Su kaynağı	**İşleme yöntemi**	**Kullanım alanı**	**İşlenen su miktarı (m^3/yıl)**		**İşleme maliyeti ($/yıl)**	
			2008	**2009**	**2008**	**2009**

- İşlenen suyun kaynağını, işlenen aylık su miktarını, işleme maliyetini ve bu suyun kullanım alanlarını belirtiniz.

Su kaynağı	**Su kullanım alanı**	**İşleme miktarı (m^3/yıl)**							
		Ocak	Şub	Mart	Nisan	Mayıs	Haz	Tem	Ağu

Su kaynağı	**Su kullanım alanı**	**İşleme Maliyeti ($/yıl)**							
		Ocak	Şub	Mart	Nisan	Mayıs	Haz	Tem	Ağu

- Belirtilen su tüketim verilerinin kaynağını (fatura, sayaç, firma kaydı, sözlü beyan vb.) belirtiniz

2.4. Atıksu Oluşumu

- Tesiste oluşan ve deşarj edilen atıksu miktarlarını, hangi proseslerden kaynaklandığını, bertaraf yöntemlerini ve mevcutsa karakterizasyonunu belirtiniz.

Atıksu kaynağı (prosesler)	**Bertaraf yöntemi**	**2008 (m^3/yıl)**	**2009 (m^3/yıl)**
	TOPLAM		

- 2010 yılı atıksu miktarlarını aylık bazda belirtiniz.

Atıksu kaynağı	**Miktarı (m^3/ay)**							
	Ocak	Şub	Mart	Nisan	Mayıs	Haz	Tem	Ağu
TOPLAM								

Atıksu kaynağı (prosesler)	**Parametreler**				
	KOİ (mg/L)	**AKM (mg/L)**	**Yağ ve Gres (mg/L)**	**pH**	**Diğer**
TOPLAM					

- Tesiste oluşan atıksuyun bertarafıyla ilgili maliyetleri yıllık bazda belirtiniz.

Bertaraf Gideri	**2008 ($/yıl)**	**2009 ($/yıl)**
Enerji maliyeti		
Arıtma kimyasalı maliyeti		
Çamur bertaraf maliyeti		
Diğer		
TOPLAM		

- Tesiste oluşan atıksuyun bertarafıyla ilgili maliyetleri aylık bazda belirtiniz.

Bertaraf Gideri	Atıksu bertaraf maliyeti ($/yıl)							
	Ocak	Şub	Mart	Nisan	Mayıs	Haz	Tem	Ağu
Enerji maliyeti								
Arıtma kimyasalı maliyeti								
Çamur bertaraf maliyeti								
Diğer								

- Belirtilen atıksu verilerinin kaynağını (fatura, sayaç, firma kaydı, sözlü beyan vb.) belirtiniz.

2.5. Katı Atık Oluşumu

- Tesiste oluşan proses kaynaklı belli başlı katı atık türlerini, miktarlarını, nerelerden kaynaklandığını ve bertaraf yöntemlerini (tesis içinde/dışında geridönüşüm, yakma, düzenli depolama vb.) belirtiniz.

Katı atık türü	Katı atık kaynağı (prosesler)	Özelliği (tehlikeli /değil)	Bertaraf yöntemi	2008 (ton/yıl)	2009 (ton/yıl)
TOPLAM					

- 2010 yılı katı atık miktarlarını aylık bazda belirtiniz.

Katı atık türü	Miktarı (m^3/ay)							
	Ocak	Şub	Mart	Nisan	Mayıs	Haz	Tem	Ağu
TOPLAM								

* Katı atık listesine yeniden kullanılmayan hammadde ve ürün kayıp/fireleri de eklenmelidir

- Belirtilen katık atık oluşum verilerinin kaynağını (fatura, firma kaydı, sözlü beyan vb.) belirtiniz.

2.6. Baca Gazı Emisyonları /Atık Gazlar

- Tesiste oluşan baca gazı emisyonu /atık gazların mevcutsa karakterizasyonu, sıcaklığı ve emisyon miktarları hakkında bilgi veriniz.

Atık Gaz	Proses (Kaynağı)	Debi (m^3/gün)	Kirletici Parametreler	Kirletici Parametrelerin Konsantrasyonu (mg/L)	Sıcaklığı (^oC)

Atık Gaz	Debi (m^3/ay)							
	Ocak	Şub	Mart	Nisan	Mayıs	Haz	Tem	Ağu

2.7. Tesis İçindeki Geri Kazanımlar

- Tesisteki yeniden kullanım/ geri kazanımları ve miktarlarını belirtiniz.

Geri kazanım türü	Miktar	Açıklama

APPENDIX B

MONITORING DATA COLLECTION FORM FOR PILOT APPLICATIONS

FİRMA VE PROJE BİLGİLERİ		
Firma Bilgileri	**Firma Adı**	
	Adres	
	E-posta	
	Web Adresi	
	Telefon	
	Faks	
	Faaliyet Konusu	
	NACE Kodu	
	Toplam Personel Sayısı	
	Firma Yetkilisi (Adı Soyadı ve Ünvanı)	
Proje Bilgileri	**Proje No**	
	Proje Adı	
	Proje Bütçesi	
	Proje Süresi	
	Proje Başlama Tarihi	
	Proje Bitiş Tarihi	

1. GENEL DEĞERLENDİRME

- Projede öngörülen uygulamalar tamamlanmış mıdır?
  (Henüz tamamlanmamış uygulamalar için hangi aşamada olunduğunu ve eksiklikleri belirtiniz)

- Tamamlanan uygulamalar planlandığı şekilde işletilebiliyor mu? Varsa aksaklıkları ve bunlara yönelik olası çözümleri belirtiniz

- Projede kullanılan ekipman, proses ve teknolojinin yenilik düzeyi, güncel teknolojilerle uyumu ve benzer sektörlerde kullanımını değerlendiriniz.

Ekipman, proses, teknoloji yenilik düzeyi

	Yenilik düzeyi (1-5)	1: çok yeni 2: yeni 3: orta 4: eski 5: çok eski
Ekipman		
Proses		
Teknoloji		

2. MAL VE HİZMET ALIMINA YÖNELİK DEĞERLENDİRME

- Proje kapsamında kullanılması öngörülen ekipman, malzeme vb. alımları tamamlanmış mı? Projenin uygulamasına yönelik finansal bir aksaklık var mıdır? Varsa bu konudaki aksaklıkları ve şu anki durumu belirtiniz.

3. İŞ ZAMAN PLANINA YÖNELİK DEĞERLENDİRME

- Projede iş zaman planı ile ilgili bir gecikme var mı? (Varsa ilgili gecikmeleri, sebeplerini ve bu gecikmelerin projenin ileriki aşamalarını nasıl etkileyeceğini belirtiniz.)

- Proje kapsamında çalışan personel ve ortalama aylık işgücü (adam/ay) gereksinimlerini belirtiniz.

Ad Soyad	Toplam çalışma Süresi (ay)	Adam/ay	Maliyet ($/ay)	Toplam tutar ($)

4. PROJENİN ÇEVRESEL PERFORMASINA YÖNELİK DEĞERLENDİRME

4.1. Hammadde Kullanımı

- Proje faaliyetleri ile ilgili olan girdileri (hammadde, kimyasal vb.), tüketim miktarlarını, kayıp/fireleri, girdi türünü/kaynağını ve tehlikeli madde içerip içermediklerini (akım şeması ile uyumlu olarak) belirtiniz.

Tüketilen girdiler	Tüketim miktarı (ton/yıl)		Kayıp/Fire (ton/yıl)		Türü/Kaynağı (geri-dönüştürülmüş vb.)	Özelliği (tehlikeli /değil)
	2008	2009	2008	2009		

- 2010 yılı girdi tüketim miktarlarını aylık bazda belirtiniz.

Tüketilen girdiler	Tüketim miktarı (ton/ay)							
	Ocak	Şub	Mart	Nisan	May	Haz	Tem	Ağu

- 2010 yılı grici kayıp/firelerini aylık bazda belirtiniz.

Tüketilen girdiler	Kayıp/fire miktarı (ton/ay)							
	Ocak	Şub	Mart	Nisan	May	Haz	Tem	Ağu

- Belirtilen girdi tüketimi kaynağını (fatura, firma kaydı, sözlü beyan vb.) belirtiniz.

4.2. Enerji Kullanımı

- Proje faaliyetleri ile ilgili kullanılan enerji miktarını kullanılan enerji türüne göre belirtiniz.

Tüketilen enerji türü	Tüketim miktarı		Tüketim maliyeti ($/yıl)	
	2008	2009	2008	2009
Kömür (ton)				
Doğalgaz (Nm^3)				
Fuel-oil (ton) (Cinsi:............)				
Elektrik (kWh)				
LPG (ton/yıl)				
Yenilenebilir (Belirtiniz)				
Diğer				
TOPLAM* (kWh)				

*Toplam enerji tüketim miktarını firmanın kullandığı enerji kaynağının kalorifik değerinden yola çıkarak kWh cinsinden hesaplayınız.

Aşağıda GRI "Sustainable Reporting" dokümanından alınan örnek dönüşüm tablosu verilmiştir.

Enerji Türü	**kWh Dönüşümü**
Kömür	$7,2x10^3$ kWh/ton
Doğal gaz	10,84 kWh/Nm^3
Fuel-oil	2,83 $x10^3$ kWh/ton
LPG	13,80 $x10^3$ kWh/ton

- 2010 yılı enerji tüketim miktarlarını aylık bazda belirtiniz.

Tüketilen enerji türü	**Tüketim miktarı (kWh/ay)**							
	Ocak	Şub	Mar	Nis	May	Haz	Tem	Ağu
Kömür (ton)								
Doğalgaz (Nm^3)								
Fuel-oil (ton) (Cinsi:.........)								
Elektrik (kWh)								
LPG (ton/yıl)								
Yenilenebilir (Belirtiniz)								
Diğer								
TOPLAM* (kWh)								

*Toplam enerji tüketim miktarını firmanın kullandığı enerji kaynağının kalorifik değerinden yola çıkarak kWh cinsinden hesaplayınız.

- Belirtilen enerji tüketim verilerinin kaynağını (fatura, sayaç, firma kaydı, sözlü beyan vb.) belirtiniz.

- Proje kapsamındaki uygulamalar sonucunda enerji kullanım miktarında azalma/artış olmakta mıdır? Bu azalma/artışların sebeplerini, hangi uygulamalardan kaynaklandıklarını açıklayınız.

4.3. Su Kullanımı

- Proje faaliyetleri ile ilgili kullanılan yılık toplam su miktarını, tüketim maliyetlerini ve kayıp/kaçak miktarlarını belirtiniz.

Su Kaynağı	**Tüketim miktarı (m^3/yıl)**		**Tüketim maliyeti ($/yıl)**		**Kayıp/Kaçak Miktarı (m^3/yıl)**	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**
Şebeke						
Yeraltı						
Diğer						
TOPLAM						

*Tüketim maliyetlerine pompa maliyetlerini de dahil ediniz.

- 2010 yılı su tüketim miktarlarını aylık bazda belirtiniz.

Su kaynağı	**Tüketim miktarı (m^3/ay)**							
	Ocak	Şub	Mart	Nisan	May	Haz	Tem	Ağu
Şebeke								
Yeraltı								
Diğer								
TOPLAM								

- 2010 yılı su kayıp/kaçaklarını aylık bazda belirtiniz.

Su kaynağı	**Kayıp/kaçak miktarı (m^3/ay)**							
	Ocak	Şub	Mart	Nisan	May	Haz	Tem	Ağu
Şebeke								
Yeraltı								
Diğer								
TOPLAM								

- Belirtilen su tüketim verilerinin kaynağını (fatura, sayaç, firma kaydı, sözlü beyan vb.) belirtiniz

- Proje kapsamında gerçekleştirilen uygulamalar sonucunda tüketilen su miktarında azalma/artma ve kullanılan su kalitesinde bir değişiklik olmakta mıdır? Bu azalma/artışların ve kalitedeki değişikliklerin sebeplerini, hangi uygulamalardan kaynaklandıklarını açıklayınız.

4.4. Atıksu Oluşumu

- Proje faaliyetleri ile ilgili atıksu miktarlarını, hangi proseslerden kaynaklandığını ve mevcutsa karakterizasyonunu belirtiniz.

Atıksu kaynağı (prosesler)	2008 (m^3/yıl)	2009 (m^3/yıl)
TOPLAM		

- 2010 yılı atıksu miktarlarını aylık bazda belirtiniz.

Atıksu kaynağı	Miktarı (m^3/ay)							
	Ocak	Şub	Mart	Nisan	May	Haz	Tem	Ağu
TOPLAM								

Atıksu kaynağı (prosesler)	Parametreler				
	KOİ (mg/L)	AKM (mg/L)	Yağ ve Gres (mg/L)	pH	Diğer
TOPLAM					

- Belirtilen atıksu verilerinin kaynağını (fatura, sayaç, firma kaydı, sözlü beyan vb.) belirtiniz

- Proje kapsamında gerçekleştirilen uygulamalar sonucunda oluşan atıksu miktarlarında azalma/artma ve atıksu kalitesinde bir değişiklik olmakta mıdır? Bu azalma/artışların ve kalitedeki değişikliklerin sebeplerini, hangi uygulamalardan kaynaklandıklarını açıklayınız.

4.5. Katı Atık Oluşumu

- Proje faaliyetleri ile ilgili oluşan proses kaynaklı katı atık türlerini, miktarlarını ve nerelerden kaynaklandığını belirtiniz.

Katı atık türü	**Katı atık kaynağı (prosesler)**	**Özelliği (tehlikeli /değil)**	**2008 (ton/yıl)**	**2009 (ton/yıl)**
TOPLAM				

- 2010 yılı katı atık miktarlarını aylık bazda belirtiniz.

Katı atık türü	**Miktarı (m3/ay)**							
	Ocak	Şub	Mart	Nisan	May	Haz	Tem	Ağu
TOPLAM								

* Katı atık listesine yeniden kullanılmayan hammadde ve ürün kayıp/fireleri de eklenmelidir

- Belirtilen katı atık oluşum verilerinin kaynağını (fatura, firma kaydı, sözlü beyan vb.) belirtiniz.

- Proje kapsamında gerçekleştirilen uygulamalar sonucunda oluşan katı miktarlarında azalma/artma olmakta mıdır? Bu azalma/artışların sebeplerini, hangi uygulamalardan kaynaklandıklarını açıklayınız.

4.6. Baca Gazı Emisyonları /Atık Gazlar

- Proje faaliyetleri ile ilgili oluşan baca gazı emisyonu/ atık gazların mevcutsa karakterizasyonu, sıcaklığı ve emisyon miktarları hakkında bilgi veriniz.

Atık Gaz	Proses (Kaynağı)	Debi (m^3/yıl)		Kirletici Parametreler	Kirletici Parametrelerin Konsantrasyonu (mg/m^3) / (ppm)	Sıcaklığı (^oC)
		2008	2009			

- 2010 yılı baca gazı emisyon ve atık gaz miktarlarını aylık bazda belirtiniz.

Atık Gaz	Debi (m^3/ay)							
	Ocak	Şub	Mart	Nisan	May	Haz	Tem	Ağu

4.7. Projedeki Geri kazanımlar

- Tesisteki yeniden kullanım/ geri kazanımları ve miktarlarını belirtiniz.

Gerikazanım türü	Miktar	Açıklama
Enerji		
Su		
Hammadde		
Atık		
Atıksu		
Diğer		

5. PROJENİN EKONOMİK PERFORMANSINA YÖNELİK DEĞERLENDİRME

5.1. Ürün

- Proje faaliyetleri ile ilgili üretilen ürünleri belirtiniz.

Ürün	Miktar (ton,m^3/yıl)	
	2008	2009

- 2010 yılı üretim miktarlarını aylık bazda belirtiniz.

Ürün	Miktarı (ton,m^3/ay)							
	Ocak	Şub	Mart	Nisan	May	Haz	Tem	Ağu
TOPLAM								

- Proje kapsamında gerçekleştirilen uygulamalar sonucunda oluşan üretilen ürün ve hizmetlerin kalitesinde bir değişiklik olmuş mudur? Bu değişiklikleri ve sebeplerini açıklayınız.

5.2. Proje Maliyetleri

- Proje için yapılan ilk yatırımları maliyetlerini, proje kapsamındaki faaliyetler için işletme maliyetlerini ve proje kapsamındaki ekonomik kazanımları (enerji, su, hammadde tasarrufu vb.) belirtiniz.

	Tutar ($)
Yatırım Maliyetleri	
Toplam	
İşletme Maliyetleri	**($/yıl)**
Toplam	
Ekonomik Kazanımlar	**($/yıl)**
Toplam	

- Proje kapsamında gerçekleştirilen uygulamalardan kaynaklı ihracat oranlarına yansıyan bir değişiklik olmuş mudur (beklenmekte midir)? Oluşan veya olması beklenen değişiklikleri ve sayısal karşılıklarını belirtiniz.

- Proje kapsamında işgücü verimliliğinde bir değişim olmakta mıdır? Değişiklikleri ve sebeplerini de belirterek değerlendiriniz.

6. PROJEDE SAĞLANAN DİĞER KAZANIMLARIN DEĞERLENDİRİLMESİ

- Çevre ve işçi sağlığı-iş güvenliği alanlarında/ risklerin azaltılmasında proje uygulamaları ile ne gibi katkılar sağlanmaktadır?

- Standart ve mevzuat yükümlülüklerinin gerçekleştirilmesinde ne gibi katkılar sağlanmaktadır?

- Tamamlanan proje, firma için rekabet avantajı getirmekte midir? Açıklayınız.

- Proje uygulamalarının firma imajına ve kapasitesine olan katkılarını belirtiniz.

APPENDIX C

QUESTIONNAIRE:
ENVIRONMENTAL MANAGEMENT IN TEXTILE PRODUCER FIRMS

Firmanın Adı:		
Kontak Kişisi:		
Kontak Kişisinin Görevi:		
İletişim Bilgileri	E-posta:	Tel:
Adres:		
Çalışan Sayısı:		
En önemli iki müşteriniz (perakendeci firmalar):		

Faaliyet Alanı(ları):

- Tekstil ☐
- Dokuma ☐
- Konfeks. ☐
- Örme ☐
- İplik ☐
- Boyama ☐

Diğer:

1. Firmanızın genel çevre politikalarını ve çevre mevzuatı ile ilgili yaklaşımını en iyi tanımlayan seçeneği işaretleyiniz.

	Kesinlikle Doğru	Kısmen Doğru	Kısmen Yanlış	Kesinlikle Yanlış	Bilmiyorum
a. Üst yönetimce onaylanmış bir çevre politikası bulunmaktadır	O	O	O	O	O
b. Uygulanmakta olan bir çevre yönetim sistemi ve çevre sorumlusu bulunmaktadır	O	O	O	O	O
c. Uygulanmakta olan bir enerji yönetim sistemi ve enerji sorumlusu bulunmaktadır	O	O	O	O	O
d. Çevre yatırımları çevre mevzuatı ile uyum sağlanacak şekilde hayata geçirilmektedir	O	O	O	O	O
e. Çevre yatırımları gerçekleştirilirken AB uyum süreci kapsamındaki potansiyel düzenlemeler takip edilmektedir	O	O	O	O	O
f. Ulusal çevre mevzuatına uyum konusunda herhangi bir sıkıntı yaşanmamakta, tüm gereklilikler kolaylıkla yerine getirilmektedir. (*)	O	O	O	O	O

(*) Ulusal çevre mevzuatına uyum konusundaki mevcut sıkıntılarınız ve eksikliklerinizi (izinler, vb.) açıklayınız:

2. Firmanızın üretim hattında kullandığı süreç, sistem ve teknolojilerin çevre yönetimi ile ilişkisini en iyi tanımlayan seçeneği işaretleyiniz.

	Kesinlikle Doğru	Kısmen Doğru	Kısmen Yanlış	Kesinlikle Yanlış	Bilmiyorum
a. Üretim verimliliğini artıran ve ekonomik faydalar sağlayan çevre yatırımları planlanmakta/ uygulanmaktadır	O	O	O	O	O
b. Üretim sistem ve teknolojilerinin belirlenmesinde çevresel etkiler gözetilmektedir	O	O	O	O	O
c. Çevre dostu hammaddeler, teknolojiler, süreçler vb. yüksek maliyetleri nedeniyle tercih edilememektedir.	O	O	O	O	O
d. Üretim süreçlerinde kullanılan hammadde, yardımcı madde, kimyasal vb. seçimi yapılırken çevreye daha az zarar verenler tercih edilmektedir.	O	O	O	O	O

3. Firmanızın çevre yönetimi kapsamında gerçekleştirdiği ölçüm, uygulama ve izleme faaliyetlerini en iyi tanımlayan seçeneği işaretleyiniz.
(Herhangi bir ifadenin firmanızın üretim süreçleri ile ilgili olmadığını düşünüyorsanız karşılığını boş bırakınız)

	Kesinlikle Doğru	Kısmen Doğru	Kısmen Yanlış	Kesinlikle Yanlış	Bilmiyorum
a. Üretilen atıksu mevcut arıtma tesisinde arıtılarak deşarj edilmektedir	O	O	O	O	O
b. Atıksu ve katı atıkların geri kazanılması ve yeniden kullanılması için çalışmalar yürütülmektedir	O	O	O	O	O
c. Katı atıklar arıtılarak bertaraf edilmekte veya bertaraf edilmek amacıyla ilgili kuruluşlara aktarılmaktadır	O	O	O	O	O
d. Hammadde/ Su/ Enerji/ Atıksu/ Katı Atık/ Emisyon miktarları üretim süreçleri ve üniteler bazında takip edilmektedir	O	O	O	O	O
e. Üretilen ürün başına gerçekleşen Hammadde/ Su/ Enerji tüketimleri ve gerçekleşen Atıksu/ Katı Atık/ Emisyon miktarları hesaplanmakta ve izlenmektedir	O	O	O	O	O
f. Hammadde/ Su/ Enerji/ tüketimleri ve Atıksu/ Katı Atık/ Emisyonların azaltılması için iyileştirme çalışmaları yapılmaktadır	O	O	O	O	O
g. Tekstil sektöründe "Kirliliğin kaynağında önlenmesine yönelik" uluslararası düzeyde kabul görmüş, "en iyi uygulamalar" ve/veya "mevcut en iyi teknikler" takip edilmektedir	O	O	O	O	O

h. Çevre yönetimi bazında firma dışından destek alarak (danışmanlık, etüt, ölçüm vb.) gerçekleştirdiğiniz faaliyetleri kısaca açıklayınız:

4. Aşağıda listelenen konuların firmanızın üretim ve maliyetleri üzerindeki etkisini en iyi tanımlayan seçeneği işaretleyiniz.

	Çok Etkili	Kısmen Etkili	Etkisiz
a. Su Tüketimi	O	O	O
b. Enerji Tüketimi	O	O	O
c. Hammadde Tüketimi	O	O	O

d. Tehlikeli Atık Bertarafı	O	O	O
e. Katı Atık Bertarafı	O	O	O
f. Atıksu Arıtımı	O	O	O
g. Bacagazı Arıtımı	O	O	O

5. Firmanızın aşağıdaki alanlarda çevresel etkileri ve maliyetleri azaltmaya yönelik mevcut veya planlanmakta olduğu faaliyetleri belirtiniz.

	Mevcut/ Planlanan Faaliyetler, Alınan Önlemler
a. Su Kullanımı	
b. Enerji tüketimi	
c. Hammadde Tüketimi	
d. Kimyasal madde yönetimi	
e. Tehlikeli Atık yönetimi	
f. Katı Atık yönetimi	
g. Atıksu yönetimi	
h. Baca gazı Arıtımı	
i. Diğer	

6. Firmanızın piyasa koşulları, pazarlar ve müşterileri ile olan ilişkisinin çevresel performansa ve ilgili maliyetlere olan etkisini en iyi tanımlayan seçeneği işaretleyiniz.

	Kesinlikle Doğru	Kısmen Doğru	Kısmen Yanlış	Kesinlikle Yanlış	Bilmiyorum
a. Çevre dostu (ekolojik, organik vb.) tekstil ürünleri pazarının büyümesi, sektörde çevresel etkilerin azaltılması açısından önemli bir fırsattır	O	O	O	O	O
b. Modaya ve tüketim trendlerine bağlı olarak ürün tercihleri çevresel etkilerin çeşitlenmesine neden olmaktadır	O	O	O	O	O
c. Müşterilerden gelen talepler ve/veya uyulması zorunlu çevresel kriterler (Eko teks 100 vb.) firmanın üretim maliyetlerini artırmaktadır	O	O	O	O	O
d. Müşterilerden gelen talepler ve/veya uyulması zorunlu çevresel kriterler (Eko teks 100 vb.) firmanın çevresel etkilerini önemli oranda azaltmaktadır.	O	O	O	O	O

e. Firmanızda çevre yönetimi bazında önlem alınmasını gerektiren müşteri taleplerini ve bu taleplere karşı yaklaşımlarınızı açıklayınız.

f. Mevcut durumda ve gelecekte üretim süreçlerini etkileyeceğini düşündüğünüz çevreyle ilgili en önemli kısıtlama ve/veya müşteri taleplerini açıklayınız. (Üründe sınır getirilen kimyasal maddeler, vb.)

APPENDIX D

MICRO SCALE ANALYSIS: TEXTILE PRODUCER COMPANIES -THE LIST OF COMPANIES EVALUATED THROUGH SURVEY STUDY AND/OR SITE VISITS-

Table D.0.1. The list of companies evaluated through survey study and/or site visits

City	Name of the Firm	Field of Activity	Type of Communication
Tekirdağ	Sanko Textil İşletmeleri San. Ve Tic. A.Ş.	Knitting, Dyeing	Questionnaire + Site visit
	Şık Makas Giyim Sanayi ve Ticaret A.Ş.	Weaving, Dyeing, Garment	Questionnaire + Site visit
	Tamteks Tekstil Konfeksiyon İmalatı ve Ticareti A.Ş.	Dyeing, Garment	Questionnaire + Site visit
	Almodo Altunlar Tekstil San. Tic. A.Ş.	Knitting, Dyeing	Questionnaire
	Bony Tekstil İşletmeleri San. Tic. A.Ş.	Knitting, Dyeing	Questionnaire + Site visit
Kayseri	Orta Anadolu Mensucat A.Ş.	Spinning, Weaving, Dyeing	Questionnaire
	Boyteks A.Ş.	Knitting, Weaving, Dyeing	Questionnaire
Bursa	Özel Tekstil İnş. San. Ve Tic. Ltd. Şti.	Weaving, Dyeing	Questionnaire
	Akbaşlar Tekstil Enerji San. Ve Tic. A.Ş.	Spinning, Knitting, Weaving, Dyeing, Garment	Questionnaire + Site visit
Afyon	Roteks/Hera Tekstil San. Tic. Ltd. Şti.	Dyeing, Garment	Questionnaire + Site visit

Table D.0.1. The list of companies evaluated through survey study and/or site visits (Continued)

Adana	BOSSA Ticaret ve Sanayi İşletmeleri T.A.Ş.	Knitting, Weaving, Dyeing	Questionnaire
İstanbul	Dominant Tekstil A.Ş.	Weaving, Dyeing, Garment	Questionnaire
Adıyaman	Modapen Tekstil San. Tic. Ltd. Şti.	Garment	Questionnaire
	Çifçi Tekstil Mak. Pls. San. Ve Tic. Ltd. Şti.	Knitting	Questionnaire
	GTEKS Gerger Tekstil San. Ve Tic. A.Ş.	Knitting	Questionnaire
	Anmed Sağlık ürünleri Gıda İnş.Tur.Taş. Tekstil San.. Ltd. Şti.	Garment	Questionnaire
	Zersu Deniz Tekstil İnş. Tic. ve San. Ltd. Şti.	Garment	Questionnaire
	Anateks Anadolu Tekstil Fabrikaları A.Ş.	Spinning, Knitting, Dyeing	Questionnaire
	Ateşoğulları Tekstil San. Tic. Ltd. Şti.	Garment	Questionnaire
Malatya	Gültekinler Tekstil San. Tic. A.Ş.	Knitting	Questionnaire
	GAP Güneydoğu Tekstil San. Tic. A.Ş.	Spinning, Knitting, Dyeing, Garment	Questionnaire
	Cendere Tekstil San. Ve Tic.	Garment	Questionnaire
	Taşkın Tekstil Tarım Gıda Tur. Teks. İth. ve İhr.	Garment	Questionnaire
	Çel-Teks Tekstil Ürünleri vr Paz. Ltd. Şti.	Garment	Questionnaire
	Karagözlüler Tekstil San. Tic. A.Ş.	Spinning, Knitting, Dyeing, Finishing	Questionnaire
	Hazyan Tekstil Ürünleri ve Kimyevi Mad. San. Tic.	Knitting	Questionnaire
	İpek Muflon Konfeksiyon Ltd. Şti.	Garment	Questionnaire

Table D.0.1. The list of companies evaluated through survey study and/or site visits (Continued)

	Özçiçek Tekstil Ürünleri San. Ve Tic. Ltd. Şti.	Spinning, Knitting	Questionnaire
	Kübrateks Tekstil San. Ve Dış Tic. Ltd. Şti.	Garment	Questionnaire
	Akbulut Tekstil Tic. Ve San. A.Ş.	Garment	Questionnaire
	Rota Tekstil Turizm San. Ve Tic. A.Ş.	Spinning, Knitting, Dyeing	Questionnaire
	Önder Tekstil Ürünleri İmalat San. Tic. A.Ş.	Garment	Questionnaire
Kahramanmaraş	Modoma Paz. Tekstil İth. İhr.San.Tic. Ltd. Şti.	Garment	Questionnaire
	Arsan Dokuma Boya San. Tic. A.Ş.	Garment	Questionnaire
	İşkur A.Ş.	Spinning, Knitting, Weaving, Dyeing, Garment	Questionnaire
	İhya Tekstil Taşımacılık Gıda Tic. Ve San. Ltd. Şti.	Knitting, Dyeing	Questionnaire
	Bozkurt Konfeksiyon San. Tic. A.Ş.	Garment	Questionnaire
	Çabasan Tekstil Boya Hayv. Gıda Tarım Tur. Org. İnş. San. Tic. A.Ş.	Knitting, Dyeing	Questionnaire
	YKB Kent Triko Teks. San. Ltd. Şti.	Garment	Questionnaire
	Dok İplik Tekstil Sanayi Ve Ticaret A.Ş.	Spinning, Garment	Questionnaire
	Dokuboy Tekstil Sanayi Ve Ticaret A.Ş.	Weaving, Knitting, Dyeing	Questionnaire
	Elif İplik Tekstil Oto.İnş. Tic. Ve San. Ltd. Şti.	Spinning	Questionnaire
	Karpa Tekstil San. Tic. Ltd.	Garment	Questionnaire
	Marteks Maraş Tekstil Sanayi A.Ş.	Spinning	Questionnaire

Table D.0.1. The list of companies evaluated through survey study and/or site visits (Continued)

	Teknomelt Teknik Mesucat San. Tic. Ve Paz. Ltd. Şti.	Garment	Questionnaire
	Nezih İplik Dokuma Teksitl San. Tic. A.Ş.	Spinning, Garment	Questionnaire
	Sır Tekstil ve Gıda San. Tic. Ltd. Şti.	Weaving	Questionnaire
	KİPAŞ Denim İşletmeleri A.Ş.	Spinning, Weaving, Dyeing, Garment	Questionnaire + Site visit
	KİPAŞ İplik Pamuk San Tic Aş	Spinning, Dyeing	Questionnaire + Site visit
	KİPAŞ Mensucat A.Ş.	Spinning, Weaving, Dyeing, Garment	Questionnaire + Site visit
Gaziantep	Trikolüks Örme Sanayi Ltd. Şti.	Knitting, Garment	Questionnaire
	Erkan Tekstil San. A.Ş.	Spinning	Questionnaire
	Ahmet Aslansoy Pamuk Tekstil A.Ş.	Spinning	Questionnaire
	Gamel Tekstil Gıda San. Ve Tic. A.Ş.	Knitting	Questionnaire
	FRM TeKSTİL Enerji Sistemleri San. Ve Tic. Ltd. Şti.	Spinning	Questionnaire
	Gümüşoğlu Tekstil San. Tic. Ltd. Şti.	Spinning	Questionnaire
	Betaş Mensucat San. Tic. A.Ş.	Spinning, Dyeing	Questionnaire
	Beyza Triko San. Tic. Ltd. Şti.	Knitting	Questionnaire
	Oral Tekstil San. Tic .A.Ş.	Garment	Questionnaire
	Doğru Plastik San. Koll. Şti.	Garment	Questionnaire
	Ritaş Holding A.Ş.	Spinning	Questionnaire
	Sayın Tekstil San. Tic. A.Ş.	Weaving	Questionnaire

Table D.0.1. The list of companies evaluated through survey study and/or site visits (Continued)

	Yaren Halı Tekstil San. Ve Tic. Ltd. Şti.	Weaving	Questionnaire
	Karayılan Tekstil İnşaat Gıda Tarım Ltd. Şti.	Knitting, Weaving, Garment	Questionnaire
	Boyar Kimya San. Tic. A.Ş.	Spinning, Dyeing	Questionnaire + Site visit
	Boyaş-Boya Kimya San. Tic.Ltd. Şti.	Spinning, Dyeing	Questionnaire + Site visit
	Canan TeKSTİL San. Ve Tic. A.Ş.	Spinning, Dyeing	Questionnaire + Site visit
	Cemre Tekstil San. Tic. Ltd. Şti.	Spinning, Dyeing	Questionnaire + Site visit
	Çapan Tekstil-Boya San. Ve Tic. Ltd. Şti.	Dyeing (Yarn Dyeing)	Questionnaire + Site visit
	Gürteks İplik San. ve Tic. A.Ş.	Spinning, Dyeing	Questionnaire + Site visit
	Karan Tekstil San. Tic. A.Ş.	Spinning, Dyeing	Questionnaire + Site visit
	Kardeşler Konfeksiyon Boya ve Örme San. Tic. Ltd. Şti.	Knitting, Dyeing	Questionnaire + Site visit
	Kristal Tekstil San. Ve Tic. A.Ş.	Spinning, Dyeing	Questionnaire + Site visit
	Kutsal Boya Tekstil San. Tic. Ltd. Şti.	Knitting, Dyeing	Questionnaire + Site visit
	Melike Tekstil San. Ve Tic. A.Ş.	Spinning, Dyeing	Questionnaire + Site visit
	Sanko Havlu Tekstil İşletmeleri San. Ve Tic. A.Ş.	Weaving, Dyeing	Questionnaire + Site visit

APPENDIX E

QUESTIONNAIRE:
ENVIRONMENTAL MANAGEMENT IN RETAILER COMPANIES (MULTINATIONAL CORPORATIONS AND LARGE ENTERPRISES)

Firma Adı :

Adres :

Sektör/ Ürünler ve Üretim (Satış) Miktarı :

Çalışan Sayısı ve Dağılımı :

Bağlı olduğu Şirket/Kurum :

Kuruluş Yılı :

Firma Yetkilisi ve Görevi :

Tel:

Faks :

E-posta:

Alım yapılan ülkeler, alım miktar ve oranları :

Türkiye Üretim Tesisleri Bilgisi (Sayı, Faaliyet Alanı Üretim Miktarı, Çevre Performansı vb.) :

Tedarikçiler :

1. Firmanızın genel çevre politikaları ve bu politikaları etkileyen unsurlar (müşteriler, mevzuatlar vb.) hakkında bilgi verir misiniz? Çevre alanında gelecek için atmayı planladığınız adımlardan ve hedeflerinizden bahseder misiniz?

2. Firmanızda Çevre Yönetim Sistemi etkin olarak uygulanmakta mıdır? Uygulanmakta ise konu ile ilgili bir belgeniz/standardınız (ör: ISO 14001) bulunmakta mıdır? Üretim tesisleriniz ve/veya tedarikçilerinizin çevresel performanslarını müşteri veya paydaşlarınız ile nasıl ve hangi yollarla paylaşıyorsunuz?

3. Sektörde rakip firmaların faaliyetlerini de göz önüne aldığınızda çevresel sürdürülebilirlik ile ilgili konuların rekabet gücünüzü nasıl etkilediğini düşünüyorsunuz?

4. Firmanızda (uluslararası firma ise Türkiye ofisinizde) Kurumsal Sosyal Sorumluluk (KSS) ve/veya çevre yönetiminden sorumlu bir birim var mı? Varsa bu birimin görevi ve işleyişi hakkında bilgi verir misiniz?

5. Tedarikçilerinizin çevresel performansının değerlendirilmesi ve/veya geliştirilmesi ile ilgili politikalarınızı firmanızın diğer sosyal sorumluluk alanları (çalışma koşulları, sağlık ve güvenlik, vb.) ile karşılaştırmalı olarak değerlendiriniz. Tedarikçi firma ile alım anlaşması yapılırken firmanın çevre performansı hangi ağırlıkta dikkate alınıyor?

6. Tedarikçilerinizin çevresel performansını değerlendirirken/geliştirirken odaklandığınız alanları öncelik sırasına göre belirtiniz. Çevresel performansı değerlendirirken/ geliştirirken listelenen alanlar bazında dikkate aldığınız kriterler ve gereklilikler ile ilgili bilgi veriniz.
(en fazla öncelikli olan alana "1" sayısını yazınız)
(en az öncelikli olan alana "13" sayısını yazınız)

	Öncelik Sırası	Çevresel Performans Değerlendirme Kriterleri ve Gereklilikler
a. Su kullanımı		
b. Enerji tüketimi		
c. Karbon yönetimi		
d. Hammadde tüketimi		
e. Kimyasal madde yönetimi		

f. Tehlikeli atık yönetimi		
g. Katı atık yönetimi		
h. Atıksu yönetimi		
i. Baca gazı arıtımı		
j. Ulusal çevre mevzuatına uyum		
k. Uluslararası standartlara uyum (uluslar arası firmalar için)		
l. Ürün özellikleri (Organik, ekolojik vb.)		
j. Diğer (belirtiniz)		

7. Şirket merkezi (uluslararası firmalar için) ile Türkiye'de uygulanan çevresel performans kriterleri/gereklililkleri arasında farklılıklar bulunuyor mu? Cevabınız evet ise konu ile ilgili bilgi verir misiniz?

8. Tedarik zincirinin farklı aşamalarını (Tier 1, Tier 2 vb.) göz önüne aldığınızda çevresel performansın değerlendirilmesi/geliştirilmesi anlamında ne tür farklı kriterler/ gereklilikler üzerinde duruyorsunuz? Farklı aşamalarda hangi detayda denetlemeler ve düzenlemeler yapıyorsunuz? Hangi standartlara veya sertifikalara sahip olmalarını bekliyorsunuz? (ISO 14001, Eko Teks 100, kullanılan kimyasallar vb)

	Çevresel Performans Değerlendirme Kriterleri ve Gereklilikler
a. Tier 1 firmaları	
b. Tier 2 firmaları	

c. Tier 3 firmaları	
d. Diğer	

9. Tedarikçilerinizin çevresel performanslarını değerlendirirken/geliştirirken izlediğiniz prosedürlerden ve metodolojiden bahseder misiniz? Gerçekleştirilen uygunluk denetimleri firmanız tarafından mı yoksa bağımsız denetçiler tarafından mı yapılıyor? Bağımsız denetçiler tarafından yapılıyorsa ilgili denetçi firmalar hangileri?

10. Varsa denetimler esnasında kullandığınız denetleme formlarını bizimle paylaşabilir misiniz? (Ayrı dosya olarak)

11. Türkiye'deki üreticilerin çevre performanslarını değerlendirirken/geliştirirken yaşadığınız sıkıntılar (teknik, politik, idari vb.) nelerdir?

12. Uygunluk denetimlerinde özellikle çevre alanında tedarikçilerinizin en sık yaşadığı problemler/eksiklikler (mevzuat, teknik, vb.) nelerdir? Bu problemleri çözme konusunda firmalar ne tür önlemler almaktadırlar? Bu problemleri çözme konusunda siz ne tür önlemler almaktasınız?

13. Tedarikçilerinize çevre alanında uyguladığınız yaptırımların sizinle olan ilişkisi dışında firmanın rekabet gücüne nasıl etki ettiğini düşünüyorsunuz? Çevre alanında alınmasını gerekli gördüğünüz önlemlerin firmaya maliyet getirdiğini düşünüyor musunuz? Çevresel sürdürülebilirliği artırırken rekabet avantajı getirebilecek uygulamaların olabileceğini düşünüyor musunuz?

14. Çevresel performansları göz önüne alındığında tedarikçi ve alt tedarikçi bazında farklı alanlarda faaliyet gösteren firmalar arasından iyi uygulama örneği olarak öne çıkan firmalarınız hangileridir? Bu firmalar ile ilgili deneyimlerinizi bizimle paylaşır mısınız? (Ayrı dosya olarak)

APPENDIX F

MESO SCALE ANALYSIS: MARKETS AND CUSTOMER RELATIONS -CONTACT DETAILS OF SURVEY RESPONDENTS FROM RETAILERS-

Below listed retailers (multinational corporations and large enterprises) were reached through questionnaires and/or telephone interviews in order to conduct the survey study. The data was complied between October 3rd and December 23rd of 2011.

Hennes and Mauritz AB (H&M)
Özgür Aksoy - *H&M Puls Trading Far East Limited Liaison Office, CSR Programme Developer*

Address : Şişli Ayazağa Büyükdere Caddesi Üçyol Mevkii
Noramin Iş Merkezi No: 237 Kat: 2 Daire: 201 Maslak
İstanbul/Turkey
Phone : +90 212 329 04 00 (ext 429)
Fax : +90 212 276 24 30
E-mail : ozgur.aksoy@hm.com

Marks and Spencer plc
Mehmet Guner - *Turkey Region Plan A, Coordinator*

Address : Dış Ticaret Merkezi A-3 Blok Kat:11 Yeşilköy
İstanbul/Turkey
Phone : +90 212 468 11 27
Fax : +90 212 465 09 73
E-mail : mehmet.guner@marks-and-spencer.com

Nike Inc.
Caner Soytaş - *Sustainable Manufacturing & Sourcing, Europe, Middle East and Africa, Manager*

Address : Ahievran Caddesi Polaris Plaza No:21 Kat:21 Maslak
İstanbul/Turkey
Phone : +90 212 365 01 62
Fax : +90 212 365 01 02
E-mail : caner.soytas@nike.com

Li & Fung Limited
Muazzez Siahpoush Kolyaei - *Vendor Complianc, Senior Manager*

Address : AHL Serbest Bölgesi Plaza B Girişi Kat:5 Yeşilköy
İstanbul/Turkey
Phone : +90 212 496 75 17
Fax : +90 212 496 78 99
E-mail : muazzezsiahpoush@lifung.com.tr

Lee Cooper (Kipaş Group)
Musa Karataş - *Sales Representative*

Address : Gaziantep Karayolu Üzeri 7.km Erkenez Mevkii
Kahramanmaraş/Turkey
Phone : +90 344 236 38 00
Fax : +90 344 236 33 07
E-mail : mkaratas@kimas.com.tr

LC Waikiki (Tema Group)
Fatma Ak - *Domestic Sourcing Manager*

Address : Evren Mah. Gülbahar Caddesi Şehit Cengiz Karcıoğlu Sok. No:6 Bağcılar
İstanbul/Turkey
Phone : +90 212 657 55 55
Fax : +90 212 657 85 30
E-mail : fatma.ak@lcwaikiki.com

Cross Jeans (Şık Makas Giyim San. A.Ş.)
Nurdan Orday - *Management Consultant*

Address : Çorlu-Çerkezköy Yolu 4. km Yulaflı Köyü Mevkii
Tekirdağ/Turkey
Phone : +90 212 550 29 29
Fax : +90 212 550 29 33
E-mail : nurdano@crossjeans.com

Sunset (Günkar Tekstil Turizm İnş. San. ve Tic. Ltd. Şti)
Derya Kavarna - *Adıyaman Production Facility, General Manager*

Address : Organize Sanayi Bölgesi Petrol Mahallesi 5.Km
Adıyaman/Turkey
Phone : +90 416 227 26 60 / 118
Fax : +90 416 227 26 64
E-mail : dkavarna@gunkar.net

Hey Tekstil San. ve Tic. A.Ş.
Burak Küçükerol - *Deputy General Manager*

Address : Mahmutbey Mah. Halkalı Cad. Atlas Sok. No:4 Mahmutbey
İstanbul/Turkey
Phone : +90 212 468 79 79 (ext 7925)
Fax : +90 212 468 79 80
E-mail : burak.kucukerol@heytekstil.com

Yeşim Tekstil San. ve Tic. A.Ş.
Dilek Cesur - *Coorporate Communication Manager*

Address : Ankara Yolu Üzeri 11 km. Gürsu Kavşağı 16580
Bursa/Turkey
Phone : +90 224 280 86 00 (ext 2412)
Fax : +90 224 331 72 22
E-mail : dilek.cesur@yesim.com

APPENDIX G

QUESTIONNAIRE:
INSTITUTIONAL SET-UP AND ENVIRONMENTAL GOVERNANCE REGARDING THE ENVIRONMENTAL ISSUES IN TEXTILE INDUSTRY

Kurum Adı	:		
Adres	:		
Kurum Statüsü	:	Kuruluş Yılı:	
Faaliyet Alanı ve İşleyiş	:		
Örgüt / Üyelik Yapısı	:		
Kurum Yetkilisi ve Görevi	:	Tel :	
Faks	:	E-posta:	

1. Genel olarak sanayi firmalarının çevre alanındaki faaliyetlerine yönelik ne tür destekler sunuyorsunuz? (finansman, farkındalık yaratma, kapasite geliştirme, danışmanlık, eğitim, sertifikasyon, vb.)

2. Sunduğunuz destekleri bölge, sektör, konu, firma ölçeği vb. bazında ayırıyor veya önceliklendiriyor musunuz? Cevabınız evet ise bu ayrımı/önceliklendirmeyi hangi kriterleri baz alarak gerçekleştiriyorsunuz? Mevcut destekleriniz kapsamında belirlediğiniz öncelikler nelerdir?

3. Tekstil ve hazır giyim sektöründe faaliyet gösteren firmaların bu tür desteklerden yararlanma oranı nedir?

4. Özel olarak tekstil ve hazır giyim sektöründe faaliyet gösteren firmaların çevre alanındaki faaliyetlerine yönelik bir destek sunuyor musunuz? (finansman, farkındalık yaratma, kapasite geliştirme, danışmanlık, eğitim, vb.)

5. Söz konusu destekler için uygulanan şartlar ve firmaların bu desteklere ulaşım olanakları nelerdir? Firmaların bu desteklere ulaşımında karşılaştıkları herhangi bir engel söz konusu mudur?

6. Tekstil sektöründe faaliyet gösteren firmalara sağlanan destekler ne şekilde duyurulmakta ve talep yaratma yönünde ne tür yöntemler kullanılmaktadır? Destek olanakları ve şartları firmalara nasıl açıklanmakta ve duyurulmaktadır?

7. Kurumunuz destek, duyuru ve yaygınlaştırma aşamalarında farklı kurumlarla işbirlikleri yapmakta mıdır?

8. Bugüne kadar bu desteklerden yararlanan tekstil firmalarının genel profili ve büyüklüğü nedir? Söz konusu firmalar tekstil sektörünün hangi üretim alanında ve aşamalarında (tier 1, 2, 3) faaliyet göstermekte, genelde hangi bölgelerde yoğunlaşmaktadırlar?

9. Tekstil ve hazır giyim sektöründe faaliyet gösteren firmaların çevresel performanslarının ne düzeyde olduğunu düşünüyorsunuz?

10. Tekstil ve hazır giyim sektörünün üretim aşamalarının hangilerinde en fazla çevresel sorununun olduğunu düşünüyorsunuz?

11. Tekstil ve hazır giyim sektöründe faaliyet gösteren firmaların çevresel performans açısından güçlü ve zayıf yönleri nelerdir?

12. Tekstil ve hazır giyim sektöründe faaliyet gösteren firmalar için çevresel açıdan ne tür tehdit ve fırsatlar söz konusudur?

13. Tekstil ve hazır giyim sektöründe faaliyet gösteren firmaların çevre mevzuatına uyum açısından en belirgin sıkıntıları nelerdir? Bu sıkıntıların temel nedenleri nelerdir?

14. Tekstil ve hazır giyim sektöründe faaliyet gösteren firmaların ne tür desteklere ihtiyaç duyduklarını düşünüyorsunuz? Siz bu ihtiyaçların hangilerine cevap verebiliyorsunuz? Gelecekte vermeyi planladığınız başka destekler var mıdır?

15. Tekstil ve hazır giyim sektörünün bugün ya da yakın gelecekte ihtiyaç duyduğu/ duyacağı ancak siz ya da diğer kurumlar tarafından sağlanmayan bir destek türü ya da alanı olduğunu düşünüyor musunuz?

16. Tekstil ve hazır giyim sektöründeki firmalara çevre alanında hizmet verebilmek ve destek sağlayabilmek için kurumunuzun kapasitesi yeterli midir? Bu açıdan kurumunuzun geliştirilmesi gereken yönleri (teknik bilgi, finansman, eğitim, işbirliği, vb.) nelerdir?

17. Tekstil ve hazır giyim ürünlerinin ihracatında yaşandığını bildiğiniz engeller ve sorunlar söz konusu mudur? Kurumunuz bu konuda önlem almakta ya da engellerin bertarafına yönelik herhangi bir katkı sağlamakta mıdır?

APPENDIX H

MACRO SCALE ANALYSIS: INSTITUTIONAL SET-UP AND ENVIRONMENTAL GOVERNANCE -CONTACT DETAILS OF SURVEY RESPONDENTS FROM INSTITUTIONS-

VISITED INSTITUTIONS

Below listed institutions were visited to conduct personal interviews with relevant experts/ executives between September 6th and October 19th of 2011.

Ministry of Environment and Urban Development
Zerrin Leblebici – *Water and Soil Management Department, Expert*
Onur Orhan – *Water and Soil Management Department, Expert*

Address : Söğütözü Cad. No:14/E Yenimahalle
Ankara/Turkey
Phone : +90 312 207 52 06
Fax : +90 312 207 65 35
E-mail : zleblebici@cob.gov.tr

Ministry of Science, Industry and Technology
Selin Engin - *Directorate General for Efficiency, Expert*
Tuğba Altınışık - *Directorate General for Industry, Expert*
Seda Çotuk - *Directorate General for Industry, Textile, Apparel and Leather Department, Expert*

Address : Eskişehir Yolu 7. Km No:154 06100
Ankara/Turkey
Phone : +90 312 201 56 10
Fax : +90 312 219 64 98
E-mail : tugba.altinisik@sanayi.gov.tr

Ministry of Economy
Mustafa Ali Yurdupak - *Department of Textile and Apparel Products, Foreign Trade Specialist*
Esin Açıkgöz - *Department of Textile and Apparel Products, Foreign Trade Specialist*
Hıfzı Oğuz Korkmaz - *Department of Textile and Apparel Products, Asst. Foreign Trade Specialist*

Address : İnönü Bulvarı No:36, 06510 Emek
Ankara/Turkey
Phone : +90 312 204 77 50
Fax : +90 312 212 88 81
E-mail : okorkmaz@ekonomi.gov.tr

Small and Medium Enterprises Development Organization (KOSGEB)
Aynur Odaman - EU and Foreign Relations Department, Director
Abdullah Karaosmanoğlu - EU and Foreign Relations Department, SME Expert
Mehmet Görkem Gürbüz - EU and Foreign Relations Department, SME Expert

Address : Abdülhak Hamit Cad. No:866 06470 Altmışevler Mamak
Ankara/Turkey
Phone : +90 312 595 28 00
Fax : +90 312 368 07 15
E-mail : gorkem.gurbuz@kosgeb.gov.tr

Union of Turkish Chambers of Commerce and Industry (TOBB)
İlke Tanlay – *Environment Directorate, Expert*

Address : Dumlupınar Bulvarı No:252 (Eskişehir Yolu 9. Km.)
Ankara/Turkey
Phone : +90 312 219 65 00
Fax : +90 312 218 23 99
E-mail : ilketanlay@gmail.com

İzmir Development Agency
Filiz Morova İneler - *Planning Programming and Coordination Unit, Expert*

Address : Şehit Fethi Bey Caddesi No:49/1 Birlik Plaza Kat:3 35210 Gümrük
İzmir/Turkey
Phone : +90 232 489 81 81 (ext 117)
Fax : +90 232 489 85 05
E-mail : filiz.morova@izka.org.tr

İpekyolu Development Agency
Vakkas Koca - Expert

Address : İncilipınar Mahallesi Muammer Aksoy Bulvarı
Vakıflar Güven İş Merkezi Kat: 2-3 Şehitkamil
Gaziantep/Turkey
Phone : +90 243 231 07 01
Fax : +90 342 231 07 03
E-mail : vakkas.koca@ika.org.tr

Gaziantep Chamber of Commerce
Fahri Tabur - Deputy Secretary General

Address : İncilipınar Mahallesi 16 nolu Sokak Şehitkamil
Gaziantep/Turkey
Phone : +90 342 220 30 30 (ext 120)
Fax : +90 342 231 10 41
E-mail : fahritabur@gto.org.tr

Gaziantep Chamber of Industry
Veysel Çelebi – Industry Department, Manager

Address : İstasyon Cad. No:2 Kat:3 Şehitkamil
Gaziantep/Turkey
Phone : +90 342 221 09 00
Fax : +90 230 16 82
E-mail : veysel@gso.org.tr

Technology Development Foundation of Turkey (TTGV)
Ferda Ulutaş - *Environmental Projects Group, Coordinator*

Address : Cyberpark Cyberplaza B-Blok Kat:5-6 Bilkent
Ankara/Çankaya
Phone : +90 312 265 02 72
Fax : +90 312 265 02 62
E-mail : fulutas@ttgv.org.tr

INSTITUTIONS RESPONDED VIA FAX/ E-MAIL MESSAGES

Below listed institutions were responded to the survey via fax/e-mail communications between September 6th and October 31th of 2011.

İstanbul Textile and Apparel Exporters' Associations (ITKIB)
Emine Açılan - *R&D Department, Director*

Address : Çobançeşme Mevkii Sanayi Caddesi, Diş Ticaret Kompleksi B Blok Yenibosna
İstanbul/Turkey
Phone : +90 212 454 03 10
Fax : +90 212 454 04 23
E-mail : eminea@itkib.org.tr

General Directorate of Electrical Power Resources Survey and Development Administration (EİE)
Erdal Çalıkoğlu - Deputy General Manager

Address : Eskişehir Yolu 7. Km
Ankara/Turkey
Phone : +90 312 295 50 00
Fax : +90 312 295 50 05
E-mail : elektriketut@eie.gov.tr

Bursa Demirtaş Organized Industrial Zone
A. Merve Kocabaş Yurtkuran - *Environment Group, Chief*

Address : DOSAB Bölge Müdürlüğü Gül Sokak No: 11 Osmangazi
Bursa/Turkey
Phone : +90 224 261 00 40
Fax : +90 224 261 00 43
E-mail : myurtkuran@dosab.org.tr

Eskon Enerji Verimliliği Danışmanlığı Per. Kont. Ve Müh. Hizm. San. Tic. Ltd. Şti. (Energy Service Company)
Tolga Erbil - *Project Coordinator*

Address : Mertoğlu İş Merkezi 1714 Sok . No: 17 Kat:2/102 Karşıyaka
Karşıyaka/İzmir
Phone : +90 232 381 98 23
Fax : +90 232 381 98 23
E-mail : t.erbil@eskonevd.com

UENCO Uluslararası Enerji ve Çevre Teknolojileri Müh. ve Müş. A.Ş (Environmental Consultancy Company)
Ülkü Özeren - *Act. General Manager*

Address : Osmangazi Mah. Battalgazi Cad. No: 19/8 P.K: 34887 Sancaktepe
İstanbul/Turkey
Phone : +90 216 311 90 92
Fax : +90 216 561 64 04
E-mail : ulku.ozeren@uenco.com.tr

EKOTEST Çevre Danışmanlık Ölçüm Hizmetleri Ltd. Şti. (Environmental Consultancy Company)
Uğur Kocalmış - *General Manager*

Address : Büklüm Sokak. 23/1-11 Kavaklıdere
Ankara/Turkey
Phone : +90 0 312 419 22 82
Fax : +90 0 312 419 22 84
E-mail : omer.kedici@ekotest.com.tr

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name:	ALKAYA, Emrah
Nationality:	Republic of Turkey (T.C.)
Date, Place of Birth:	March 1982, Ankara
Marital Status:	Married
Phone:	+90 536 326 20 84
Email:	ealkaya@ttgv.org.tr

EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	Middle East Technical University Environmental Engineering	2008
BS	Middle East Technical University Environmental Engineering	2006
High School	Ankara Anatolian High School (German)	2000

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2008–to date	Technology Development Foundation of Turkey (TTGV)	Expert
2008	TEMPO Müh. Müş. Ltd. Şti.,	Env. Engineer
2006–2008	Middle East Technical University Department of Env. Engineering	Researcher/ Project Assistant

CONTRIBUTED PROJECTS/PROGRAMS

1. 2013–to date: *Fund Manager*, "Green Future Accelerator Fund", an Accelerator Fund for Cleantech Start-up Companies for promoting Green Entrepreneurship in Turkey, managed by TTGV.

2. 2010–to date: *Project Expert,* "Industrial Energy Efficiency in Turkey - GF/TUR/08/004", supported by Global Environmental Facility (GEF), UNDP and UNIDO as executing agencies, TTGV, EIE, KOSGEB, MOSIT and TSE as local counterparts.

3. 2009–to date: *Project Expert,* "BSN Anatolia - Business Support Network of Anatolia" Services in support of business and innovation, supported by the EU CIP Framework Programme - Enterprise Europe Network (EEN), TTGV, KOSGEB, METUTECH, KSO, KTO, ETSO.

4. 2008–to date: *Project Expert,* "Environmental Project Supports" a financial support program for private sector projects in the field of environmental technologies and energy efficiency managed by TTGV.

5. 2012–2013: *Project Manager* "Better Environment - Better Business (BEBB)" Specific Action: Services for SMEs in the field of environment through the Enterprise Europe Network, supported by the EU Competitiveness and Innovation Framework Programme, EIV, ECCI, IHM, TTGV, KCCIC, BIC, LICC.

6. 2013: *Project Expert,* "Public innovation partnership for better policies and instruments in support of eco-innovation (ECOPOL)" as a scale-up partner (subcontractor), supported by the EU Competitiveness and Innovation

Framework Program, PRO INNO Europe initiative LADEC, ADI, LEV, PTJ, MAROP, SP, APA.

7. 2013: *Independent Project Auditor*, "Renewable Energy and Environmental Technologies Financial Support (Grant) Programme" targeting private sector and not-for-profit organizations, launched by İzmir Development Agency.

8. 2011–2013: *Project Expert*, "Industrial Symbiosis Project in Iskenderun Bay – Implementation Phase" Supported by BTC Crude Oil Pipeline Company Regional Development Initiative, BTC, ISL, TTGV.

9. 2011–2012: *Project Expert*, "Dissemination of Eco-efficiency (Cleaner Production) Applications in İzmir" supported by İzmir Development Agency (İZKA), TTGV and EBSO.

10. 2010–2012: *Project Expert*, "Services in the Field of Environmental Management and Cleaner Production in Textile Industry", TTGV as the subcontractor within the scope of "Harnessing sustainable linkages for SMEs in Turkish textile sector" – a joint project between UNDP, ILO and UNIDO.

11. 2010–2011: *Project Expert*, "Integration of the Assets and Challenges of Turkey within CP/RACs Strategy to Promote Green Entrepreneurship in the Mediterranean Countries" supported by Regional Activity Centre for Cleaner Production (CP/RAC), Spain, TTGV.

12. 2008–2011: *Project Expert*, "United Nations Industrial Development Organization-UNIDO Eco-efficiency (Cleaner Production) program", the sub-project of "MDG-F 1680: Enhancing the Capacity of Turkey to Adapt to Climate Change" Joint UN Project, TTGV, METU, UNIDO.

13. 2009–2010: *Project Expert,* "Identification of Framework Conditions and R&D Requirements for Dissemination of Cleaner Production Practices in Turkey," TTGV, Ministry of Environment and Forestry, METU.

14. 2008–2010: *Project Associate,* "CSOContribution2SCP - Partnering to Enhance Civil Society Organisations' Contribution to Research in Sustainable Consumption & Production" EU FP7 Project, CSCP, ANPED, SEI, SERI, WWF-UK, TTGV, ECODES, GREEN LIBERTY, MAMA-86.

15. 2006–2008: *Researcher,* "Organic Acid Production from Municipal and Agro-Industrial Wastes", The Scientific and Technical Research Council of Turkey, ÇAYDAG-104I127, METU, Ankara.

16. 2007: *Researcher,* "Biogas Production and the Natural Systems of Wastewater Treatment at the Community Scale", A Consulting Work to Baku-Tbilisi-Ceyhan Pipeline Company, METU, Ankara.

17. 2005–2006: *Researcher,* "Utilization of Dairy Cattle Manure in Conventional Anaerobic Reactors for Sustainable Exploitation via Biogas Production", A Consulting Work to YABATAŞ İnş. Müh. Dan. San. ve Tic. Ltd. Şti., METU.

INTERNATIONAL PEER-REVIEWED ARTICLES (SCI/SCI EXPANDED)

1. Alkaya E. and Demirer G.N. 2013 "Greening of production in metal processing industry through process modifications and improved management practices", Resources, Conservation and Recycling, 77, 89–96.

2. Alkaya E. and Demirer G.N. 2013 "Sustainable textile production: a case study from a woven fabric manufacturing mill in Turkey", Journal of Cleaner Production, in Press.

3. Ulutas, F., Alkaya, E., Bogurcu, M., and Demirer G.N. 2012. "Determination of the framework conditions and research-development needs for the dissemination of cleaner (sustainable) production applications in Turkey", International Journal of Sustainable Development & World Ecology, 19(3), 203-209.

4. Alkaya E. and Demirer G.N. 2011. "Anaerobic acidification of sugar-beet processing wastes: Effect of operational parameters", Biomass and Bioenergy, 35(1), 32-39.

5. Alkaya E. and Demirer G.N. 2011. "Anaerobic mesophilic co-digestion of sugar-beet processing wastewater and beet-pulp in batch reactors", Renewable Energy, 3(36), 971-975.

6. Alkaya E. and Demirer G.N. 2010. "Anaerobic-fed and sequencing-batch treatment of sugar-beet processing wastes: A comparative study", Water Environment Research, 83(3), 247-255.

7. Alkaya E., Erguder T.H. and Demirer G.N. 2010. "Effect of operational parameters on anaerobic co-digestion of dairy cattle manure and agricultural residues: A case study for the Kahramanmaraş region in Turkey", Engineering in Life Sciences, 10(6), 552–559.

8. Alkaya E., Kaptan S., Özkan L., Uludağ-Demirer S. and Demirer G.N.. 2009. "Recovery of acids from anaerobic fermentation broth by liquid-liquid extraction", Chemosphere, 77, 1137–1142.

9. Alkaya E. and Demirer G.N. "Improving resource efficiency in surface coating/painting industry: practical experiences from a small-sized enterprise" Clean Technologies and Environmental Policy, under peer-review process.

10. Alkaya E. and Demirer G.N. "Reducing water and energy consumption in chemical industry by sustainable production approach: A pilot study for polyethylene terephthalate (PET) production" Journal of Water and Climate Change, under peer-review process.

11. Alkaya E., Böğürcü M., Ulutaş F., and Demirer G.N. "Adaptation to Climate Change in Industry: Improving Resource Efficiency through Sustainable Production Applications", Water Environment Research, under peer-review process.

12. Alkaya E. and Demirer G.N. "Water recycling and reuse in soft drink/beverage industry: A case study for sustainable industrial water management in Turkey", Water and Environment Journal, under peer-review process.

13. Alkaya E. and Demirer G.N. "Minimization and valorization of seafood processing wastes by onsite recycling and reuse" Journal of Material Cycles and Waste Management, under peer-review process.

14. Alkaya E. and Demirer G.N. "Sectoral assessment of the Turkish textile industry for the diffusion of sustainable production approach" Journal of Environmental Science and Management, under peer-review process.

OTHER INTERNATIONAL PEER-REVIEWED ARTICLES (NON-SCI)

1. Ulutas, F., Alkaya, E., Bogurcu, M., & Demirer, G. N. 2012. "The national capacity assessment on cleaner (sustainable) production in Turkey" Sustainable Cities and Society, 5(0), 30–36. doi:10.1016/j.scs.2012.05.006

2. Ulutas, F., Alkaya, E., Bogurcu, M., and Demirer G.N. 2011. "A comparative analysis of Turkish and European Union environmental legislation regarding cleaner (sustainable) production concept" International Journal of Environment and Sustainable Development, 10(3), 246-266.

INTERNATIONAL CONFERENCE PROCEEDINGS/PRESENTATIONS

1. Alkaya E, Böğürcü M, Ulutaş F, Demirer G N, "Adaptation to Climate Change in Industry: Demonstration Projects for Water Saving Through Eco-Efficiency Approach" 15th The European Round Table on Sustainable Consumption and Production (ERSCP), 2 - 4 May 2012, Bregenz, Austria.

2. Böğürcü M., Alkaya E., Ulutaş F., Demirer G.N.2012 "Capacity Building and Dissemination of Cleaner (Sustainable) Production on a Regional Basis" The 10th Global Conference on Sustainable Manufacturing, 31 October-02 November 2012, İstanbul, Turkey.

3. Alkaya E., Böğürcü M., Ulutaş F. "Corporate Social Responsibility and Greening of Supply Chain in Textile Industry in Turkey", The 10th Global Conference on Sustainable Manufacturing, 31 October-02 November 2012, İstanbul, Turkey.

4. Alkaya E, Ulutaş F "The State of the Art of Green Entrepreneurship in Turkey", The 10th Global Conference on Sustainable Manufacturing, 31 October-02 November 2012, İstanbul, Turkey.

5. Alkaya E, Böğürcü M, Ulutaş F, Demirer G N, "A New approach to industrial waste recycling in Turkey: Industrial symbiosis in Iskenderun Bay" International Conference on Recycling and Reuse 4-6 June 2012 – İstanbul, Turkey.

6. Ulutaş F., Alkaya E., Böğürcü M., Demirer G.N. "Assessment of existing national capacity on cleaner (sustainable) production in Turkey", 3rd International Conference on Eco-efficiency 9-11 June 2010, Egmond aan zee, Netherlands.

7. Böğürcü M., Ulutaş F., Alkaya E., Demirer G.N. "Sectoral priority analysis for cleaner (sustainable) production applications in Turkey", 3rd International Conference on Eco-efficiency 9-11 June 2010, Egmond aan zee, Netherlands.

8. Ulutaş F., Alkaya E., Demirer G.N. "Adaptation to climate change through eco-efficiency: opportunities and challenges for turkey", 3rd International Conference on Eco-efficiency 9-11 June 2010, Egmond aan zee, Netherlands.

9. Alkaya E., Erguder T.H. and Demirer G.N. 2009 "Anaerobic semi-continuous co-digestion of dairy cattle manure and agricultural residues: Effect of operational parameters," Internationale Wissenschaftstagung Biogas Science 2009 Band:1 121–136.

10. Alkaya E., Kaptan S., Özkan L., Uludağ-Demirer S. and Demirer G.N. "Recovery of volatile fatty acids from anaerobic acidification broth by liquid-

liquid extraction" The 9th Annual Conference On Renewable Energy From Organics Recycling, 19-21 October 2009 Minneapolis-Minnesota, USA.

SELECTED NATIONAL PUBLICATIONS

1. Ulutaş, F., Alkaya, E., Böğürcü, M., Dündar, A.K., Işıtan, K., Ersin, S., İneler F.M., Gürsoy, S., Mangır, K., Demirer, G.N. (2012), "Strategy report on the dissemination of eco-efficiency (cleaner production) applications in İzmir", İzmir Development Agency publications, ISBN: 978-605-5826-08-6, İzmir.

2. Böğürcü, M., Alkaya, E., Ulutaş, F., Demirer G.N. "Integration/dissemination of cleaner (sustainable) production on regional context and establishing a basis for activities", 13th Industrial Pollution Control Symphosium (EKK-2012), 17-19 October 2012, İstanbul Technical University, İstanbul.

3. Alkaya, E., Böğürcü, M., Ulutaş, F. (2012) "Life cycle assessment and its applications for building heat insulation materials" Environment, Science & Technology, Chamber of Environmental Engineers, 3(4), 261-274.

4. Alkaya, E., Böğürcü, M., Ulutaş, F., Demirer G.N. (2012) "Adaptation to climate change in industry: Pilot projects for water savings through eco-efficiency approach" Water and Environmental Technologies, 45.

5. Alkaya, E., Böğürcü, M., Dündar, A.K., Işıtan, K., Ulutaş, F., Demirer G.N. (2011), "Eco-efficiency (cleaner production) in industry: a guide for methods and applications" prepared within the scope of United Nations Industrial Development Organization - UNIDO Eco-efficiency Program, TTGV Publications, Ankara.

6. Alkaya, E., Böğürcü, M., Ulutaş, F., Demirer G.N. “Adaptation to climate change in industry: Pilot projects for water savings through eco-efficiency approach" 9th National Environmental Engineering Congress, 5-8 October 2011, Samsun.

7. Alkaya, E. “Cleaner Production and Eco-efficiency”, Waste Resources Session, Environment Summit, İzmir International Fair, 16 September 2011, İzmir.

8. Alkaya, E., Altay T.A., Ata, A.B., Çakar, S.Ö., Durtaş, P. (2011) “Assessment of technologies for the production of value-added bioproducts from agricultural wastes in Turkey”, as part of Sectoral Analyses Studies-1, TTGV High Technology Projects Supports Report.

9. Alkaya, E., Böğürcü, M., Ulutaş, F. “Life cycle assessment and its applications for building heat insulation materials” 9th National Environmental Engineering Congress, 5-8 October 2011, Samsun.

10. Alkaya, E., Bükülmez, E. Dündar, A.K. (2011) “Assessment of technologies for the adaptation of climate change in Turkey”, as part of Sectoral Analyses Studies-2, TTGV High Technology Projects Supports Report.

11. Alkaya, E., Böğürcü, M., Ulutaş, F., Demirer G.N. “Adaptation to climate change in industry: Pilot projects for water savings through eco-efficiency approach" International Sustainable Water and Wastewater Management Symposium (USAYS). 26-28 October 2010, Konya.

12. Alkaya E. “Valorization of cotton fiber production by-products/residues: Current applications and technological advances”, 2nd National Solid Waste Congress (UKAY), Mersin University, 18–20 October 2010, Mersin, Turkey.

13. Alkaya, E. “Current energy situation in the World and in Turkey”, Seminar on Industrial Energy Efficiency and Finance, Small And Medium Enterprises Development Organization (KOSGEB) Kahramanmaraş Chamber of Trade and Industry (KMTSO), 21 June 2010, Kahramanmaraş.

14. Alkaya E. (2008) "Biorefining of sugar-beet processing wastes through anaerobic biotechnology: Waste stabilization and bioproduct formation)”, A Master of Science Thesis, Middle East Technical Universtiy (METU), Ankara.

15. Alkaya E. and Demirer G.N. “Volatile fatty acid production through anaerobic acidification of sugar-beet processing wastes”, National Symposium on Environmental Issues, Kocaeli University, 14–17 May 2008, Kocaeli.

16. Özkan L., Alkaya E., and Demirer G.N., 2008. “Recycle/reuse of water and wastewater” Water and Health, Community and Physician, 23(1), 69-74.

17. Alkaya E., Erguder T.H. and Demirer G.N. "Cleaner production opportunities in the sugar manufacturing industry", Wastewater Seminar on the Problems in Sugar Factories, General Directorate of Turkish Sugar Factories and the Ministry of Environment and Forestry, 12 Dec 2006, Ankara, Turkey.

BOOKS/BOOK CHAPTERS

1. Alkaya E., Böğürcü M., Ulutaş F. and Demirer G.N., 2011. “Cleaner (Sustainable) Production in Textile Wet Processing”, in “Non-Conventional Textile Waste Water Treatment”, Editor: A. El Nemr, Nova Science Publishers Inc., New York, USA.