AN ENVIRONMENTAL STRATEGY FOR MEDIUM SCALED SYNTHETIC LEATHER MANUFACTURING FACILITY

by

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AN ENVIRONMENTAL STRATEGY FOR MEDIUM SCALED SYNTHETIC LEATHER MANUFACTURING FACILITY

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Dedicated to my family…

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ABSTRACT

Environmental friendly production through industries has become one of the most favorable necessities in recent years due to gradually increasing environmental concerns. It is a fact that the old manufacturing facilities, which are the initial step of environmental pollution, are lack of environmental technologies. By taking this into consideration, in this study, the effects of a medium scale synthetic leather facility on the environment were evaluated before and after the application of the proposed strategy to show the improvements in water consumption, waste generation, energy consumption, and the emissions.

The results of the study showed that the implementations of the proposed strategy minimized the effects of the focused synthetic leather facility on the environment.

In the facility, the dye preparation unit was separated from the process line to prevent of extra water consumption and indoor pollution. In line with energy audits the water leakage points were determined and the facility's conventional taps were replaced with the photocell basin taps to reduce the water consumption for the domestic usage. All of these improvements in the water consumption systems led to a 38,5 % reduction of in the water consumption rates.

In order to minimize energy consumption, energy audits were started by the facility. The audits determined energy consumption and energy loss points and captured a picture of the operations which caused waste in energy. The major energy consuming equipment and their energy efficiencies were identified. Lightning systems were supported by multiple glazing windows and mercury containing fluorescent lighting replaced with energy saving LED lighting, or high-pressure sodium or ceramic metal bulb lighting. All of these energy audits and the improvements enabled a reduction from 812.574kwh/year to 569.963kwh/year and led to a 30% reduction in the energy consumption rates.

The synthetic leather facility had no waste management plan and all types of wastes were collected together. In order to separate collection of the hazardous wastes and non-hazardous wastes, waste management plan and a separate collection were put into practice

at the facility. Through the waste management policy; the waste was collected based on its type. The reuse of waste in production cycles as secondary raw material was started. Waste was disposed of by licensed companies, and waste management training for employees were also given in the synthetic leather facility. Both the generation of the waste itself as well as effects of the disposed waste on the environment were minimised.

While the synthetic leather facility's emission measurement results did not exceed the limit values, the odour level was high throughout the facility. The VOC emissions were creating this pervasive odour. Furthermore, indoor air emissions were at the harmful level according to occupational health and safety. The synthetic leather facility did not have a ventilation system or effective emission collection system. The door and window systems were the only source of ventilation. The facility's emissions were not under control. For controlling the system emissions and reducing the low – value VOCs; waste gas collection and combustion systems, and the new ventilation systems were installed. Since these improvements, the synthetic leather facility does not have any reduction in the waste gas, but indeed, it started to prevent high level of indoor air pollution. Another result is that the facility has had huge odour reduction efficiency approximately 78%. When the by-pass stack flue gas and combustion system analysis results are compared, there is an emission reduction efficiency of around 98%. After the all emission systems' improvements, waste gas emissions and their effect on environment have been brought under control.

ÖZET

Son yıllarda giderek artan çevresel kaygılar nedeniyle sanayide çevre dostu üretim, en önemli gerekliliklerden biri haline gelmiştir. Üretim tesislerinin çoğunda, çevre teknolojileri uygulamalarının yetersiz olduğu bir gerçektir. Bu nedenle bu çalışmada, orta ölçekli bir suni deri tesisi için, su tüketimi, atık üretimi, enerji tüketimi ve emisyon azaltımı açısından çevresel bir strateji belirlenmiş, stratejinin uygulama öncesi ve sonrası çevre üzerine etkileri değerlendirilmiştir.

Çalışma sonuçlarına bakıldığında önerilen strateji ve çevre teknolojilerinin uygulanması ile su deri fabrikasının çevresel etkilerinin minimize edilebileceği gösterilmiştir.

Tesiste, boya hazırlama ünitesi ilave su tüketimini ve iç ortam hava kirliliğini önlemek amacıyla kapalı bir alan içerisine alınarak proses hattından ayrılmıştır. Enerji denetimleri doğrultusunda su kayıp noktaları belirlenmiş ve tesisteki musluklar su israfını engellemek içi fotosel musluklar ile değiştirilmiştir. Su tüketim sistemlerindeki bu iyileştirmeler tüm su tüketimi oranlarında % 38,5'lik bir azalma ile sonuçlanmıştır.

Enerji tüketimini en aza indirebilmek için, enerji denetimleri tesis tarafından başlatılmış ve bu denetimlerle enerji tüketim ve kayıp noktaları belirlenmiştir. Tesis çatısına pencereler açılarak gün ışığından faydalanma yoluna gidilmiş, olağan floresan lambalar LED lambalarla değiştirilmiştir. Tüm bu çalışmalar doğrultusunda tesisin yıllık enerji tüketiminde % 30'luk bir azalma sağlamıştır.

Suni deri tesisi için öncelikli olarak bir atık yönetim planı hazırlanmış ve bu atık yönetim planı doğrultusunda atıkların türüne gore ayrı toplanması ve yetkili firmalar tarafından bertaraf edilmesi sağlanmıştır. Çalışanlara atık yönetim planı kapsamında eğitimler verilerek katılımları sağlanmıştır. Tesiste oluşan atık miktarlarının azaltılmasının yanı sıra atıkların doğru şekilde bertaraf edilmesi de sağlanmıştır.

Suni deri tesisi bacalarında emisyon değerleri sınır değerleri aşmamakla birlikte

tesiste koku ve iç ortam havasında solvent miktarı yüksek seviyede bulunmaktaydı. Tesiste emisyon sistemine bağlı bulunan ıslak arıtıcı çamur oluşumuna sebep oluyordu ve bu çamur evsel atık ile karıştırılıyordu. Tüm bunların önüne geçmek amacıyla arıtma sisteminde yer alan ıslak arıtma yerine, yakma sistemi yapılması, proses bacalarının yakma sistemine bağlanması, emisyon kaynağı gibi işlev gören kapı ve pencerelerin yerine iç ortam havalandırma sisteminin kurulması ve bu emisyonların da kontrol altına alınması önerilmiştir. Tüm bu iyileştirmeler sonucunda suni deri tesisi koku azalma verimi % 78 olarak, yakma sistemi bypass hattı ve yakma sistemi çıkış bacası karşılaştırıldığında yaklaşık %98 bir arıtma verimi elde edilmiştir. Böylece tesis emisyon ve imisyonları kontrol altına alınmıştır.

TABLE OF CONTENTS

ACKNOWLEDGMENTS iv

ABSTRACT v

ÖZET vii

LIST OF FIGURES xi

LIST OF TABLES xii

LIST OF SYMBOLS/ABBREVIATIONS xiv

1. INTRODUCTION 1

2. LITERATURE REVIEW 4

2.1. Synthetic Leather Industries 4

2.2. Water Consumption 10

2.3. Energy Consumption 11

2.4. Waste Generation 18

2.5. Emissions and Odour 25

2.6. Legal Procedures 33

3. PREVIOUS SITUATION OF THE SYNTHETIC LEATHER FACILITY AND THE SUGGESTED ENVIRONMENTAL STRATEGY 38

3.1. Synthetic Leather Manufacturing Processes Used in the Studied Facility 38

3.2. Water Consumption in the Facility 44

3.3. Energy Consumption in the Facility 44

3.4. Waste Generation in the Facility 47

3.5. Emission Collection and Treatment Systems in the Facility 49

3.6. Suggested Environmental Strategy 57

3.6.1 Suggested improvements to reduce water consumption 57

3.6.2 Suggested improvements to reduce energy consumption 58

3.6.3 Suggested improvements to reduce waste generation 58

3.6.4 Suggested improvements to reduce emissions 59
4. RESULTS AND DISCUSSIONS 60
4.1. Evaluation of the Facility in Terms of Water Consumption 60
4.2. Evaluation of the Facility in Terms of Energy Consumption 63
4.3. Evaluation of the Facility in Terms of Waste Generation 66
4.4. Evaluation of the Facility in Terms of Emission Generation 69
5. CONCLUSION 83
REFERENCES 86
REFERENCES NOT CITED 96

LIST OF FIGURES

Figure 2.1. Manufacturing processes in PU industry 9
Figure 2.2. Development of waste treatment in the EU 2004-2010 20
Figure 2.3. A hierarchy of solid waste management 24
Figure 2.4. Hazardous waste management hierarchy in Turkey, (a) existing state, (b) targeted state, (c) targeted after 2020 25
Figure 2.5. Control techniques of the VOCs emissions 26
Figure 3.1. Synthetic leather manufacturing process flow chart 39
Figure 3.2. Synthetic leather products of the facility 40
Figure 3.3. Synthetic leather manufacturing facility layout 42
Figure 3.4. Synthetic leather manufacturing facility machinery layout 43
Figure 3.5. Synthetic leather facility LNG tank 46
Figure 3.6. Schematic of the spray scrubber 50
Figure 4.1. Principle of a VOC recuperative incinerator 69
Figure 4.2. Emission collection and treatment system design 71

LIST OF TABLES

Table 2.1. Turkey's synthetic leather production in 2010 5

Table 2.2. Turkey's synthetic leather production in 2012 6

Table 2.3. The distribution of Turkey's energy related CO_2 emissions 1990 -1995 11

Table 2.4. Waste generation in 2010 18

Table 2.5. Waste treatment (1000 tonnes) 2010 19

Table 2.6. Distributions of the waste generation rates by sectors 20

Table 2.7. Manufacturing industry waste indicators 21

Table 2.8. Analysis of various VOC control techniques 27

Table 2.9. Global CO_2 production from VOC oxidation 29

Table 2.10. Turkey's total greenhouse gas emits 30

Table 2.11. Odour treatment processes 31

Table 2.12. Turkish environmental legislations related with the middle scale facilities. 34

Table 2.13. Emission limits related with the facility 34

Table 2.14. The discharge limits of the facility 36

Table 3.1. Monthly production rates of the facility 41

Table 3.2. Chemical consumption rates in 2009 41

Table 3.3. Synthetic leather facility LNG consumption rates 45

Table 3.4. The lightning system estimated electrical consumption rates 46

Table 3.5. Synthetic leather facility electric consumption rates 47

Table 3.6. Wastes from synthetic leather production process 48

Table 3.7. Analysis results of KB 1 (Boiler Flue) 51

Table 3.8. Analysis results of PB 1 (Process Flue 1) 52

Table 3.9. Analysis results of PB 2 (Process Flue 2) 52

Table 3.10. Analysis results of PB 3 (Process Flue 3) 53

Table 3.11. Analysis results of PB 4 (Process Flue 4) 53

Table 3.12. Analysis results of PB 5 (Process Flue 5) 54

Table 3.13. Total emissions 54

Table 3.14. Measuring standard methods 55

Table 3.15. Odour measurements of the facility 55

Table 4.1. Water consumption rates of the hotel 62

Table 4.2. Lightning system electrical consumption rates after the improvements 64

Table 4.3. Electricity consumption rates after the improvements 65
Table 4.4. Energy consumption rates before and after the improvements 66
Table 4.5. Domestic waste generation rates of the hotel 68
Table 4.6. Characteristics of the combustion unit 71
Table 4.7. Characteristics of by-pass stack and combustion system flue 72
Table 4.8. By-pass stack gas monitoring results 72
Table 4.9. Combustion system output stack gas monitoring results 73
Table 4.10. By-pass and combustion system output stack measurement results and removal efficiencies 73
Table 4.11. Analysis results of KB 1 (Boiler) 75
Table 4.12. Analysis results of Ventilation Shaft 1 76
Table 4.13. Analysis results of ventilation shaft 2 77
Table 4.14. Analysis results of ventilation shaft 3 78
Table 4.15. Analysis results of incinerator shaft 79
Table 4.16. Total emissions 80
Table 4.17. Odour measurement results 80
Table 4.18. Comparison chart of the synthetic leather facility's emissions before and after the improvements 81
Table 4.19. Investment and operating costs of the emission and odor treatment systems 82

LIST OF SYMBOLS/ABBREVIATIONS

Symbol	Explanation
DMF	Dimethylformamide
DMS	Dust monitoring system
DOP	Dioctyl phthalate
EPA	Environmental Protection Agency
FID	Flame Ionization Detector
Gg	Greenhouse gas
LED	Light Emitting Diode
LNG	Liquefied Natural Gas
MEK	Methyl ethyl ketone
NMVOC	Non-methane volatile organic compounds
PU	Polyurethane
PVC	Polyvinyl chloride
RTO	Regenerative Thermal Oxidation
SMEs	Small and Medium Enterprises
UV	Ultraviolet
VOCs	Volatile organic compounds

1. INTRODUCTION

Today environmental technologies are the rhythm of the sustainability and they are never-ending. People have an enormous need for sustainability that the industry does not understand effectively yet. The old manufacturing facilities, which are the initial step of environmental pollution, do not have environmentally sensitive technologies. In synthetic leather industry, environmental pollution can originate from several stages in the production processes. The synthetic leather is used for making shoes, bags, suitcases and decorations. With the application of new processes and technologies, synthetic leather poses an advantage unparalleled by natural leather in aspects of variety, design and colour, style, price and performance. Enjoying its advantages of universal application, low cost and high profitability in industry, however, synthetic leather brings considerable pollution, which is proven by the fact that in the past decade synthetic leather industry has been shifted from developed countries such as Europe and the USA to China mainland and other places. Despite its tremendous market demand and sizable profit, synthetic leather after all pollutes to a certain extent.

Environmentally friendly production by using innovative and/or improved technologies should be enforced to the industries by regulations and costumer standpoint on environmental issues to protect the environment and sustainability. Sustainability and the prevention of environmental pollution focus on safeguarding natural resources against exploitation, in the name of productivity and competitiveness, by the industries. It is a major concern in many countries and is leading to strict regulations regarding the environmental impact during production, use of natural sources and protection of the environment.

Companies around the world have shown interest in innovations that are a part of environmental friendly manufacturing. Environmental friendly technologies in the industries involve integrating environmental thinking into new product development including design, material selection, manufacturing processes and delivery of the product to the consumers. Environmental friendly technologies have found support in industries which aim to find solutions to the environmental problems. Problems are widespread

including the pollution prevention, material recovery, odour, recycling, remanufacturing, natural source consumption efficiency, to eliminate the use and generation of substances hazardous to human health and the environment, etc. Environmentally friendly technologies provide a sustainable environment for the next generations. To this end, the extent of the problems and improver actions need to be identified. The good thing about society is that the industries have an environmental awareness to various environment-related problems that have been encountered in the last decades. However, it is crucial to take corrective action to environmental problems in all scale industries before the environmental damage.

It is extremely important to integrate environmentally friendly thinking into every type of industrial process. Innovations about environmentally friendly production have the following two key topics:

1. understanding the industrial production and its impact on the environment at each of its processes
2. finding the environmental strategies for existing production processes and applying innovative environmental technologies with minimum costs.

The first topic is necessary for drawing lines to determine how the production can affect the environment with its processes. In the existing processes, all the environmental effects should draw a frame to develop the environmental strategy and then this strategy should be put into action as the actual innovations in the facility. During the development of the strategy, there are different objectives that the industries may focus on such as energy consumption, waste minimization, chemical usage and safety, monitoring their waste generation... etc. for examining their effect on the environment. Regardless of the type of the industry, the strategy should be realized to minimize the effects on the environment with minimum costs.

This study focuses on the development of an environmentally friendly production strategy for a synthetic leather facility to reduce its effects on the environment. In the study, the effects of the focused synthetic leather facility on the environment, in terms of water consumption, waste generation, energy consumption, and the emissions, were

evaluated before and after the application of the proposed strategy. To determine the system efficiency, regular measurements of emission generation, source consumption, carbon footprint amounts… etc. will be done. The study includes three phases as the former state of the facility, the facility after the application of environmental technologies and the analysis results and efficiency of the strategy.

The objectives of the study are;

- To explain the current technology used in the synthetic leather manufacturing facility.
- To set up a new strategy to reduce the environmental effects.
- To measure the emission collection and treatment systems, water and energy consumption and waste generation before and after the application of the proposed strategy to show the improvements.
- To compare the system efficiency before and after the application of the proposed strategy to show the improvements.

It is not possible to accept the traditional "grow first, and clean up later" understanding today. The shift to environmentally friendly technologies in production processes poses problems in terms of enriching the overall environmental performance of the supply and the demand chain and involvement of various industries. The adverse effects of synthetic leather facilities on the environment can be reduced by using environmental technologies. Thus it may result in more environmentally friendly production.

2. LITERATURE REVIEW

2.1. Synthetic Leather Industries

Synthetic leather industry generally is classified as three sub-sectors; PVC coated synthetic leather, polyurethane coated synthetic leather and synthetic suede. The synthetic leather is an important material of plastic industry for making shoes, bags, suitcases and decorations.

PVC coating is made in the early stages of synthetic leather industry. PVC coated products have a wide usage and application area and they are cheaper than the other synthetic leather types. PVC coated synthetic leather is used in the fields of automobile upholsteries, home and office furnishings, bags, slippers, shoes, raincoats, overcoats, coats… etc. Polyurethane has been used for approximately 15 years in synthetic leather production. Although PU products are more expensive than PVC products, they are more sanitary and ecological. PU coated synthetic leather products are preferred for clothing and footwear such as coats, jacket, pants, shirt, etc.

In 2010, Turkey's determined synthetic leather production is given in Table 2.1. As it is shown in Table 2.1, synthetic leather production of Turkey was 171.864.000 m/year.

Table 2.1. Turkey's synthetic leather production in 2010.

Synthetic Leather Facilities	**Production Line Number**	**Capacity 24*22 (m/year)**
Besa	1	5.544.000
Depar	1	5.544.000
Feza	1	5.544.000
Flokser	4	22.176.000
Gezer	3	16.632.000
Gürle	1	5.544.000
Gürteks	1	5.544.000
Hakteks	1	5.544.000
Hefa	2	11.088.000
Nur	1	5.544.000
Oziteks	1	5.544.000
Örteks	1	5.544.000
Pelle	1	5.544.000
Pençe	2	11.088.000
Persu	1	5.544.000
Plastisan	1	5.544.000
Politeks	1	5.544.000
Simplast	1	5.544.000
Sur	1	5.544.000
Şahinler	2	11.088.000
Teknofin	1	5.544.000
Teksplast	1	5.544.000
Vinteks	1	5.544.000
Total Production (Annually)	**31**	**171.864.000**
Total Production (Monthly)	**31**	**14.322.000**

In 2012, Turkey's determined synthetic leather production is given in Table 2.2. As it is shown in Table 2.2, synthetic leather production of Turkey was 225.984.000 m/year.

Table 2.2. Turkey's synthetic leather production in 2012.

Synthetic Leather Facilities	**Production Line Number**	**Capacity 24*22 (m/year)**
Asya	1	4.224.000
Besa	1	5.544.000
Depar	1	5.544.000
Emre	1	5.544.000
Feza	1	5.544.000
Flokser	5	27.720.000
Gezer	2	11.088.000
Gürle	1	5.544.000
Gürteks	1	5.544.000
Güzelcan	1	5.544.000
Hakteks	1	5.544.000
Hefa	2	11.088.000
Napa	1	5.544.000
Nur	1	5.544.000
Oziteks	1	5.544.000
Örteks	2	11.088.000
Pelle	1	5.544.000
Pençe	2	11.088.000
Persu	2	11.088.000
Plastisan	1	5.544.000
Politeks	2	11.088.000
Rambo	1	5.544.000
Simplast	1	5.544.000
Sur	1	5.544.000
Şahinler	2	11.088.000
Teknofin	1	5.544.000
Teknoplast	1	5.544.000
Teksplast	1	5.544.000
TUT	1	5.544.000
Vinteks	1	5.544.000
Total Production (Annually)	**41**	**225.984.000**
Total Production (Monthly)	41	**18.832.000**

According to Table 2.1 and Table 2.2, Turkey's synthetic leather production is raised from 171.864.000 m/year to 225.984.000 m/year in last 3 years and it also continues its growth.

The advent and development of synthetic leather cause a reduction in natural leather industry. Synthetic leather provides an advantage such as low cost and high profitability in the industry and in aspects of variety, design, colour, style, price and performance, however, synthetic leather reveals pollution, which is presented by the fact that in the past decade the said industry has shifted in succession from European and American developed countries to China mainland and other places. Despite of its benefits, synthetic leather has incontestable environmental pollutions (Xu and Zhiping, 2011).

In synthetic leather production, some solvents are added as thinners and additives to avoid excessive viscosity of polyurea-formaldehyde (Air Resources Board, 1978). Odour originates from the emission of volatile organic compounds (VOCs) in solvents, including dimethyl formamide (DMF), methyl ethyl ketone (MEK) and toluene. Furthermore, emission of these VOCs has adverse health effects such as the lungs absorb the vapours which are taken up from the gastrointestinal tract. The absorbed VOCs are deposited in adipose tissue and in the nervous system. The glycine, in the liver exhaled, holds and conjugates with absorbed VOCs. In the central nervous system, dizziness, weakness, confusion, and incoordination are occurred by the VOCs (US EPA, 1977).

In contrast with toluene taken poorly through the skin, its vapour is absorbed rapidly from the lungs, and liquid toluene is taken up readily from the gastrointestinal tract (Wolkoff et al., 1999; Tichenor and Palazzolo, 1997). The adipose tissue and the central nervous system is where toluene is deposited in the body (Carlsson and Lindqvist, 1997). The effects of toluene on the central nervous system, such as dizziness, weakness, confusion and incoordination, are the same reaction like the other organic solvents. The result of the toluene toxicity is euphoria which is caused by a practice of sniffing glue, paint thinner, or toluene itself, the latter instance resulting in a schizophreniform psychosis in one case (Weisenberger, 1977; Tarsh, 1979). The life threatening metabolic acidosis characterized by a high anion gap or by hyperchloremia and other findings consistent with renal tubular acidosis is caused by sniffing of the toluene (Fishman and Oster, 1979; Taher et al., 1974).

Since the flow rate of flue gas is large and the composition of VOCs is very complicated, controlling of the VOC emissions is difficult (Dyro, 1978; Mixfield et al., 1975). In France, using the emission combustion system provides 60% VOCs treatment efficiency in the PU factories (Morvan et al., 2003). Meanwhile, using the biofilter, provides 70% VOCs treatment efficiency at PU industries in Korea (Chang et al., 2001). It is critical to understand the VOCs pollution sources and emission characteristics before treating the VOCs in PU industry. The cost and efficiency of control strategies are also important to reduce VOCs emission rate (Ergas, 1993; Findlay and Nirmalakhandan, 1996).

The coating process in dry process involves adding some solvents as thinners and additives to avoid excessive viscosity of the painting materials (Chang and Jeng, 1998). Owing to their low boiling point and high volatility, these thinners can easily seep out of the painting materials during coating processes or drying processes and subsequently cause air pollution. As an important manufacturing process in PU production, coating process can ensure anti-erosion feature of PU. The drying processes are performed after coating, subsequently producing a large amount of VOCs emissions.

There is no water effluent in the synthetic leather production system. The main pollution sources are the emissions of the solvents. The sources of the VOCs emissions are shown in Figure 2.1.

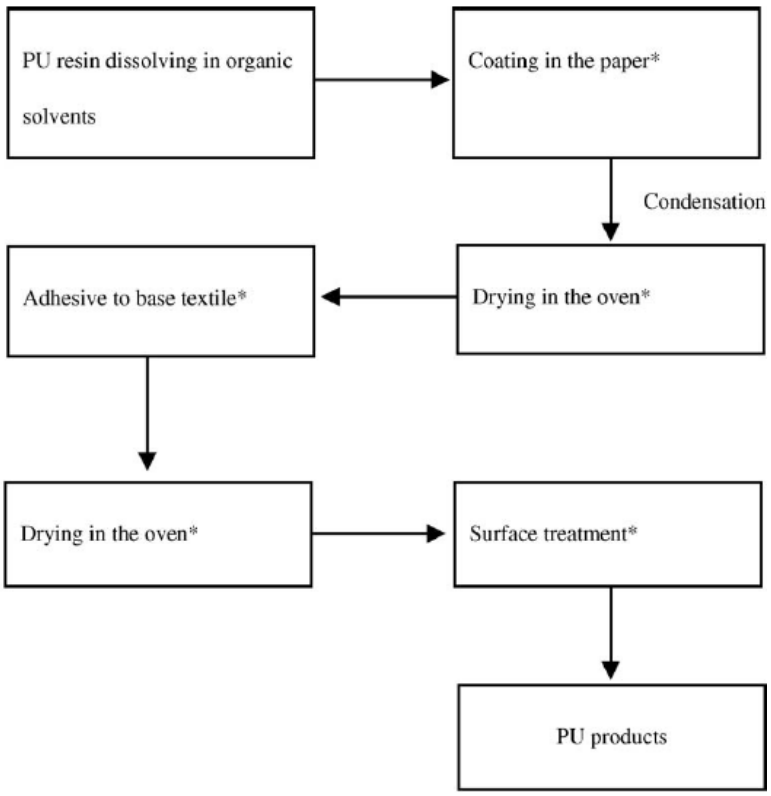

Figure 2.1. Manufacturing processes in PU industry (Chang and Lin, 2006).

Note: "*" denotes the pollution sources.

In the synthetic leather production process PVC powder, DOP (dioctyl phthalate), PVC stabilizers (based on Ca and Zn salts), calcite, titanium oxide, nitrogen dicarbon amide, various pigments and dyes, mineral spirits and kerosene are used as raw materials. They are mixed till a homogeneous mixture is obtained. After the mixing operation, the synthetic leather is coated in the silicone paper. Spread product is subjected to baking operation for drying. After the baking oven, the product is cooled in cooling channel. At the end, the product is separated as the carrier paper and leather. At the end of the process, the product is subjected to the surface treatment and it is printed through to customer demand as pattern, embossed, perforated, lacquer and sanding.

2.2. Water Consumption

Water is becoming scarce and that causes an enhanced pressure on the globalized economy, and draws more attention from the community (McKinsey and Company, 2009). Water, through the heightened consumption demand and by changes in the consumption systems as the goods and services are provided from different locations of activities, is affected by global economic development (World Water Assessment Programme, 2009). As a result of economic growth in developing countries, living standards are rising, causing increased consumption and production of goods and demand for water resources (Stoeglehner et al., 2011).

The search for innovative industrial technologies or methodologies and risk prevention designed, not only for ensuring a sustainable and clean environment, but also for sustainable competitiveness delineates the main problem (European Commission Community Research, 2004). Increasing water consumption and the future agricultural demands to meet poses one of the most important problems relative to the environment and sustainability on earth (Cojocariu et al., 2012). The water management practices present water consumption and pollution over the entire production and supply chains as very important (Hoekstra et al., 2009).

Hoekstra and Hung (2002) put forward the “water footprint” term. The water footprint determination is a useful way to quantify water use throughout the supply chain, providing valuable insights into the largest components and locations of water consumption, and the potential effects on local watersheds, and future water availability to serve the needs of communities, nature, companies, producers and suppliers (TCCC and TNC, 2010).

Thevendiraraj et al. (2003) states that water is used in most process industries for a wide range of applications. Processes and systems using water today are being subjected to increasingly stringent environmental regulations on effluents and there is growing demand for fresh water. For providing the better water management and wastewater minimization

all these changes have increased. Water consumption minimization techniques can effectively reduce overall fresh water demand and the overall effluent generated.

2.3. Energy Consumption

Turkey's carbon emissions have risen with the country's energy consumption. The distribution of Turkey's energy related carbon dioxide (CO_2) emissions between 1990 and 1995 are listed in Table 2.3. It can be seen from the Table 2.3 that CO_2 emissions have raised very much in the industries. In this context, the Turkish government attempts to minimize energy related CO_2 and other greenhouse gas emissions through measures aimed at improving energy efficiency, increasing the shares of new and renewable energy sources, switching from high carbon to low carbon fuels, adopting emission reducing systems, limiting the use of energy and preventing losses in energy distribution systems (Hepbasli and Ozalp, 2003).

Table 2.3. The distribution of Turkey's energy related CO_2 emissions between 1990 -1995 (Hepbasli and Ozalp, 2003).

Sectors	**CO_2 emissions (in Gg)**				
	1997	**1998**	**2000**	**2005**	**2010**
Power Generation	71,056	75,832	100,119	150,180	221,388
Industry	50,304	57,530	54,170	83,276	128,983
Transportation	34,307	32,274	53,211	62,800	79,399
Others	35,983	33,108	46,078	51,593	56,694
Total	**191,650**	**198,744**	**253,578**	**347,850**	**486,465**

In the industries, energy efficiency is the critical point for improving energy protection, environmental sustainability and economic performance. Christoffersen et al. (2006) and Kannan and Boie (2003) state that energy management is advantageous for industrial companies for financial, environmental or societal reasons. For decreasing the energy consumption and the related CO_2 emissions, implementing an energy management

can be a solution. Within the scope of energy management the addition of energy efficiency into production is one important lever to improve production systems towards energy efficiency as it may be the basis for successfully implementing energy efficiency improvement measures. Blackstone (2008) demonstrates that the term ‘management’ can be defined as “the functions of planning, organizing, and controlling the transformation process and its utility in providing a good or service to customers”. O’Callaghan and Probert (1977) define ‘energy management’ as “applying to resources as well as to the supply, conversion and utilization of energy”. Monitoring, measuring, recording, analyzing, critically examining, controlling and redirecting energy and material flows through systems are included by energy management so that the least amount of power is expended to achieve worthwhile aims.

In the synthetic leather facility, energy management in the production also includes control, monitoring, and improvement activities for energy efficiency. Energy efficiency performance has to be paid attention simultaneously with other important performance areas of industrial companies, such as cost, flexibility, delivery time, and quality (Schönsleben, 2007).

Schönsleben et al. (2010) and Srivastava (2007) suggest that over the last decade, the importance of carbon emissions and energy efficiency as critical factors in production management have increased and the changing concept of sustainability has created new economic opportunities in the manufacturing sectors. At the same time EC (2009) puts forward that there is no convenient method to provide effective energy efficiency in production management. Small and medium sized enterprises (SMEs) account for about 99% of total enterprises, about 58% of total value added, and create about 3.25 million jobs in the EU. They play a critical role in promoting energy efficient manufacturing. Anderson and Newell (2004), Eichhammer (2004) and Thollander et al. (2007) claim that barriers for SMEs to introduce energy management and to implement energy efficiency measures have been discussed widely in the energy efficiency gap debate. Kannan and Boie (2003) and Shipley and Elliot (2001) underline that as SMEs often lack initiation, market information, expertise and financial resources, they are more likely to benefit from external information. So it is important to support SMEs to increase energy efficiency in their manufacturing processes.

Saidur (2010) states that in the area of energy management; the energy audit is the key for decision-making. Energy auditing is thus a dependable and systematic approach in the industrial sector. Energy auditing assists organizations to examine their energy use and discover areas where energy can be consumed, determine feasible energy conservation methods that will enhance their energy efficiency, serve to identify all the energy streams in a facility, quantify energy usage, in an attempt to balance the total energy input with its use.

Bureau of Energy Efficiency (2010) put forwards that in any industry, the three top operating expenses are often found to be energy, labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus the energy management function constitutes a strategic area for cost minimisation.

Saidur (2010) suggests that energy auditing requires a systematic approach from the formation of a suitable team, to achieving and maintaining energy savings. The lots of benefits such as lower energy consumption and minimising the environmental pollution can be provided by energy audits. Energy audits can improve the overall performance of the total system and the profitability and productivity. They can also provide slower depletion of natural resources and narrowing demand supply gap.

Saidur (2010) puts forward that there can be three types of energy audits:

1. Preliminary audit
2. General audit
3. Detailed audit

Saidur (2010) claims that a preliminary audit (it can be called as simple audit, screening audit or walk-through audit) is the simplest and quickest type of audit and conducted in a limited time-span. Interviews with workers, a general review of the operating data, site visits to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency are involved in a preliminary audit. It focuses on major energy supplies and demands of the industry. The scope of the

preliminary audit is to highlight energy costs and to identify wastages in major equipment processes it sets priorities for optimizing energy consumption. It checks energy usage and energy management in facilities. Preliminary energy audits use existing, or easily obtained data.

The Bureau of Energy Efficiency (2010) states that a preliminary energy audit is performed to:

- provide the best management commitment.
- determine energy consumption in the organization.
- estimate the scope for saving.
- identify immediate (especially no-/low-cost) improvements/ savings.
- define areas for more detailed study/measurement.

Saidur (2010) demonstrates that the general audit, alternatively called mini-audit, site energy audit or complete site energy audit, expands the preliminary audit's scope such as collecting more detailed information about facility operation and performing a more detailed evaluation of energy conservation measures identified. Energy consumption profiles are determined by general audit. In-depth interviews with facility operating personnel are conducted to provide a better understanding of major energy-consuming systems as well as insight into variations in daily and annual energy consumption and demand.

The detailed audit (alternatively called a comprehensive audit, investment-grade audit, maxi audit, or technical analysis audit) widens the general audit's scope and a dynamic model of energy-use characteristics of both the existing facility and all energy conservation measures identified are ensured by the detailed audit. Extensive attention is given to understanding the operating characteristics of all energy-consuming systems and also situations that cause load profile variations on short and longer term bases (e.g. daily, weekly, monthly, annual). Sub metering of major energy-consuming systems and monitoring of system operating characteristics are complementary factors for existing utility data (Saidur, 2010).

The Bureau of Energy Efficiency 2010 claims that generally, detailed energy auditing is carried out in three phases: Phases I, II and III as follow : Phase I – pre-audit phase, Phase II – audit phase, and Phase III – post-audit phase.

According to Saidur (2010), Bureau of Energy Efficiency (2010) and Abdelaziz et al. (2011), in order to carry out a detailed energy audit in the industry, there are many means needed to get the related data for motor energy consumption. Some of these tools are:

1. Fuel efficiency monitoring; this determines oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.

2. Clamp-on power meter; the meter is used to measure power consumption, current drawn, load factor and power factor. The meter should have a clamp-on feature to measure current and probes to gauge voltage so that measurements can be recorded without any disruption to normal operation.

3. Leak detectors; the detectors are ultrasonic instruments. Leak detectors can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities.

4. Portable tachometer; the meter assists in measuring the speed of the motor. An optical type tachometer is preferable due to the ease of measurement.

5. Thermocouple sensor; the sensors are useful to measure the temperature of the motor so that temperature can be controlled whether the motor is overheated or not. Thus motor failure or damage is prevented by the sensor. Moreover, temperature rising will cause a motor to use more energy. The auditor determines motor efficiency by knowing the temperature. The most commonly used sensors in industry are RTDs and thermistors.

6. Data logger; the loggers are used to monitor and log data such as temperatures, motor current, and power. Data loggers are generally portable and their sensors can accept different inputs.

Energy efficiency courses and training programs are important to sensitize people, who are involved in the industrial sector, about energy efficiency. In general the industrial energy management courses can be taken by engineers who are working in industry or who are at the university level. In both of these, an energy management certificate is given to the participants who complete the course successfully and submit an energy conservation report. Generally technological, environmental, social and economical dimensions of energy efficiency are focused on these courses (Hepbasli and Ozalp, 2003; Sola et al., 2006; and Abdelaziz et al., 2011).

Dufort and Infante-Rivard (1999) posit that efficient production and a good working environment are complementary in the industries. The elimination of inefficiencies and accident hazards caused by inadequate conditions in the workplace is essential in getting the job done efficiently and safely. The attention to these important details is widely referred to as ‘‘good housekeeping’’. Every phase of industrial operations is contained by housekeeping. The avoidance of congestion and attention to such details as an orderly layout of the whole workplace, the marking of aisles, adequate storage arrangements, and suitable provision for cleaning and maintenance are required by the good housekeeping.

Dufort and Infante-Rivard (1999) suggest that the following are some of the basic elements of good housekeeping that save energy in any industrial company:

1. Lighting: Well-distributed artificial light and effective use of available daylight could save energy significantly.

2. Waste removal: Adequate facilities to prevent congestion and disorder. Some of these elements are:

(a) Painting the walls: Light-coloured walls reflect light. Dirty or dark-coloured walls absorb light.

(b) Maintaining the light fittings: Attention to light fittings should be an integral part of any good housekeeping program. Dirty lamps and shades, and lamps whose output has

deteriorated with use, deprive employees of essential light. Lighting efficiency can be developed by 20–30% simply by cleaning of the lamps and reflectors.

(c) Disposing of scrap and preventing spillage: It's a common practice to let the floor catch all the waste and then spend time and energy cleaning it up. It is better to provide convenient containers for scrap and waste and educate employees to use them. Safety will be provided, expense will be saved, and the factory will be a better place for working.

(d) Looking after your first aid gear: First aid equipments should be kept clean conditions and fully stocked. They should be always ready in the event of accidents, illness or emergency.

(e) Inspecting fire-control equipment: It is essential to ensure that all fire-fighting equipment such as extinguishers and fire hoses is regularly inspected and kept in good working order. Fire protection should be in good working order. Doors and exits should always be kept clear of obstructions.

(f) Regular maintenance: Maintenance is the most important element of good housekeeping. Regular maintenance allows the management team to repair machinery, broken windows, damaged doors, defective plumbing, and leaking, broken floor surfaces. A good maintenance program will make provision for the inspection, lubrication, upkeep and repair of tools, equipment, machines and processes.

(g) Preparing a check list: A sound method to ensure that housekeeping is done is for management to prepare a checklist to suit the requirements of the workplace.

2.4. Waste Generation

According to Eurostat, the statistical office of the European Union (EU), the total generation of waste in the EU -27 (27 member states of the EU) was about 2.570 million tonnes in 2010 (Table 2.4). 3.7 % of the total waste, 94.5 million tonnes, was identified as hazardous waste.

Table 2.4. Waste generation in 2010 (Eurostat).

	Waste from economic activities and households		Agri-culture, forestry & fishing (Section A)	Mining & quarrying activities (Section B)	Manu-facturing (Section C)	Energy (Section D)	Construction & demolition activities (Section F)	Other economic activities (Sections E and G to U)	House-holds
	Total	of which, hazardous							
EU-27 (1)	*2 569 850*	*94 460*	*39 570*	*727 320*	*279 960*	*84 880*	*854 550*	*362 630*	*220 940*
Belgium	44 256	1 992	277	465	9 789	1 243	3 224	24 461	4 798
Bulgaria	165 877	13 542	618	150 214	3 306	8 032	79	1 231	2 396
Czech Republic	23 758	1 363	114	115	4 202	1 540	9 354	5 099	3 334
Denmark	14 033	1 338	77	25	1 215	213	2 104	7 009	3 390
Germany	363 545	19 931	256	24 493	48 981	9 087	190 990	53 426	36 312
Estonia	19 000	8 962	110	6 453	3 716	6 534	436	1 320	430
Ireland	19 808	1 972	101	2 196	3 259	334	1 610	10 578	1 730
Greece (2)	*68 644*	*253*	*0*	*38 152*	*5 703*	*11 181*	*6 828*	*2 826*	*3 954*
Spain	137 519	2 991	5 817	31 732	16 480	2 339	37 947	20 006	23 198
France	355 081	11 538	1 682	1 053	20 382	993	260 226	41 439	29 307
Italy	*179 034*	*6 655*	*349*	*1 263*	*43 086*	*3 090*	*69 732*	*29 043*	*32 472*
Cyprus	2 373	37	129	382	132	3	1 068	198	461
Latvia	*1 495*	*67*	*75*	*3*	*501*	*20*	*12*	*278*	*606*
Lithuania	5 583	110	456	7	2 653	68	357	782	1 261
Luxembourg	10 440	379	3	18	498	2	8 731	803	385
Hungary	15 735	541	488	87	3 134	2 718	3 072	3 372	2 865
Malta	1 288	17	3	0	9	1	989	149	138
Netherlands	119 142	4 565	3 948	184	14 179	1 156	78 331	12 253	9 091
Austria	34 883	1 473	550	269	2 958	453	9 010	17 019	4 623
Poland	159 458	1 492	1 543	61 547	28 618	20 291	20 818	17 751	8 890
Portugal	38 347	1 625	193	1 206	9 766	456	11 071	10 193	5 464
Romania	218 830	703	18 353	177 441	7 346	5 888	238	3 438	6 127
Slovenia	5 096	117	141	12	1 457	558	1 509	691	728
Slovakia	10 545	437	526	166	2 712	878	1 786	2 759	1 719
Finland	104 337	2 559	2 772	54 851	15 211	1 445	24 645	3 732	1 681
Sweden	117 618	2 515	309	89 026	7 835	1 479	9 381	5 551	4 038
United Kingdom	*334 127*	*7 285*	*681*	*85 963*	*22 837*	*4 885*	*100 999*	*87 223*	*31 539*
Liechtenstein	62	2	0	12	15	0	0	35	0
Norway	9 433	1 763	195	366	2 687	28	1 543	2 385	2 229
Croatia	668	45	0	1	154	1	2	509	0
FYR of Macedonia	2 328	150	0	855	1 017	4	0	0	451
Serbia	33 623	11 145	0	26 458	1 146	6 019	0	0	0
Turkey (3)	64 765	1 018	0	0	10 735	25 525	0	50	28 454

In line with Eurostat data in 2010, 2.366 million tonnes of waste was treated in the EU-27; this includes the treatment of waste that was imported into the EU-27. Table 2.5 shows the types of applied waste treatment and disposal techniques in the EU -27. Disposal

operations were applied to 48.2 % of the waste within the EU-27 in 2010. 46.3 % of the waste was sent to recovery operations (other than energy recovery). The remaining 5.4 % of the waste was incinerated.

Table 2.5. Waste treatment (1000 tonnes) 2010 (Eurostat).

	Total	Energy recovery	Incineration without energy recovery	Recovery other than energy recovery	Disposal other than incineration
EU-27	*2 365 860*	*85 790*	*42 710*	*1 096 450*	*1 140 900*
Belgium	44 334	1 320	2 580	38 797	1 636
Bulgaria	160 049	144	8	1 836	158 061
Czech Republic	18 247	767	55	13 220	4 204
Denmark	8 793	2 120	0	5 870	803
Germany	349 564	28 423	12 646	241 563	66 932
Estonia	17 953	336	0	5 956	11 661
Ireland	9 421	168	43	3 356	5 854
Greece	*67 523*	*135*	*29*	*5 251*	*62 108*
Spain	132 688	2 523	412	80 289	49 464
France	336 396	14 241	7 809	201 053	113 294
Italy	*127 894*	*2 459*	*5 157*	*87 826*	*32 452*
Cyprus	2 371	7	7	1 381	976
Latvia	*1 386*	*18*	*0*	*646*	*721*
Lithuania	4 546	111	2	1 062	3 371
Luxembourg	12 546	32	124	6 286	6 105
Hungary	13 424	859	82	5 125	7 357
Malta	1 202	0	7	129	1 065
Netherlands	116 573	6 276	4 809	58 290	47 197
Austria	29 751	1 364	1 649	14 982	11 756
Poland	146 580	3 804	369	109 695	32 712
Portugal	20 115	2 343	419	7 583	9 771
Romania	197 376	1 524	242	6 638	188 973
Slovenia	5 638	282	35	3 816	1 504
Slovakia	8 387	255	109	4 210	3 812
Finland	105 630	9 847	389	31 999	63 395
Sweden	110 476	6 261	87	16 587	87 541
United Kingdom	*316 991*	*171*	*5 635*	*143 008*	*168 178*
Norway	6 292	1 280	276	2 566	2 170
Croatia	31	18	3	3	6
FYR of Macedonia	2 106	0	1	331	1 775
Serbia	33 059	26	1	565	32 466
Turkey (1)	60 230	143	81	14 627	45 380

The development of waste treatment methods in the EU-27 is shown in Figure 2.2. Waste disposal decreased from 2004 to 2008. The waste recovery steadily increased from 893 million tonnes in 2004 to 1 096 million tonnes in 2010. An analysis of the latest data for 2010 shows that 193 million tonnes of waste recovery was used in excavated areas for the purpose of slope reclamation or safety or for engineering purposes in landscaping.

Waste incineration and energy recovery were increased by 19.6 % from 108 million tonnes in 2004 to 129 million tonnes in 2008 and was unchanged in 2010.

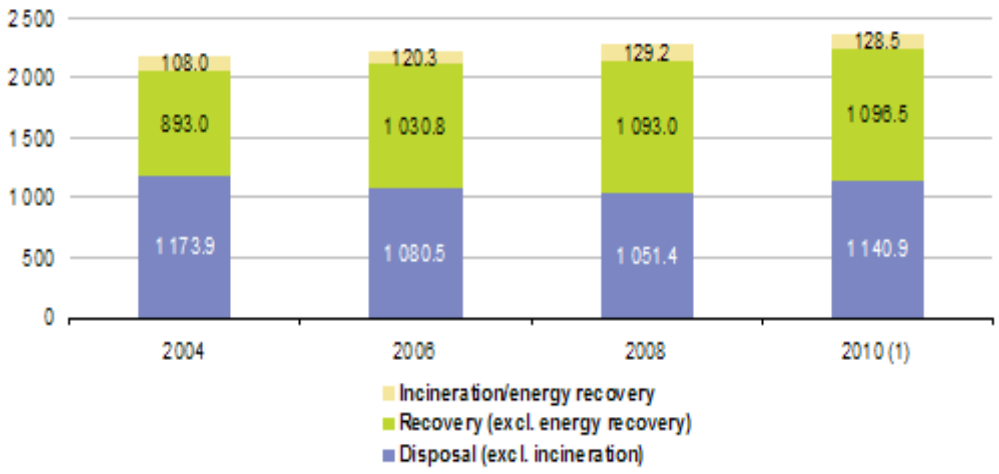

Figure 2.2. Development of waste treatment in the EU 2004-2010 (million tonnes) (Eurostat).

Table 2.6 shows the waste generation survey of Turkey, which is prepared by the Turkish Statistical Institute, for the years 2008 and 2010.

Table 2.6. Distributions of the waste generation rates by sectors (Turkish Statistical Institute, Environmental Statistics, 2012).

	2008		**2010**	
	Total Waste	**Hazardous Waste**	**Total Waste**	**Hazardous Waste**
Manufacturing Industries (1000 tonnes /year)	12 482	1 136	13 366	964
Thermal Power Plants	25 622	24	18 748	(**)
Organized Industrial Zones	255	34	313	(**)
Mining	...	...	729 750	2 314
Health Organizations	50	50	60	60

Table 2.7 shows the Turkey's Manufacturing Industry Waste Indicators for the years 2000, 2004, 2008 and 2010.

Table 2.7. Manufacturing industry waste indicators (Turkish Statistical Institute, 2012).

	2000	**2004**	**2008**	**2010**
Rate of waste generated (1000 tonnes/year)	17.059	17.497	12.482	13.366
Recovered or reused within the facility (1000 tonnes/year)	1.460	1.346	614	887
Recovered or reused outside the facility(1000 tonnes/year)	5.917	7.943	4.559	3.745
Ultimate disposal (1000 tonnes/year)	9.683	8.209	7.309	8.734
Dumping site (1000 tonnes/year)	1.242	1.646	970	1.017
Controlled landfill (1000 tonnes/year)	303	894	921	1.032
Co-incineration/ Incineration (1000 tonnes/year)	26	200	228	(**)
Stored within the establishment (1000 tonnes/year)	2.125	767	1.843	2.692
Used as filling material (1000 tonnes/year)	2.646	629	3.190	(**)
Dumped into lake or river (1000 tonnes/year)	2.754	3.879	0	-
Others (1000 tonnes/year)	586	194	158	189
Rate of hazardous waste generated (1000 tonnes/year)	1.308	1.196	1.136	964
Recovered or reused within the facility (1000 tonnes/year)	142	71	7	11
Recovered or reused outside the facility (1000 tonnes/year)	343	248	229	183
Ultimate disposal (1000 tonnes/year)	823	877	900	770

As shown in Figure 2.2, 35-45% percent of all waste is disposed of into landfills; the rest of the waste is reused, recycled and transformed to an economic asset in the EU-27. However, Table 2.7 shows that the rates of recovered or reused waste are very low in Turkey. Turkey's adaptation process to European Union is a critical issue in terms of environment. Waste management might be the first step in order to provide harmonization with the EU. Waste management includes the minimisation, collection, transport, processing, recycling, disposal, and monitoring of the waste materials. A typical waste management system comprises minimisation, collection, transportation, pre-treatment, processing, and the final abatement of residues. The waste management system also consists of the whole set of activities related to handling, treating, disposing or recycling of the waste materials.

The United States Environmental Protection Agency (US EPA) first used the waste minimization procedure, developed it and extended it with additional steps which were found appropriate for use in process industries in order to get optimal waste minimization options. Reyes-Cordoba et al. (2008) suggests that in industrial applications, the implementation of existing methodologies for waste minimisation has failed to get significant benefits. The lack of a comprehensive approach that integrates and guides the application of the proper tool depending on the case accounts for this. Existing methodologies have been prepared for particular steps in the process of life cycle and they need detailed information which may not be available and could result in being too costly to obtain.

According to Waste Minimisation, London UK (1995), waste minimisation is the extensive term applied to a variety of measures that protect resources through the abatement of raw materials.

The UK Environment Agency, An Environmental Good Practice Guide for Industry (1997) defines waste minimisation as: ‘‘the reduction of waste at source, by understanding and changing processes to reduce and prevent waste". This is also known as process or resource efficiency. Waste minimisation also includes the substitution of less environmentally harmful materials in the production process.’’ From a range of national descriptions, a composite working definition has been produced, it is: ‘‘Prevention and/or

reducing the generation of waste, improving the quality of waste generated, including reduction of hazard and encouraging re-use, recycling and recovery'' (Institute of Wastes Management, Northampton UK, 1996).

Phillips et al. (1998) suggests that waste minimisation needs to develop its definition and it will be subscribed to by a range of agencies and that can be used in a wide variety of contexts in the UK. Notwithstanding this, a significant number of publications have been produced extolling the benefits of waste minimisation to the commercial, industrial as well as the domestic sector. A wide range of organisations have produced guides for all sectors. Promoting the waste hierarchy is required so that more emphasis is placed upon minimisation. Limitations and issues need further investigation, particularly the hierarchy's applicability and use for local authorities concerning domestic waste (Wilson, 1995). In some cases the hierarchy must be viewed only as a guide to find the best practical environmental option. The possible financial benefits for companies need also to be stated more carefully and perhaps conservatively. It has been shown that annual first year savings, on average, are around 0.27% of turnover and that assuming the cost of implementing is around £6000, companies with less than £2.2 million turnover may not consider the effort to be beneficial (Johnston and Stokes, 1995). Productivity needs to be considered in more sophisticated environmental terms (Chung et al., 1997). For analysing waste management systems, the innovative methods need to be developed (Chang et al., 1996).

Different versions of solid waste treatment hierarchies exist. The following order (Figure 2.3) is suggested as one of those affordable hierarchies (Finnveden et al., 2005).

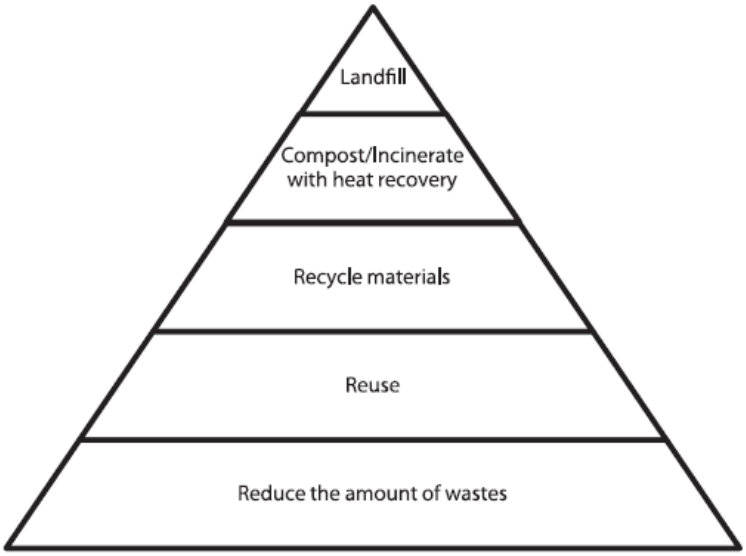

Figure 2.3. A hierarchy of solid waste management (Othman et al., 2013).

Salihoğlu (2010) underlines that the high consumption of chemicals in the industrializing world has caused many residual hazardous substances. In line with increasing consumption chemicals, contaminated wastes are produced and they have reached to threatening levels in terms of quantity and hazardous content. The increasing use of chemicals in the industrializing world has resulted in many residual hazardous substances. Wastes produced due to increasing trend of consumption have reached to threatening levels in terms of quantity and hazardous content.

In Turkish Hazardous Waste Control Regulation, wastes having one or more of the features of "being explosive, flammable, combustible, producing flammable gases, causing oxidation, corrosiveness, causing acute and/or chronic poisoning, leading to infection and forming toxic gas, being eco-toxic and producing liquid extraction" are identified as 'hazardous waste'. Hazardous waste list of Turkey is prepared in line with the European Waste Catalogue (2000/532). Hazardous Waste Control Regulation adopts the main Hazardous Waste Minimisation hierarchy approach, which is shown in Figure 2.4 (a), for preventing waste formation at source, reduction, recycling, incineration/energy production, and disposal. However, the pyramid operates inversely in Turkey; both solid and hazardous wastes are mostly disposed in landfill sites and although very limited, some are reused through incineration and energy production (Yetis, 2007).

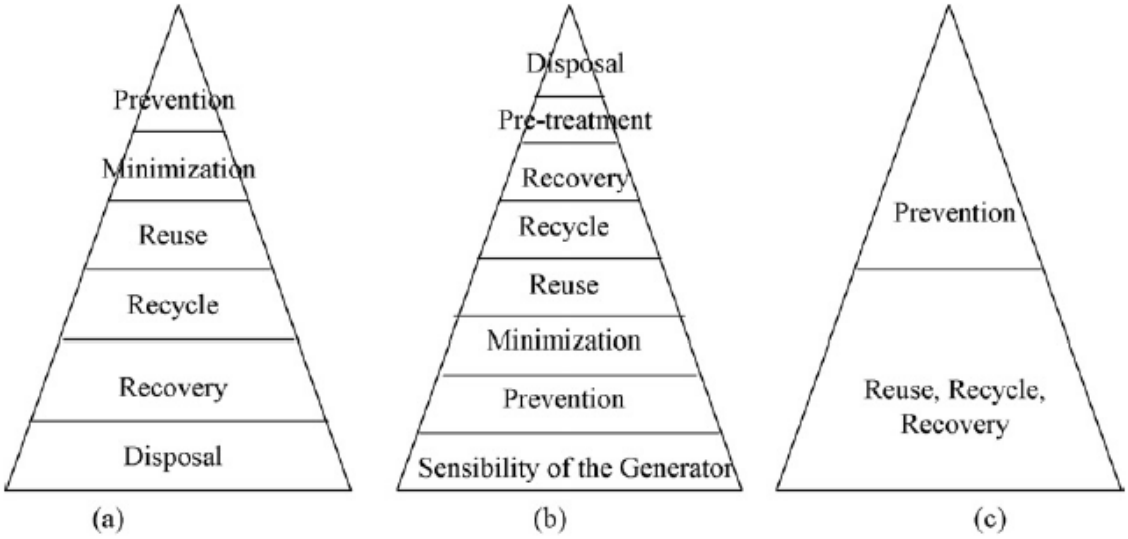

Figure 2.4. Hazardous waste management hierarchy in Turkey, (a) existing state, (b) targeted state, (c) targeted after 2020 (Salihoğlu, 2010).

2.5. Emissions and Odour

The control of volatile organic compounds (VOCs) is an important part of reducing odour and emissions in the synthetic leather producing processes. Air Resources Board (1978) puts forward that emissions of these volatile organic compounds (VOCs) cause serious odour problems and adverse health effects. National Archives and Records Administration (1998) and US EPA (1977) underlines that the vapours are absorbed rapidly from the lungs and taken up readily from the gastrointestinal tract, but poorly through the skin. They are deposited in adipose tissue and in the central nerve system. The effects of VOCs on the central nerve system are related to dizziness, weakness, confusion, and co-ordination. Wadden et al. (1995) and Smith and Brown (1993) demonstrates that sniffing of VOCs has also resulted in some cases in life threatening metabolic acidosis characterized by a high anion gap or by hyperchloremia and other findings consistent with renal tubular acidosis.

Khan and Ghoshal (2000) demonstrate that the techniques for controlling the VOCs emissions, which are shown in Figure 2.5, can be classified as two main groups: (i) process

and equipment modification and (ii) add-on-control techniques. In the first group, modification of the process equipment is applied to control of VOCs emissions. In the second group, an additional technique has to be adopted to control emissions. Although the first group is the most effective and efficient method, its applicability is limited, it is not possible to modify the process and/or the equipment. The techniques in the second group are further classified into two sub-groups, namely the destruction and the recovery of VOCs. Two possible approaches to control VOC emissions are recovery and destruction. Recovery methods are adsorption and condensation. Destruction methods are incineration and biodegradation. The appropriate technology is determined through the economic and applicability factors. Recovery technologies enable cost and energy saving. Destruction technologies provide the benefit of not requiring subsequent disposal of the VOC. Recovery methods are effective in high value VOCs. Mixtures or low value solvents favour destruction methods. Analysis of various VOCs control techniques are shown in Table 2.8.

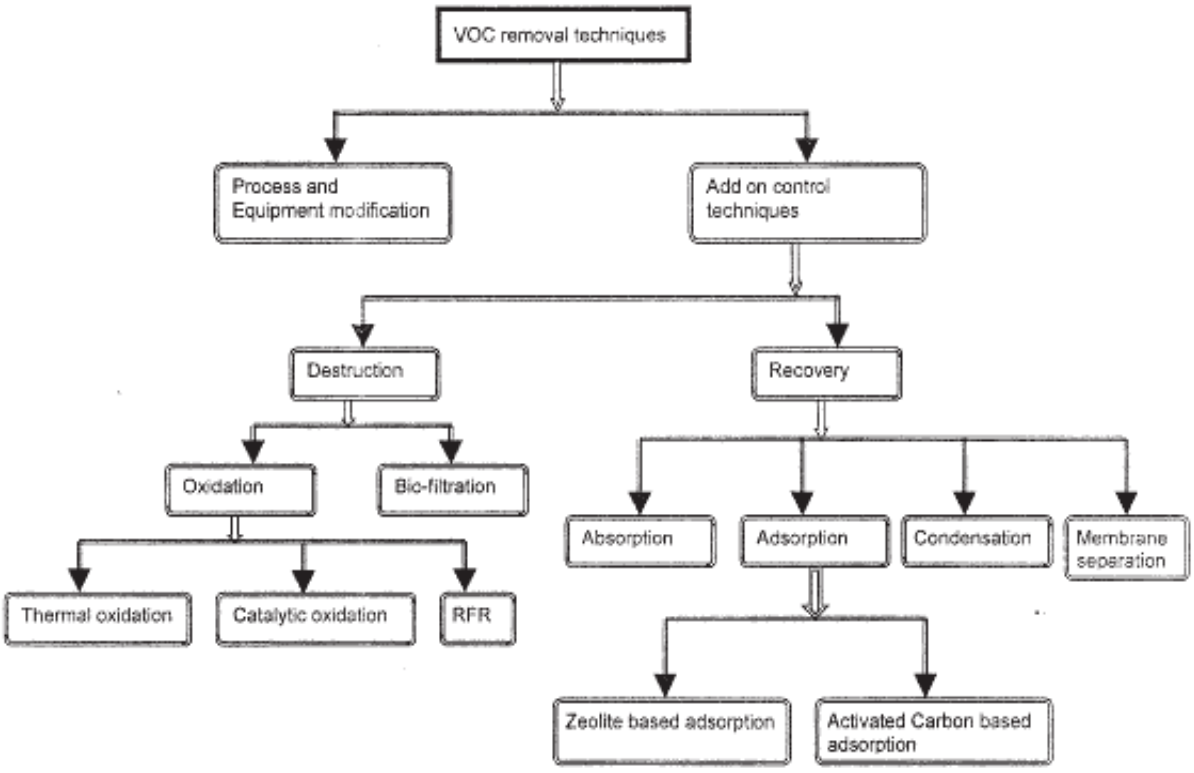

Figure 2.5. Control techniques of the VOCs emissions (Khan and Ghoshal, 2000).

Thermal incineration of VOCs has been evaluated by means of a two step series reaction approach, VOC → CO → CO_2, so that the rates of VOCs and CO oxidation may both be considered. Temperature and concentration profiles have been obtained for oxidation of several VOCs as functions of space time *t*. Appropriate conditions for 99.99% removal of VOCs and 99.5% oxidation of intermediate CO appear to be 930 to 980K inlet temperature, 0.05 to 0.06 kmol auxiliary fuel per kmol dry waste air and 90 to 130% excess air for auxiliary fuel, without heat recovery. These conditions yield approximately 0.4 seconds space time and an *L*/*di* ratio for the oxidation section of the incinerator of approximately 2 to 3. Heat loss from the incinerator should be less than 2% of the total heat from auxiliary fuel and VOCs combustion and incinerator design should therefore be optimized with respect to fuel and insulation costs (O'Reilly, 1998).

Table 2.8. Analysis of various VOC control techniques (Khan and Ghoshal, 2000).

Techniques	Annual operating cost $/cfm	Removal efficiency %	Secondary waste generated	Positive remarks	Negative remarks
Thermal oxidation	15–90 for recuperative, 20–150 for regenerative	95–99	Combustion products	Energy recovery is possible (maximum up to 85%)	Hallogenated and other compounds may require additional control equipment downstream
Catalytic oxidation	15–90	90–98	Combustion products	Energy recovery is possible (maximum up to 70%)	Efficiency is sensitive to operating conditions. Certain compounds can poison the catalyst. May require additional control equipment downstream
Bio-filtration	15–75	60–95	Biomass	Requires less initial investment, less non-harmful secondary waste, and non-hazardous	Slow, and selective microbes decomposes selective organics, thus requires a mixed culture of microbes (which is difficult). No recovery of material.
Condensation	20–120	70–85	Condensate	Product recovery can offset annual operating costs	Requires rigorous maintenance. Not recommended for the materials having boiling points above 33°C
Absorption	25–120	90–98	Wastewater	Product recovery can offset annual operating costs	Requires rigorous maintenance. May require pretreatment of the VOCs. Design could be difficult due to lack of equilibrium data
Adsorption					
Activated carbon	10–35	80–90	Spent carbon and collected organics	Recovery of compounds, which may offset annual operating costs	Susceptible to moisture, and some compounds (ketones, aldehydes, and esters) can clog the pores, thus decreasing the efficiency
Zeolite	15–40	90–96	Collected organic, spent zeolite after several cycles	Effective in more than 90% RH, Recovery of compounds offsets annual operating costs	High cost of zeolite, restricted availability.
Membrane separation	15–30	90–99	Exhausted membranes	No further treatment, recovery of solvent may offset the operating costs	Membranes are rare and costly

Incineration removes VOCs from low-concentration airstreams, but incineration of the VOCs requires additional fuel to heat the system. Incineration is a rapid, exothermic oxidation process that converts VOCs to carbon dioxide and water. Organic material in the off gas is destroyed by incineration; therefore, recovery and reuse of solvents are not possible. Combustion of waste gas with a low heating value may require auxiliary fuel to maintain the desired combustion temperature. Waste gas with heating value sufficient to burn may still require auxiliary fuel for flame stability and to maintain a sufficiently high furnace temperature to ensure complete combustion of VOCs. Preheating the combustion air by means of a heat exchanger will decrease the auxiliary fuel requirement. Problems can occur if a VOC is relatively non-combustible and its decomposition leads to noxious or toxic gases (Engleman and Hunter, 1999).

Aoife Grant et al. (2010) estimate that NMVOC emission could contribute 500 Tg C yr_1 as CO_2. Suntharalingam et al. (2005) suggests that 220 Tg C yr_1 as CO_2 was created from the oxidation of NMVOCs, an estimate solely based on weighted average CO production from NMVOCs oxidation (Duncan et al., 2007). Methane was also assumed to undergo quantitative conversion to CO_2 (CH_4 ¼ 0:96), contrary to results obtained by the study of Aoife Grant et al. (2010). Global budget estimates of CO_2 production from VOCs oxidation (Aoife Grant et al., 2010), assuming all CO produced from each VOC is oxidised to CO_2, is shown in Table 2.9. Thermal incineration of VOCs can produce nitrogen oxides. Factors affecting the rate of nitrogen oxide formation during combustion include the following: the rate of excess air available, the peak flame temperature, the length of time that the combustion gases are at a peak temperature, and the cooling rate of the combustion products.

Table 2.9. Global CO_2 production from VOC oxidation (Aoife Grant et al., 2010).

Tg C yr_1 as CO_2			
NOx	0 pptv	160 pptv	2000 pptv
Methane	245.96	363.96 ± 127.38	361.69
Ethane	1.54	6.14 ± 2.57	6.87
Propane	0.24	0.90 ± 0.31	1.42
$>C_4$ alkanes	3.40	21.66 ± 8.01	37.65
Ethene	9.13	13.01 ± 4.94	13.49
Propene	2.02	4.98 ± 1.94	5.20
trans-2-Butene	2.91	5.90 ± 2.59	6.20
Benzene	0.75	1.53 ± 0.47	2.49
Toluene	1.52	3.33 ± 1.03	4.11
Formaldehyde	1.92	1.92 ± 0.67	1.92
Isoprene	257.96	384.29 ± 153.72	405.81
α-Pinene	2.91	24.27 ± 7.77	36.60
β-Pinene	2.57	9.66 ± 2.99	18.86
Methanol	66.45	67.0 ± 23.45	66.79
Total NMVOC Excl. CO_2 from CO oxdn.	69.9	147.2	175.0
All routes	353.3	544.6 ± 210.5	607.4
Total VOC (incl. others)[c]	599.3	915.5[c]	969.1

According to Turkish Statistical Institute's survey about Turkey's total greenhouse gas emits between 1990 and 2010 is shown in Table 2.10.

Table 2.10. Turkey's total greenhouse gas emits (Turkish Statistical Institute, 2010).

Years	million tonnes of CO_2 equivalent					The rate of increase compared to 1990 (%)
	Energy	Industrial Treatments	Agricultural Activities	Wastes	Total	
1990	132,13	15,44	29,78	9,68	**187,03**	**-**
1995	160,79	24,21	28,68	23,83	**237,51**	**26,99**
2000	212,55	24,37	27,37	32,72	**297,01**	**58,80**
2005	241,75	28,78	25,84	33,52	**329,90**	**76,39**
2006	258,56	30,70	26,50	33,88	**349,64**	**86,95**
2007	288,69	29,26	26,31	35,71	**379,98**	**103,16**
2008	277,71	29,83	25,04	33,92	**366,50**	**95,96**
2009	278,33	31,69	25,70	33,93	**369,65**	**97,64**
2010	285,07	53,90	27,13	35,83	**401,92**	**114,90**

Waste gas is one of the main environmental issues of many industries and production processes at the local, regional or even global scale. The emission minimising is an essential measure to protect both public health and the environment. Complaints from the public due to odorous emissions from or waste gases of industries are increasing significantly in many countries. This leads to more emphasis on odour assessment (Mahin, 2001; Sucker et al., 2001; Frechen, 2000).

Schlegelmilch et al. (2005) suggest that there is a large variety of options available for treating the odorous emissions effectively. For a sustainable solution of an industrial odour problem, there is more involved than just the installation of a waste gas treatment system. Firstly, an odour assessment should be done where all actual and potential odour emission sources are recorded and characterised. Fugitive emissions, which may have an enormous impact on the overall odour problem, are important so they need more focusing. According to the composition and condition of the waste gases, an appropriate treatment system must be selected.

Schlegelmilch et al. (2005) underlines that people are sensitive to very low concentrations of odorous substances so the treatment of odorous emissions is required for lots of industrial processes. The applicability of the different treatment processes mainly depends on the composition, temperature, amount, moisture, and particulate content of the waste gas. Demand and availability of land area and the financial budget are the crucial parameters for the feasibility of a treatment process design. For the treatment processes, it can be impossible to reach the required efficiencies. Thus, selection and design of suitable treatment processes must focus on to find an optimum where the required treatment efficiency is achieved as cost-effectively as possible, using a technology that is adapted to the specific conditions. Combination of different treatment methods is more effective than the using only one treatment system. Commonly used odour treatment processes along with corresponding design options are shown in Table 2.11. The main task is to know which system is best applicable for a specific odorous emission through this treatment options.

Table 2.11. Odour treatment processes (Schlegelmilch et al, 2005).

Process	**Options**
Adsorption	Different adsorbents (activated carbon, activated alumina, silica gels, zeolites, etc.)
Absorption	Physical absorption; chemical absorption
Biological waste gas treatment	Bioscrubbers; biotrickling filters; biofilters
Waste gas incineration	Thermal afterburners; catalytic incinerators; regenerative thermal oxidation (RTO)
Non-thermal oxidation processes	Ozone, UV, non-thermal plasma

The molecules of odorous compounds attach to solid surfaces in adsorption processes. Commonly used adsorbents are activated carbon, activated alumina, silica gels and zeolites. In industrial applications, adsorbers are mostly designed as fixed bed reactors, with the gas passing through a stationary bed. Adsorption is commonly used as an enrichment step prior to thermal gas treatment (Anguil, 1998). It can also be combined with other technologies, like biofiltration.

In the absorption process, compounds of the waste gas are dissolved in a scrubbing liquid. The solubility of the substances and the gas–liquid interfacial surface mainly control the mass transfer (Buonicore, 1992). The selection of a suitable solvent is critical for the solubility, as discussed by Freudenthal et al. (2005). Packed columns, jet and venturi scrubbers, plate columns and spray scrubbers are used to provide a large interfacial surface (Fischer, 2001; Heining, 1998; Buonicore, 1992). Chemicals are added to the scrubbing liquid which will react with the dissolved waste gas compounds and thus add to the scrubbing liquid regeneration. In these cases, the reaction products must be removed. Applying to the oxidants is also common in chemical scrubbing (Valentin, 1993). In the absorption processes, chemical application is high, and reaction products must be removed and treated or disposed. The advantage of this process is the formation of an ammonium sulphide solution, which can be sold as a fertiliser. This process often is combined with a subsequent biofilter to remove remaining odours (Hahne and Vorlop, 2001; Sattler et al., 2000). Acidic substances, like hydrogen sulphide (H_2S) can be treated with caustic scrubbers using diluted sodium or potassium hydroxide. This way, organic sulphur compounds can also be removed (Dammann et al., 2001). Salt or sludge is generated and they cause considerable costs for disposal (Fischer, 2004).

Biological waste gas treatment systems depend on the activity of microorganisms, which are able to degrade organic contaminants from the emission system (Bardtke, 1990). The microorganisms oxidise odorous substances to CO_2 and H_2O or other odourless products. Thus, biological systems sustainably diminish odorous emissions. In biological treatment systems, few chemicals must be applied. The costs of the system such as investment, operational and energy costs are relatively low. They are operated at atmospheric pressure and ambient temperatures (Ergas and Cardenas-Gonzales, 2004; Devinny et al., 1999). Biofilters and bioscrubbers/biotrickling filters are commonly used for the treatment of odorous emissions as a biological waste treatment system.

UV treatment or non-thermal plasma as ‘‘cold’’ oxidation techniques are used for the treatment of the odorous exhaust air. The technology is based on the UV induced formation of highly reactive radicals and ions which can oxidise organic molecules. High performance UV radiators are used for effective treatment, resulting in a very high energy demand not considered suitable for treatment of odorous waste gas (Fischer, 2001; Fischer,

2004). In investigations at several plants using non-thermal plasma technology, Fischer (2004) measured efficiencies between 0% and nearly 100%. The composition of the waste gas and process technology affect the results. The results of applying a non-thermal ionisation system show that a removal of the identified main odour causers (limonene, *a*-pinene and dimethyl disulfide) in the waste gas of the biological waste treatment is possible under optimal process configurations (Steinberg et al., 2004).

Schlegelmilch et al. (2005) puts forward that thermal treatment can be basically applied to any exhaust gas. As a general rule, the lower limit for autothermal combustion is a concentration of organic compounds of 1 g/m^3. For thermal treatment, catalytic and non-catalytic techniques are applied. Catalytic processes can be done at lower temperatures, resulting lower energy demand. In addition for non-catalytic processes, energy costs can be significantly decreased by using advanced systems with heat recovery (recuperative thermal oxidisers, regenerative thermal oxidisers). Thermal waste gas treatment has gained in importance due to more stringent exhaust air requirements in recent years. Furthermore, thermal waste gas treatment may be considered on sites where a combustion facility is operated anyway, e.g., for steam generation. However, corrosion and deposits on the combustion unit may occur depending on the composition of the waste gas. Thermal waste gas treatments have the high operating costs for providing the natural gas addition and they cause the formation of secondary emissions like nitrous and sulphur oxides.

2.6. Legal Procedures

According to Turkish legislation, the facility should be in conformity with the legal laws and regulations which are determined and listed in Table 2.12.

Table 2.12. Turkish environmental legislations related with the middle scale facilities.

Laws & Regulations	**Date**
Law of Environment	09.08.1983
Environmental Impact Assessment Regulation	16.12. 2003
Environmental Noise Assessment and Management Regulation	04.06.2010
Hazardous Chemicals Regulation	11.07.1993
Hazardous Waste Control Regulation	14.03.2005
Industry Based Air Pollution Control Regulation	03.07.2009
Packaging Wastes Control Regulation	24.08.2011
Solid Wastes Control Regulation	14.03.1991
Vegetable Waste Oil Control Regulation;	19.04.2005
Waste Batteries and Accumulators Control Regulation;	31.08.2004
Waste Oil Control Regulation	30.07.2008
Water Pollution Control Regulation	31.12.2004
General Principles of The Waste Management Regulation	05.07.2008
Control of Odor Causing Emissions Regulation	04.09.2010
Soil Pollution Control and Point Source Contaminated Fields Regulation	08.06.2010

In accordance with Industry Based Air Pollution Control Regulation, (2009), legal emission limits, related with the facility, are shown in Table 2.13

Table 2.13. Emission limits related with the facility (Industry Based Air Pollution Control Regulation, 2009).

Type of Pollutant	**Limit Values**
Boiler Stack Height (from roof) (m)	3
Gas Velocity (m/sec)	4
The Concentration of Dust (mg/Nm^3 3% ref O_2)	10
Dust Emission (kg/h)	10
The Concentration of CO (mg/Nm^3 3% ref O_2)	100
The Concentration of SO_2 (mg/Nm^3 3%ref O_2)	100
SO_2 Emission (kg/h)	60
NO Emission (kg/h)	20
The Concentration of NO_2 (mg/Nm^3 3% ref O_2)	800
Process Stack Height (from roof) (m)	1,5
CO (kg/h)	500
NO_2 (kg/h)	40
VOC (kg/h)	30

In accordance with Control of Odour Causing Emissions Regulation, emission limit values are defined in a facility which is running at full capacity conditions. At least three odour samples should be taken from the source of emissions at different times, days and hours. The samples should be measured by olfactometer. If the average odor concentrations of the samples are;

a) 1000 Odour Unit/m^3 or less, in the facility, no action shall be taken on the odor removal.

b) in the range of 1000-10000 Odour Unit/m^3, odour measurements can be made around the facility.

c) greater than 10,000 Odour Unit/m^3, odour source prevention techniques and methods should be used.

According to Water Pollution Control Regulation, if the facility discharges to the sewage system, discharge water characteristics should adopt the discharge limits of regional sewerage. The synthetic leather production facilities do not generate process wastewater. In Turkish regulations there is no specific discharge limits for synthetic leather production facilities. The synthetic leather facilities should conform to the general wastewater discharge standards in their region. In line with Istanbul Water and Sewerage Administration Discharge Limits Regulation (2003), the synthetic leather facility discharge limits are given in Table 2.14.

Table 2.14. The discharge limits of the facility (Istanbul Water and Sewerage Administration Discharge Limits Regulation, 2003).

Type of Pollutant	**Limit Values**
Temperature (^{0}C)	40
pH	6.5-10.0
Suspended Solids (mg/L)	500
Oil and Grease (mg/L)	250
COD (mg/L)	4000
SO_4^- (mg/L)	1700
Total Sulphur (mg/L)	2
Phenol (mg/L)	20
Free Chlorine (mg/L)	5
Total Nitrogen (mg/L)	-
Phosphorus (mg/L)	-
Arsenic (mg/L)	3
Total CN^- (mg/L)	10
Total Pb (mg/L)	3
Total Cd (mg/L)	2
Total Cr (mg/L)	5
Total Hg (mg/L)	0.2
Total Cu (mg/L)	2
Total Ni (mg/L)	5
Total Zn (mg/L)	10
Total Sn (mg/L)	5
Total Ag (mg/L)	5
Cl^- (mg/L)	1000

In Turkey, industrial waste is managed according to the Solid Waste Control Regulation (1991) and the Hazardous Waste Control Regulation (1995). These regulations underline the principles of collection, transportation, recycling, reuse, recovery and disposal of industrial waste. Turkish Regulations stipulate that waste has to be disposed of by an appropriate method. In accordance with Hazardous Waste Control Regulation, hazardous waste has to be disposed of separately from non-hazardous waste in sanitary landfills. Leachate and gas control practices are also well defined in these regulations. Although, according to the regulations, the term ‘waste management’ refers to source

minimization, collection, transformation, reuse or/and recycling and disposal. The solid waste should be collected separately according to their types for preventing the environmental pollution and contributing to the economy. Related to the same regulations, solid waste collection and transportation should be provided by sealed garbage containers. In accordance with the principles of Hazardous Waste Control Regulation, hazardous waste should be disposed of and transport by licensed companies. Contaminated waste is identified in Hazardous Waste Control Regulation.

3. PREVIOUS SITUATION OF THE SYNTHETIC LEATHER FACILITY AND THE SUGGESTED ENVIRONMENTAL STRATEGY

The present study is specifically concerned with diminishing the environmental effects of a medium scale synthetic leather facility located in Marmara Region. The capacities of the synthetic leather manufacturing facility approximately are; 3.000.000 m^2/year as PVC synthetic leather and 350.000 m^2/year as PVC polyurethane synthetic leather. Facility was established on 2500 m^2 closed area in 2007. Although it was established five years ago, its machineries are too old. The facility aims to be an example for high-quality artificial leather manufacturing industries. The facility also aims to provide qualified service and production for both domestic and foreign markets. The productions of the facility are bags, shoes, garments, upholstery, slippers, etc. exported to Europe, North Africa, the Middle East and twenty countries. PVC and polyurethane-based synthetic leather production is only carried out by the facility.

3.1. Synthetic Leather Manufacturing Processes Used in the Studied Facility

PVC powder, DOP (dioctyl phthalate), PVC stabilizers (based on Ca and Zn salts), calcite, titanium oxide, nitrogen dicarbon amide, various pigments and dyes, mineral spirits and kerosene are raw materials used in the synthetic leather production. Raw materials are weighed and put into high-speed blender according to their types. Mixing is continued till a homogeneous mixture is obtained. After the mixing operation, the synthetic leather pulp is passed through single-triple cylinders (rolls). In this stage synthetic leather pulp is mixed once again in single-triple cylinders for a good homogenization. The synthetic leather pulp is thinned to decrease its viscosity as "Release Paper" and poured & spread on silicone paper. Spread product is subjected to baking operation in the baking ovens. Baking ovens consist of three pre-baking oven (dimensionally; 6.5m, 8.0m and 11m and the temperature of the oven is; 160 ^{0}C), a

lamination furnace (dimensionally 17.0 m and the temperature of the furnace is; 230 ^{0}C) and a cooling channel. The synthetic leather pulp is baked in the pre-baking ovens and then it goes to the chemical swelling process in lamination oven at 230 ^{0}C. After the chemical swelling process in lamination oven, the product is cooled in cooling channel and then winding process starts. In the winding process, the product is separated as the carrier paper and leather. Synthetic leather is printed through to customer demand as pattern, embossed, perforated, lacquer and sanding. At the end of the process, the product is subjected to the quality control and packed. The flow chart of the synthetic leather production process is drawn in Figure 3.1. The some synthetic leather product photos of the facility were taken in the facility and they are shown in Figure 3.2.

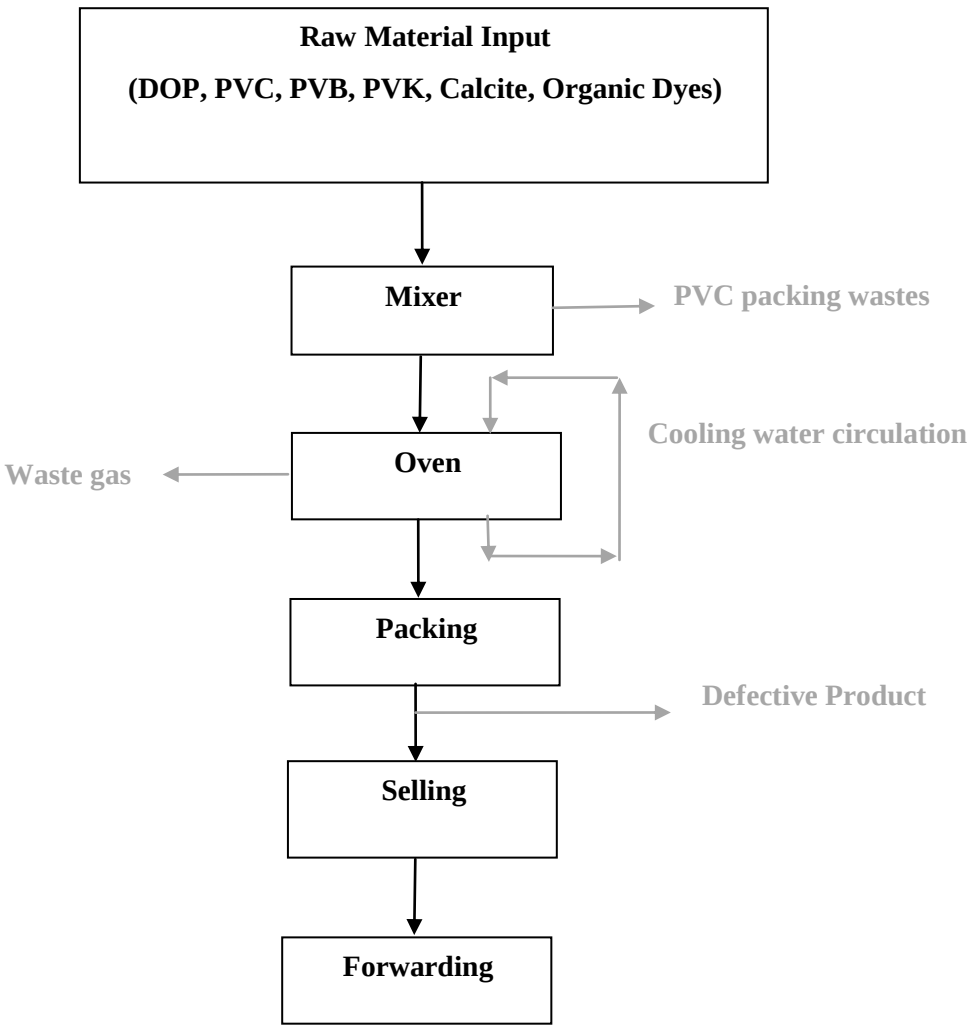

Figure 3.1. Synthetic leather manufacturing process flow chart.



Figure 3.2. Synthetic leather products of the facility.

Monthly synthetic leather production, is taken from the private synthetic leather facility's capacity report in 2009, is given in Table 3.1. The chemicals like PVC, DOP, $CaCO_3$, ADC, polyurethane and permuthane are used to produce the pulp of the synthetic leather. The chemical consumption, is taken from the private synthetic leather facility's capacity report in 2009, is given in

Table **3.2**.

Facility Layout and plant machinery layout are taken from the facility and shown in Figure 3.3 and Figure 3.4 respectively. On the facility layout, the letters are used as unit codes. In the layout; layout codes' mean; a: administrative building, b: cafeteria, c: fuel tank and fuel oil boiler, d: chemical site, e: stair gaps, f: DOP tanks, g: overwhelming unit, h: mixers, i: baking ovens, j: quality control and enwrapping unit, k: paper repair unit, l: embossing machinery unit, m: raw materials storage area, n: fabric opening, o: paper stock area, p: fabric stock area, q: finished product area, r: drilling machinery unit, s: packing and t: treatment system.

Table 3.1. Monthly production rates of the facility (Capacity report of the synthetic leather facility, 2009).

Months (2009)	**Synthetic Leather Production Rates (m)**
January	307.000
February	315.000
March	426.000
April	380.000
May	480.000
June	602.000
July	500.000
August	425.000
September	400.000
October	485.000
November	355.000
December	400.000
Total Production in 2009	**5.075.000**

Table 3.2. Chemical consumption rates in 2009 (Capacity report of the synthetic leather facility, 2009).

	PVC	**DOP**	**$CaCO_3$**	**ADC**	**Polyurethane**	**Permuthane**
January	144825	93466	28122	2450	4972	1815
February	148655	95938	28866	2514	5103	1863
March	200839	129617	38999	3397	6895	2517
April	179295	115713	34815	3033	6155	2247
May	226453	146147	43973	3830	7774	2838
June	283904	183225	55128	4802	9746	3558
July	235789	152172	45785	3988	8094	2955
August	200361	129308	38906	3389	6878	2511
September	188631	121738	36628	3191	6475	2364
October	228847	147692	44437	3871	7856	2868
November	167566	108143	32538	2834	5752	2100
December	188631	121738	36628	3191	6475	2364
Total Consumption	**2393796**	**1544897**	**464825**	**40490**	**82175**	**30000**

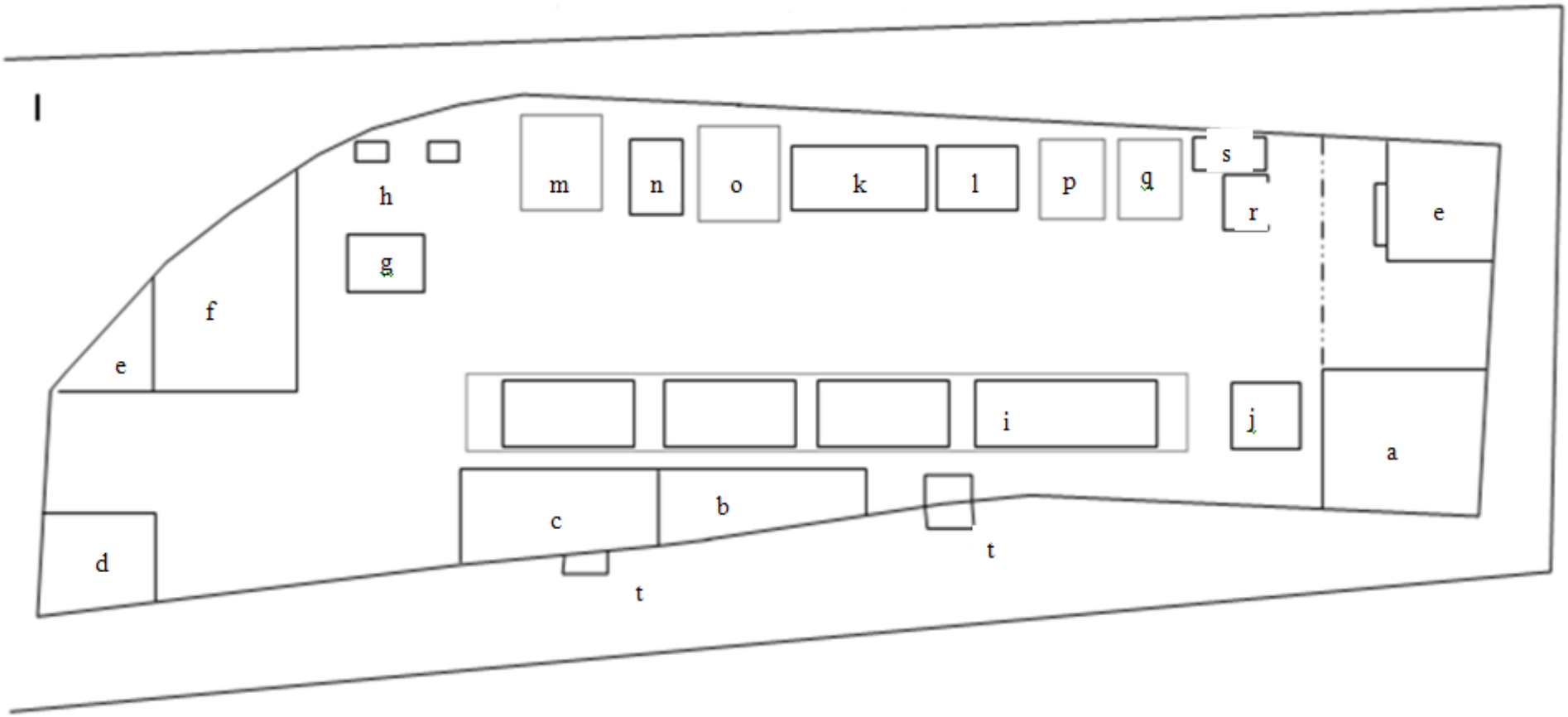

Figure 3.3. Synthetic leather manufacturing facility layout, (Synthetic Leather Facility Layout,2009)

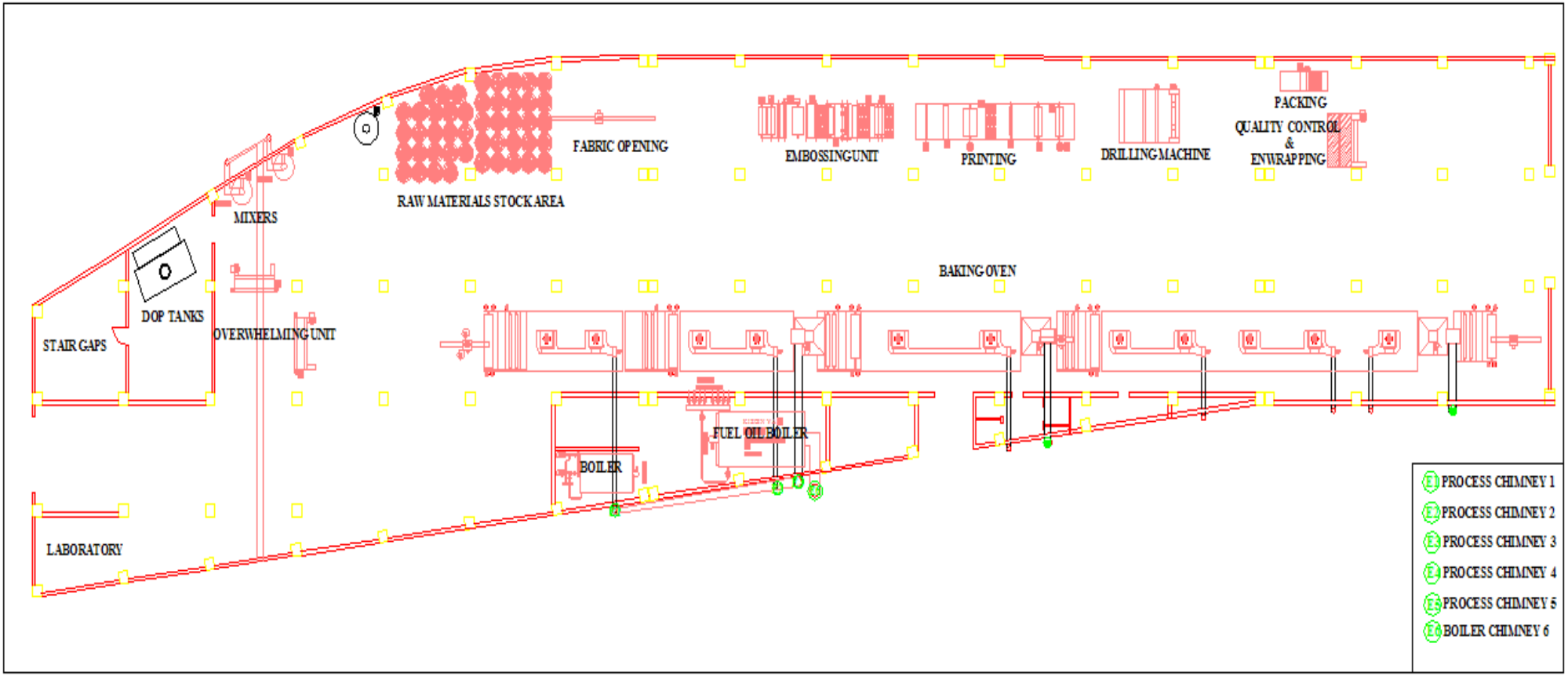

Figure 3.4. Synthetic leather manufacturing facility machinery layout, (Synthetic Leather Facility Machinery Layout, 2009).

3.2. Water Consumption in the Facility

In the facility impact area, the potential use of any surface water source is not available. The rain water is collected from the facility roof by a rain water harvesting system. In the facility the rain water and the tap water are used in a closed circuit water cooling system. Therefore, there is no wastewater sourced from the process. Water circulation points are shown in Figure 3.1. In the facility, the wastewater is sourced only from the domestic use.

The facility has 20 employees, water needs of employees is maximum 200 lt/day. By accepting an average of 100 litres, the need for total water use (drinking and general usage)*:

Qmax = 20 people x 200 litres/person-day = 4000 litres/day = 4 m^3/day.
Qort = 20 people x 100 litres/person-day = 2000 litres/day = 2 m^3/day.

The maximum and average daily water consumptions respectively are 4 m^3/day and 2m^3/day.
* Per capita water consumption values were taken from Metcalf & Eddy (1994).

The determined synthetic leather production facility total water consumption rate was around 65 m^3/ month.

3.3. Energy Consumption in the Facility

The liquefied natural gas (LNG) had been used as an energy source in the production line of the synthetic leather facility. Before the improvements, the monthly electricity consumption of the facility was approximately 812.574kWh. The rate of electrical energy used per meter of product was 0,147 kWh/ meter product.

In 2009, the value of natural gas as fuel consumption was 366.603 m^3/year. In the facility there is one hot oil boiler which has 70% working efficiency. Fuel supply rate of the hot oil boiler was 85m^3/h. In 2009, the thermal capacity of the facility was 2,326 MW. The synthetic leather facility had an LNG tank for energy supply. Monthly LNG consumption rates of the synthetic leather facility are taken from the LNG consumption reports and they are given in Table 3.3. Photo of the LNG tank, taken in the facility, is shown in Figure 3.5. There is a 250kWh capacity generator with a 200 lt capacity diesel tank in the facility.

Table 3.3. Synthetic leather facility LNG consumption rates (The Synthetic Leather Facility LNG Consumption Bills, 2009).

Months	**LNG Consumption (Sm^3)**
January	25.470
February	25.935
March	41.000
April	35.000
May	39.800
June	37.800
July	25.760
August	30.424
September	24.600
October	28.154
November	22.120
December	30.540
Total	**366.603**



Figure 3.5. Synthetic leather facility LNG tank.

The estimated daily electricity usage by the lightning system was 275kw. The detailed information about the lightning system electricity consumption rates are estimated and given in Table 3.4.

Table 3.4. The lightning system estimated electrical consumption rates.

	Number of the lightning	**Consumption (w)**	**Total work time**	**Daily Consumption (kwh)**
Fluorescent	100	250	10 hour	250
Energy Consumption for lightning (kwh)				250
Energy loses (kwh)				25
Average Daily Energy Consumption for Lightning (kwh)				275
Total Annually Energy Consumption for Lightning (kwh)				82.500

Before the improvements, the synthetic leather facility's annual electricity consumption was 812.574kwh. The detailed information about the electrical consumption rates are given in Table 3.4.

Table 3.5. Synthetic leather facility electric consumption rates (The Synthetic Leather Facility Electricity Consumption Bills, 2009.

Months (In 2009)	**Electric (kWh)**
January	78.345
February	80.240
March	72.345
April	76.240
May	79.960
June	59.200
July	67.016
August	65.248
September	39.080
October	76.654
November	73.228
December	45.018
Monthly Average Consumption	67.714
Total Consumption of 2009	**812.574**

3.4. Waste Generation in the Facility

In the facility there was not a waste management procedure and all types of wastes were collected together and the composition of the wastes was identified as domestic solid waste. Domestic solid waste was taken by municipality and disposed to the city's sanitary landfill. There is no formation of a radioactive waste in the synthetic leather manufacturing facility. The hazardous wastes (chemical containers, drums) from chemical usage in the production were taken by manufacturers of the chemicals. Food is provided by sub-contractor so there is no formation of vegetable oil waste. Defective products were sold to subsidiary industries. Wastes, which may occur during the production, were determined and they are listed in Table 3.6. There was no information about contaminated wastes. Although contaminated wastes are identified as hazardous wastes, they were mixed with domestic wastes and they were disposed in municipality's non-hazardous waste landfill.

In line with Eurostat that is the statistical office of the European Union, in 2010, in our country, the average waste generation 1.12 kg/person/day, while the European countries, this value is 1,37 kg/person/day. The average rate of solid waste produced in Istanbul is taken as 1,12 kg/person/day.

Solid waste rate from 20 employees at the facility is;
20 people x1,12 kg/person/day = 22,4 kg/day

Table 3.6. Wastes from synthetic leather production process.

Hazardous Waste Control Regulation Waste Code	**Waste Type**
15	Packing waste, not otherwise specified absorbers, wiping cloths, filter materials and protective clothing
15 01	Packaging (Packaging waste, which is collected separately by the municipality, is included)
15 01 01	Paper and cardboard packaging
15 01 02	Plastic packaging
15 01 03	Wood packaging
15 01 04	Metallic packaging
15 01 05	Composite packaging
15 01 06	Mixed packing
15 01 07	Glass packaging
15 01 10*	Packaging materials which are contaminated by residues of hazardous substances or dangerous substances
15 02	Absorbents, filter materials, wiping cloths and protective clothing
15 02 02*	Absorbents which are contaminated by dangerous substances, filter materials (oil filters not otherwise specified), wiping cloths and protective clothing
15 02 03	Except 15 02 02 absorbents, filter materials, wiping cloths and protective clothing

3.5. Emission Collection and Treatment Systems in the Facility

In synthetic leather manufacturing; PVC powder, DOP (dioctyl phthalate), PVC stabilizers (based on Ca and Zn salts), calcite, titanium oxide, nitrogen dicarbon amide, various pigments and dyes, mineral spirits and kerosene are used as raw materials. Raw materials are weighed according to the type of synthetic leather in the boilers, stirred in high-speed blender until a homogeneous mixture is obtained, and passed in the rollers (waltz). Depending on the formulation, the product is thinned according to the viscosity and poured over a cloth or silicone paper. Products are subjected to oven baking heated by hot oil at 150 – 200 °C. Products are subjected to pattern, embossed, perforated, lacquer-making processes according to the consumer requests. Dense fume is composed of four baking ovens, one embossing unit and the cooling unit. These fumes and organic vapours are sent to the main suction ventilator by the collection channels which are over cooking ovens, embossing and the cooling unit.

The synthetic leather facility has five process stacks and one boiler stack as emission sources. Combustion gases and dust measurements are done in boiler stack. The boiler stacks' analysis results are given in Table 3.7. VOCs and dust analysis are performed by Ekotest, an accredited laboratory. In line with Ekotest report process stacks' analysis results are given in Table 3.8, Table 3.9, Table 3.10, Table 3.11 and Table 3.12. Total emission analysis results are listed in Table 3.13.

Dust concentration measurements were done by using DMS that makes manual isokinetic sampling of flue dust at the roof. Gas analyses were done by using Messtechnick Eheim Visit 02 gas analyzer that works with electrochemical cells measuring principle. VOC measurements were done by the FID Testa device. According to wet bulb thermometer method, moisture determinations were done. Flue gas velocity and flow rate were measured with the principle of pitot tube. Toxic gas concentrations were measured by using electrochemical cells. According to DIN, in soot measuring; an automated manner is used with separate pump, 1.63 liters of gas passed on filter paper and Bacharach scale was used for comparison of the soot amount that was collected in filter paper. Toxic gas concentrations were read within 1 ppm sensitivity, representing

less than 5% of reading error. Dust measurements were done manually by isokinetic sampling device. FID was used for measuring VOC concentrations directly. Measurement methods are listed in Table 3.14.

In the synthetic leather facility, wet scrubber was used for the waste gas treatment. The wet scrubber design of the synthetic leather facility is shown in Figure 3.6. The treatment sludge, which is classified as hazardous waste, was occurred by the synthetic leather facility waste gas treatment system. The synthetic leather production facility did not have a waste management and the treatment sludge was mixed with domestic waste.

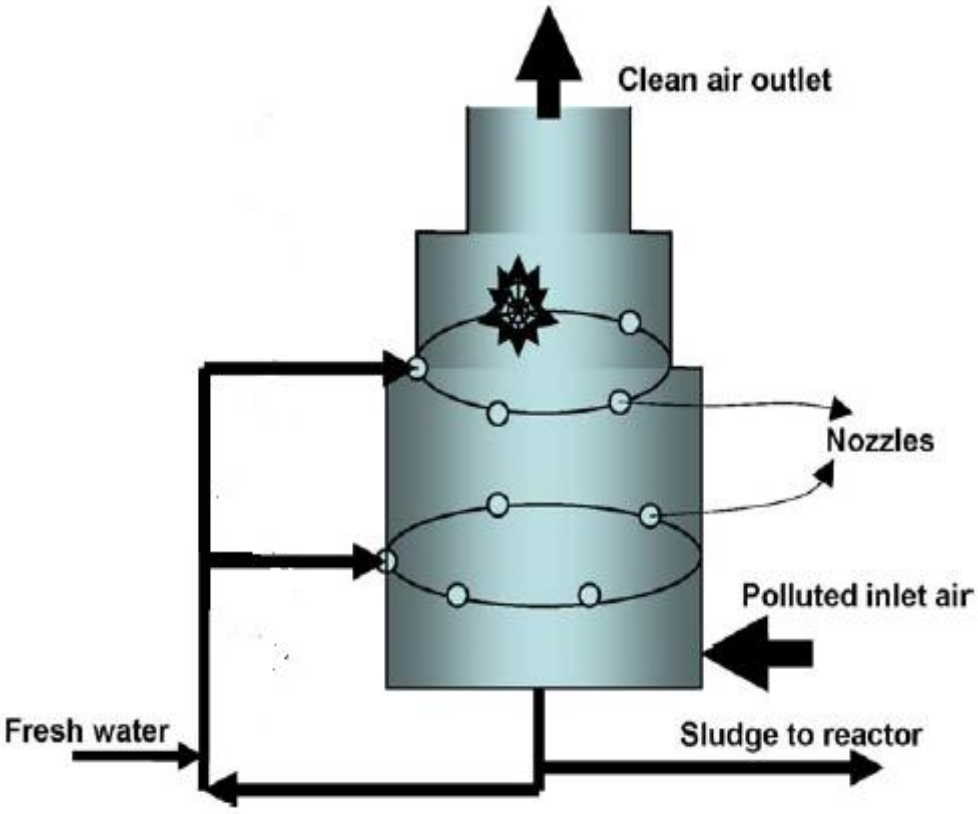

Figure 3.6. Schematic of the spray scrubber (Bozorgi et al., 2006).

Table 3.7. Analysis results of KB 1 (Boiler Flue) (Ekotest Report, 2009).

Fuel Type	LNG				
Fuel Lower Thermal Value (kcal/m^3)	8.250				
Capacity (kcal/h)	2.000.000				
Fuel Consumption (m^3/h)	242,42				
Nominal Thermal Power (MW)	2,326				
Stack Height (from ground), m	17,00				Limit
Stack Height (from roof), m	4,00				3[1]
Analysis Date	17.11.2009				
Analysis	1st	2nd	3rd	Average	
Gas Temperature (^{0}C)	114,1	114,7	114,9	114,6	
Gas Velocity (m/sn)	4,2	4,3	4,2	4,2	4[2]
Cross-Section of the Stack(m^2)	0,126				
Gas flow rate under Operation Conditions (m^3/h)	1899	1944	1899	1914	
Gas flow rate under Normal Conditions (m^3/h)	1262	1290	1259	1270	
The Concentration of Dust (mg/Nm^3)	1,70	1,69	2,22	1,87	
The Concentration of Dust (mg/$Nm^3$3% ref O_2)	6,10	5,95	7,82	6,33±1,92	10[3]
Dust Emission (kg/h)	0,002	0,002	0,003	0,002±0,001	10[4]
The Concentration of CO (mg/Nm^3)	12,50	18,75	17,50	16,25	
The Concentration of CO (mg/Nm^3 3% ref O_2)	45,00	66,18	61,76	57,65±12,09	100[3]
CO Emission (kg/h)	0,016	0,024	0,022	0,021±0,004	5[5]
The Concentration of SO_2 (mg/Nm^3)	*	*	*	*	
The Concentration of SO_2 (mg/Nm^3 3% ref O_2)	*	*	*	*	100[3]
SO_2 Emission (kg/h)	*	*	*	*	60[5]
The Concentration of NO (mg/Nm^3)	9,38	10,71	8,04	9,38	
NO Emission (kg/h)	0,012	0,014	0,010	0,012±0,002	20[5]
The Concentration of NO_2 (mg/Nm^3)	14,38	16,43	12,32	14,38	
The Concentration of NO_2 (mg/Nm^3 3% ref O_2)	51,75	57,98	43,49	51,07±10,747	800[3]
NO_2 Emission (kg/h)	0,018	0,021	0,016	0,018	
The Concentration of O_2 (%)	16,0	15,9	15,9	15,9	
The Concentration of CO_2 (%)	2,8	2,9	2,9	2,9	

*not detected.

Table 3.8. Analysis results of PB 1 (Process Flue 1) (Ekotest Report, 2009).

Induced Draught	**Available**				**Limit Value**
Stack Height (from roof), m	1,50				1,5[1]
Analysis Date	17.11.2009				
Analysis	1st	2nd	3rd	Average	
Gas Temperature (^{0}C)	35,2	35,2	35,3	35,2	
Gas Velocity (m/sn)	8,4	8,3	8,4	8,4	4[2]
Cross-Section of the Stack (m^2)	0,300				
Gas flow rate under Operation Conditions (m^3/h)	9072	8964	9072	9036	
Gas flow rate under Normal Conditions (m^3/h)	7883	7789	7880	7851	
The Concentration of Dust (mg/Nm^3)	2,90	3,15	2,92	2,99±0,866	173[3]
Dust Emission (kg/h)	0,023	0,025	0,023	0,023±0,007	10[4]
The Concentration of VOC (mg/Nm^3)	14,95	14,95	15,11	15,00	*
VOC Emission (kg/h)	0,118	0,116	0,119	0,118±0,013	$10^6/3^5$

Note 1: VOC values are given as propane gas.

Note 2: As VOC content; Class II, 1 - di (2-ethylhexyl) phthalate, 2 - Dioktilftalat, Class III, (chloro ethane) has an organic vapour and gas emissions.

Table 3.9. Analysis results of PB 2 (Process Flue 2) (Ekotest Report, 2009).

Induced Draught	**Available**				**Limit**
Stack Height (from roof), m	1,50				1,5[1]
Analysis Date	17.11.2009				
Analysis	1st	2nd	3rd	Average	
Gas Temperature (^{0}C)	23,4	23,4	23,4	23,4	
Gas Velocity (m/sn)	4,9	5,0	5,1	5,0	4[2]
Cross-Section of the Stack (m^2)	0,720				
Gas flow rate under Operation Conditions (m^3/h)	12701	12960	13219	12960	
Gas flow rate under Normal Conditions (m^3/h)	11475	11710	11944	11710	
The Concentration of Dust (mg/Nm^3)	2,98	3,02	2,88	2,96±0,859	169[3]
Dust Emission (kg/h)	0,034	0,035	0,034	0,035±0,010	10[4]
The Concentration of VOC (mg/Nm^3)	16,23	16,39	16,88	16,50	*
VOC Emission (kg/h)	0,186	0,192	0,202	0,193±0,013	$10^6/3^5$

Note 1: VOC values are given as propane gas.

Note 2: As VOC content; Class II, 1 - di (2-ethylhexyl) phthalate, 2 - Dioktilftalat, Class III, (chloro ethane) has an organic vapour and gas emissions.

Table 3.10. Analysis results of PB 3 (Process Flue 3) (Ekotest Report, 2009).

Induced Draught	**Available**				**Limit Value**
Stack Height (from roof), m	3,00				1,5[1]
Analysis Date	17.11.2009				
Analysis	1st	2nd	3rd	Average	
Gas Temperature (^{0}C)	41,1	41,3	41,3	41,2	
Gas Velocity (m/sn)	9,9	9,7	9,6	9,7	4[2]
Cross-Section of the Stack (m^2)	0,063				
Gas flow rate under Operation Conditions (m^3/h)	2228	2138	2160	2190	
Gas flow rate under Normal Conditions (m^3/h)	1899	1860	1840	1866	
The Concentration of Dust (mg/Nm^3)	2,67	2,75	3,30	2,91±0,844	178[3]
Dust Emission (kg/h)	0,005	0,005	0,006	0,005±0,002	10[4]
The Concentration of VOC (mg/Nm^3)	87,27	86,14	86,30	86,57	*
VOC Emission (kg/h)	0,166	0,160	0,159	0,162±0,037	$10^6/3^5$

Note 1: VOC values are given as propane gas.

Note 2: As VOC content; Class II, 1 - di (2-ethylhexyl) phthalate, 2 - Dioktilftalat, Class III, (chloro ethane) has an organic vapour and gas emissions.

Table 3.11. Analysis results of PB 4 (Process Flue 4) (Ekotest Report, 2009).

Induced Draught	**Available**				**Limit Value**
Stack Height (from roof), m	8,00				1,5[1]
Analysis Date	17.11.2009				
Analysis	1st	2nd	3rd	Average	
Gas Temperature (^{0}C)	48,9	49,0	49,0	49,0	
Gas Velocity (m/sn)	9,8	9,9	9,8	9,8	4[2]
Cross-Section of the Stack (m^2)	0,283				
Gas flow rate under Operation Conditions (m^3/h)	9970	10072	9970	10004	
Gas flow rate under Normal Conditions (m^3/h)	8295	8377	8292	8321	
The Concentration of Dust (mg/Nm^3)	2,98	3,03	2,71	2,91±0,844	172[3]
Dust Emission (kg/h)	0,025	0,025	0,022	0,024±0,007	10[4]
The Concentration of VOC (mg/Nm^3)	88,71	88,55	89,36	88,88	*
VOC Emission (kg/h)	0,736	0,742	0,741	0,740±0,089	$10^6/3^5$

Note 1: VOC values are given as propane gas.

Note 2: As VOC content; Class II, 1 - di (2-ethylhexyl) phthalate, 2 - Dioktilftalat, Class III, (chloro ethane) has an organic vapour and gas emissions.

Table 3.12. Analysis results of PB 5 (Process Flue 5) (Ekotest Report, 2009).

Induced Draught	**Available**				**Limit Value**
Stack Height (from roof), m	1,50				1,5[1]
Analysis Date	17.11.2009				
Analysis	1st	2nd	3rd	Average	
Gas Temperature (^{0}C)	30,2	30,2	30,2	30,2	
Gas Velocity (m/sn)	4,7	4,7	4,7	4,7	4[2]
Cross-Section of the Stack (m^2)	0,810				
Gas flow rate under Operation Conditions (m^3/h)	13705	13414	13705	13608	
Gas flow rate under Normal Conditions (m^3/h)	12105	11848	12105	12019	
The Concentration of Dust (mg/Nm^3)	2,31	3,17	3,09	2,85±0,828	169[3]
Dust Emission (kg/h)	0,028	0,038	0,037	0,034±0,010	10[4]
The Concentration of VOC (mg/Nm^3)	17,20	17,68	18,16	17,68	*
VOC Emission (kg/h)	0,208	0,209	0,220	0,212±0,013	10[6]/3[5]

Note 1: VOC values are given as propane gas.

Note 2: As VOC content; Class II, 1 - di (2-ethylhexyl) phthalate, 2 - Dioktilftalat, Class III, (chloroethane) has an organic vapour and gas emissions.

In the process emission sources coded as PB-1, PB-2, PB-3, PB-4 and PB-5, the dust concentrations did not exceed the limit value provided by the regulations for desired conditions.

The emission sources coded as PB-1, PB-2, PB-3, PB-4 and PB-5, the organic and inorganic vapour emissions did not exceed the limit value provided by the regulations for desired conditions.

Table 3.13. Total emissions (Ekotest Report, 2009).

Type of Pollutant	**Total Emissions (kg/h)**	**Limit Values (kg/h)**
Dust	0,123 ± 0,037	10
CO	0,021 ± 0,004	500
NO_2	0,018 ± 0,003	40
VOC	1,425 ± 0,165	30

Table 3.14. Measuring standard methods (Ekotest Report, 2009).

Parameter	Method
Dust	ISO 9096:2003, TS EN 13284-1
CO	ISO 12039:2005
CO_2	ISO 12039:2005
O_2	ISO 12039:2005
SO_2	7935:1999
$NO\text{-}NO_2\text{-}NO_x$	EPA CTM 022:1998
VOC	TS EN 13526:2003, TS EN 12619: 2001

Odour sampling was carried out through the EN 13725 standard. In line with this method, three samples were taken from each measurement point with a vacuum pump.

Olfactometry method (EN13725) is used for analysis of odour measurement. The odour concentration of the sample is determined by the diluting of the sample till the neutral air is obtained. The numerical value of the current sample is the result of the reached odour threshold concentration and the neutral air volume (threshold level of dilution, or the number of odour). The odour concentration unit is rate of the odour / volume or "odour unit/m^3". High amount of the dilution to the threshold odour level refers to the magnitude of the odour concentration.

The synthetic leather facility odour analysis results in the process stacks are shown in Table 3.15. In accordance with Control of Odour Causing Emissions Regulation, odour samples were taken from the facility by TUBİTAK-MAM, when the facility was running at full capacity conditions. Three odour samples were taken from the process stack. The samples were measured by olfactometer. The results show that the average odour concentration of the facility is in the range of 1000-10000 Odour Unit/m^3.

Table 3.15. Odour measurements of the facility (TUBİTAK-MAM, 2009).

Odour Measurement Method	EN 17325			
Sampling Points	Sample 1 OU/m^3	Sample 2 OU/m^3	Sample 3 OU/m^3	Average OU/m^3
In the process Stack	2170	2580	2896	2531

According to the Intergovernmental Panel on Climate Change (IPCC) 2006 guide book, prepared by WHO and UNEP, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are identified as direct greenhouse gases; nitrogen oxides (NO_x), carbon monoxide (CO), non-volatile organic carbons-except methane (NMVOC), perfluoro carbons (PFC), sulphur fluoride (SF_6), and sulphur dioxide (SO_2) gases are identified as indirect greenhouse gases. Fuel consumption is defined as one of the sources of greenhouse gas emissions in the IPCC methodology. The greenhouse gas emissions are calculated by using natural gas consumption of the facility (which is declared as 242.42 m^3/hour by the facility). From fuel consumption at the facility; CO_2 was calculated as 3701.82 tons/year and CH_4 was calculated as 0.331 tons/year.

The exhaust gases, which have nominal thermal power more than 500kW, moved vertically with unimpeded outflow gas from the stack into the atmosphere and the velocity of exhaust gases is measured as over the 4 m / sec. in the process emission sources coded as PB-1, PB-2, PB-3, PB-4 and PB-5.

-ppm

C (mg/Nm^3) = C (ppmV)*(M/22,4)

C (mg/Nm^3): mass concentration in normal conditions (1^0C, 1 atm)

C (ppmV): volumetric concentration

M : Molecular weight of gas

- Transformations of carbon dioxide and oxygen in the extra air

Formulas of carbon dioxide transformations

$$mg/Nm^3\ (ref.) = \frac{CO2\ \%\ (ref.)}{CO2\ \%\ (measured)} \text{ x } mg/Nm^3\ (measured)$$

mg/Nm^3 (ref.): Corrected mass concentration

CO_2% (ref.) : CO_2 percentage as reference

CO_2% (measured): Measured carbon dioxide percentage in the flue gas

mg/Nm^3 (measured): Measured mass concentration in the flue gas

Formulas of oxygen transformations

$$mg/Nm^3\ (ref) = \frac{21 - O2\%\ (ref)}{21 - O2\%\ (measured)} \text{ x } mg/Nm^3\ (measured)$$

mg/Nm^3 (ref.): Corrected mass concentration

O_2% (ref.) : O_2 percentage as reference

O_2% (measured): Measured oxygen percentage in the flue gas

mg/Nm^3 (measured): Measured mass concentration in the flue gas

Transformation of carbon dioxide to oxygen in the extra air

$$O_2\,\% = \frac{21 x CO2\,\%\,(measured)}{CO2\,\%\,(max)}$$

- Calculation of Dust Concentration

(FLW - FFW) / The rate of flow captured (m^3) x n_k =mg/Nm^3

FLW: The last result of the filter weighing (mg)

FFW: The first result of the filter weighing (mg)

3.6. Suggested Environmental Strategy

3.6.1 Suggested improvements to reduce water consumption

In the synthetic leather production facility the estimated maximum and the average daily water consumptions were 4 m³/day and 2m³/day respectively and the determined synthetic leather production facility average water consumption rate was 65 m^3/month. For providing the reduction of the water consumption, the photocell basin taps were suggested. Water distribution system audit was also suggested to prevent water loses. The dye preparation unit was not placed in an area separated from the process line, causing to powder paints to spread the floor in and around the facility. The cleaning of the powder paints increased the water consumption. The separation of the painting unit was suggested for preventing the extra water consumption and indoor pollution of the facility.

3.6.2 Suggested improvements to reduce energy consumption

The synthetic leather manufacturing facility used LNG as an energy source. Liquefied natural gas impounding area, which is shown in Figure 3.5, had a risk of fire. The natural gas was suggested to be supplied from the Istanbul Gas Distribution Industry and Trade inc. transmission network to mitigate the fire risk. The environmental energy audit had not been done before in the synthetic leather facility, so energy audit was also suggested. Additionally another suggestion on lighting system was the change of conventional bulbs with energy saving light emitting diodes (LED) bulbs.

3.6.3 Suggested improvements to reduce waste generation

The synthetic leather facility has different type of wastes as it is mentioned in Table 3.6. The preparation of an integrated solid waste management system was suggested regarding the separate collection and handling of the hazardous waste.

Waste materials, which are generated from manufacturing processes, can be classified as hazardous and non hazardous solid waste. Non hazardous waste is defined as containers and packaging, food scraps, yard trimmings, and miscellaneous inorganic wastes processes and hazardous waste is defined as contaminated wastes from the processes. The waste management system should include the following aims: 1 reduction of total amount of waste by minimization and recycling, 2 recycling of wastes into production cycles as secondary raw material and 3 reductions of waste quantities. The waste management system should be integrated into the synthetic leather manufacturing facility. Waste quantity is an important parameter to determine the waste collection schedule and to transportation of the collected waste. In the waste management strategy, wastes should be collected as their types and disposed by licensed disposing and recycling companies. Environmental friendly technologies should be encouraged in

synthetic leather manufacturing processes and so reduction of waste should be encouraged.

3.6.4 Suggested improvements to reduce emissions

The synthetic leather facility's emission collection system analysis results are presented in Table 3.7, Table 3.8, Table 3.9, Table 3.10, Table 3.11, and Table 3.12. Through these analysis results, VOCs values did not exceed the limit VOCs value determined by the regulation. Although the analysis results display that VOC value was not over the limit value in the facility, the odour level was high around the facility. As it has been well known VOCs create odour. For controlling the system emissions and reducing the low – value VOCs; installations of the waste gas combustion system, waste gas collection systems' combination and the new ventilation systems were suggested.

4. RESULTS AND DISCUSSIONS

In the frame of sustainable development, various strategies including practices of environmental technologies can be developed for manufacturing industries. However there is no one perfect strategy for the manufacturing processes. The strategies should be changed continuously based on the environmental, economical and manufacturing conditions of the facilities. The various environmental measures and the analyses make possible to verify the efficiency of the new environmental strategies. The following criteria are used to evaluate the efficiency of the proposed strategy: (1) minimisation in air emissions, (2) reduction in solid wastes (3) generation of hazardous/harmful/toxic materials, (4) energy consumption, (5) reduction in the water consumption amounts, and (6) reduction in odour. According to analysis results, feasible environmental strategy should be chosen for green production and sustainability.

4.1. Evaluation of the Facility in Terms of Water Consumption

Water management is an important component to provide the environmental friendly production. It is a kind of strategy to meet the water demand when and where it is needed. The proposed strategy should include adjusting and optimizing the water consumption systems in order to reduce the water consumption in the production line. Before the improvements, the estimated maximum and the average daily water consumption rates were between 4 m^3/day and 2 m^3/day in the synthetic leather production facility. The average monthly water consumption was about 65m^3/month.

Another important water consumption source in the facility was the dye preparation unit. The dye preparation unit was not separated from the process line and placed in the centre of the facility. Non isolated dye preparation unit was causing to powder paints to spread the floor in and around the facility. The cleaning of the powder paints increased the water consumption. The separation of the painting unit was suggested for preventing the extra water consumption and indoor pollution of the facility.

In the scope of energy audits, the cooling water system of the synthetic leather facility was controlled, the water leakage points were determined and the loss of water by percolation was prevented.

In a previous water consumption reduction study, done for a hotel before the synthetic leather facility study, the hotel's water consumption systems were replaced with the photocell basin taps which have water consumption as less than 12lt per minute. The hotel's annual water consumption rates are shown in Table 4.1. The water consumption in the old system decreased from 0,670 m^3/person to 0,547m^3/person after the application of photocell basin taps. The suggested improvements can lead to water savings as 0,123m^3/person (Proje Parkı, 2010).

In the synthetic leather facility, based on the water consumption study done for the hotel, the conventional taps were replaced with the photocell basin taps to reduce the water consumption for the domestic use.

The implementation of all water consumption reduction systems and the consequent improvements in the synthetic leather facility led to a reduction of 38,5% in water consumption rates. The average monthly water consumption rate of the synthetic leather facility decreased from 65 to 40 m^3/month.

Table 4.1. Water consumption rates of the hotel (Proje Parkı, 2010).

Years	**Months**	**Number of People**	**Water Consumption m^3**	**Annual Water Consumption m^3/person**
2009	January	1,380	1,076	0.670
	February	1,778	2,313	
	March	1,974	1,497	
	April	2,047	1,164	
	May	2,225	1,309	
	June	1,787	1,471	
	July	2,005	1,145	
	August	2,810	1,259	
	September	2,275	1,108	
	October	2,651	1,675	
	November	1,988	1,496	
	December	2,153	1,281	
Total (2009)		25,073	16,794	0.670
2010	January	1,921	1,076	0.547
	February	2,019	2,313	
	March	2,383	1,497	
	April	2,443	1,164	
	May	2,734	1,309	
	June	2,516	1,471	
	July	3,692	1,145	
	August	2,276	1,259	
	September	2,832	1,245	
	October	2,974	1,525	
	November	2,321	1,158	
	December	2,012	1,307	
Total (2010)		30,123	16,469	0.547
Total water savings (0,670m^3/person - 0,547m^3/person)				**0,123**

4.2. Evaluation of the Facility in Terms of Energy Consumption

The synthetic leather manufacturing facility used liquefied natural gas (LNG) as an energy source. Before the implementations of the suggested improvements in the synthetic leather facility LNG was stored in a tank, which was very close to the facility, and LNG was leading the risk of fire. The natural gas was suggested to be replaced with the LNG and supplied from the Istanbul Gas Distribution Industry and Trade inc. transmission network to eliminate the fire risk.

An energy audit was also suggested to determine the energy loss points. The energy audit was done to increase the energy efficiency and to reduce the cost of energy in the synthetic leather facility. A detailed examination was done while considering the information provided by facility's energy consumption, operating practices and energy consuming equipment. The energy audit was started by investigation of the manufacturing processes, and the energy consumption data in the synthetic leather facility. The information data was analysed to determine the facility's energy consumption points and to get a picture of the operations which causing to energy wasting. The synthetic leather facility layout and equipment inventory were prepared and the facility's construction features, wall and roof materials, insulation levels, door and window sizes were determined. Major energy consuming equipment and their energy efficiencies were identified.

As a result of the environmental energy audit, the following changes were suggested to be done to increase the energy efficiency of the facility:

(a) The use of cooling water under low load should be reduced and the cold water outlet temperature setting should be increased in the air conditioning system,

(b) Previously the air compressor system had a leakage causing the compressor to work more than normal to maintain the required pressure in the compressed air line and increased the electricity consumption. Trygg and Karlsson (2005) suggest that air compressor system should be converted to a system with electrically powered tools, so

that an air-free chiller is installed and a screw type air compressor is used to replace the centrifugal type. Thus, the coefficient of utilization can be raised.

(c) Previously the lighting system of the synthetic leather facility did not include any daylight. The daylight was suggested to be used as an alternative light source to reduce the energy consumption in the facility. Daylighting design might provide the sun light to supplement or replace artificial lighting in the synthetic leather facility. A daylight harvesting system might reduce the energy costs and improve the quality of the work environment. For the synthetic leather facility, multiple glazing windows were suggested to be placed on the facility's roof. Moreover it was suggested to replace mercury containing fluorescent lighting with energy saving LED lighting, or high-pressure sodium or ceramic metal bulb lighting. After the lighting system suggestions, estimated energy consumption data by the lightning system is given in Table 4.2.

Table 4.2. Lightning system electrical consumption rates after the improvements.

	Number of the lightning	**Consumption (w)**	**Total work time**	**Daily Consumption (kwh)**
LED lightning	100	135	10 hour	135
Energy Consumption for lightning (kwh)				135
Energy loses (kwh)				0
Average Daily Energy Consumption for Lightning (kwh)				135
Total Annually Energy Consumption for Lightning (kwh)				40.500

(d) As Jayamaha (2006) and Teitel et al. (2008) suggest, in the fans, pumps and motors, the electricity consumption rates should be reduced by means of the motor switching for an energy-efficient motor-driven system. Moreover variable frequency drives can be an excellent choice for adjustable speed-drive users, because they allow operators to fine-tune processes while reducing costs of energy and equipment maintenance in the heating, ventilating and air-conditioning. The electricity usage can be reduced if motors are combined with frequency control.

(e) Other energy conservation precautions such as controlling the discharge oxygen concentration and minimizing excess air, recycling the cooling water and waste heat, and

lowering the discharge temperature to below the original design setting, can be effective for energy savings.

After the energy audit and the improvements, the synthetic leather facility's annual electricity consumption rate decreased from 812.574 kwh to 569.963 kwh and led to a 30% reduction in the energy consumption. The detailed information about the electrical consumption rates are taken from the electricity consumption bills and they are given in Table 4.3.

Table 4.3. Electricity consumption rates after the improvements (The Synthetic Leather Facility Electricity Consumption Bills, 2012).

Months	**Electric Consumption (kWh)**
January	40.601
February	43.250
March	49.412,65
April	46.782
May	48.016
June	45.436
July	51.791
August	44.825
September	57.753
October	50.213
November	44.327
December	47.555
Average Monthly Consumption	47.497
Total Consumption	**569.963**

Table 4.4 shows the electricity consumption rates in the facility after the implementations. The energy audit and the consequent improvements realised in the synthetic leather facility led to an important decrease in the energy consumption rates. It is then not wrong to say that the energy audits might be the first step to initiate the improvements for energy saving.

Table 4.4. Energy consumption rates before and after the improvements.

	Before (kwh)	**After (kwh)**
Estimated lightning system electric consumption rates	82.500	40.500
Total electricity consumption rates	812.574	569.963
Total Energy Savings (812.574 kwh – 569.963 kwh)	**242.611 kwh**	
Percentage of the energy consumption reduction	**30%**	

4.3. Evaluation of the Facility in Terms of Waste Generation

The synthetic leather manufacturing facility did not have any waste management system formerly. In the facility, all types of wastes were mixed and they were identified as domestic solid waste. In the synthetic leather facility, the domestic solid waste was collected by municipality and disposed to the city's sanitary landfill. The hazardous wastes (chemical containers, drums, etc.) sourced from the usage of chemicals were collected by manufacturers of the chemicals. The contaminated wastes, which are also hazardous waste, were mixed into domestic waste so there was no information about the contaminated wastes. The contaminated "hazardous" wastes were used to dispose with municipal solid waste into the municipality's non-hazardous solid waste landfill.

In order to prevent mixing of the hazardous wastes and non-hazardous wastes what cause an extremely and extensive danger for living creatures and environment at natural sites or at municipality landfills, measures should be taken by highlighting waste management and separate collection in the facility. Waste management action plan should be worked on for improving of the current irregular storage areas.

The waste management systems consist of the whole set of activities related to handling, treating, disposing or recycling of the waste materials. Through a waste management system; the hazardous and non-hazardous waste amounts should be determined, the wastes should be collected based on their types, and they should be disposed by licensed disposing and recycling companies.

The synthetic leather facility has different type of wastes as it mentioned in Table 3.6. In the synthetic leather facility, set up of an integrated solid waste management system regarding the separate collection and handling of the wastes was suggested. The waste management system should include the following aims: the reduction of total amount of waste by minimization and recycling, the recycling of wastes into production cycles as secondary raw material, and the reductions of waste quantities.

The waste materials, generated from manufacturing processes, should be classified as hazardous and non-hazardous solid waste. In the facility non-hazardous wastes are containers, packaging wastes, food scraps, yard trimmings, and miscellaneous inorganic wastes. The hazardous wastes are the contaminated wastes sourced from the manufacturing processes.

In the waste management system, wastes should be collected separately and disposed according to their types. In the synthetic leather facility the aim should be the zero waste. The waste quantity is an important parameter to determine the waste collection schedule and to transportation of the collected waste.

In a previous waste generation reduction study done for a hotel, the hotel's staffs received training on waste management four times in a year. The hotel's monthly waste generation rates are shown in Table 4.5. In the hotel, for decreasing the waste generation, packaging waste and organic waste separation process began in 2010. Thus the rate of organic waste produced per person has reduced. As it is shown in Table 4.5, for the hotel, the waste generation rate before the waste management trainings was 1,886 kg/person and the waste generation rates in the improved system with the integrated waste management system and the waste management trainings is 0,803 kg/person. The suggested improvements can lead to waste minimisation as 1,083 kg/person (Proje Parkı, 2010).

Table 4.5. Domestic waste generation rates of the hotel (Proje Parkı, 2010).

Years	Months	Number of People	Domestic Waste Generation (kg)	Annual Domestic Waste Generation (kg/person)
2010	January	2348	-	1,886
	February	3381	-	
	March	4109	-	
	April	4724	-	
	May	5166	-	
	June	4670	10719,50	
	July	5447	9494,50	
	August	4080	6830,75	
	September	5341	7899,50	
	October	5725	11505,00	
	November	4037	9325,30	
	December	2563	4325,15	
Total 2010		**31863**	**60099,7**	**1,886**
2011	January	2.628	3075	0,803
	February	2.796	329	
	March	6.889	8187	
	April	7.980	9089	
	May	8.444	11451	
	June	8.486	2760	
	July	10.513	5790	
	August	3.939	4790	
	September	9.812	4680	
	October	9.300	6390	
	November	5.794	5510	
	December	7.168	5160	
Total 2011		**83749**	**67211**	**0,803**
Total waste reduction(1,886kg/person - 0,803kg/person)				**1,083**

In the synthetic leather facility, to decrease the waste generation, waste management trainings for employees were also suggested.

After all these improvements, in the synthetic leather facility the wastes is started to be collected according to their types and all the wastes is started to be disposed by using appropriate methods After the separate collection and the waste management trainings are

given in the synthetic leather facility, the generation and the effects of the wastes on the environment are minimised.

4.4. Evaluation of the Facility in Terms of Emission Generation

The synthetic leather facility's emission collection system former state analysis results are presented in Table 3.7, Table 3.8, Table 3.9, Table 3.10, Table 3.11, and Table 3.12. As it is shown in these tables, VOCs results of the facility did not exceed the limit VOCs value which is determined by the regulation. On the other hand the odour level was identified as high level around the facility. As it has been well known VOCs create odour. For controlling the system emissions and reducing the low – value VOCs; installations of the waste gas combustion system, waste gas collection systems' combination and the new ventilation systems are suggested. The suggested waste gas combustion system is shown in Figure 4.1.

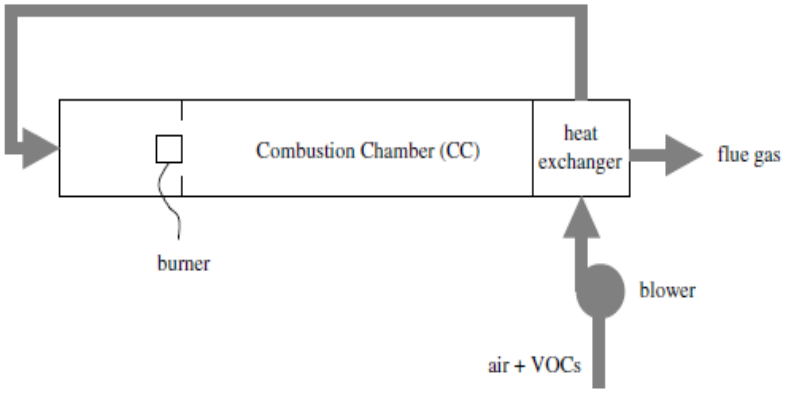

Figure 4.1. Principle of a VOC recuperative incinerator (Salvador et al., 2005).

In the manufacturing processes of the synthetic leather facility, PVC powder, DOP (dioctyl phthalate), PVC stabilizers (based on Ca and Zn salts), calcite, titanium oxide, nitrogen dicarbon amide, various pigments and dyes, mineral spirits and kerosene are used to get synthetic leather pulp. Raw materials should be weighed according to the type of synthetic leather in the boilers, stirred in high-speed blender until a homogeneous mixture is obtained, and passed in the rollers (waltz). Depending on the formulation, the

product is thinned according to the viscosity and poured over a cloth or silicone paper. Products are subjected to oven baking at 150-200 ° C. Ovens heated by hot oil. Products are subjected to pattern, embossed, perforated, lacquer-making processes according to customer requests. HC containing particles, steam and smoke from the PVC and baking ovens in the factory is treated as two processes for provide 99% the disposal rate. In the first process, with comprehensive cooling equipment, gas is cooled to 3 ^{0}C and condensed, and then it is subjected to an efficient showering. In the second process, temperature of the gas is extracted to an adequate level for the complete combustion with a burner for being disposed. Out of these two processes; bagged dry carbon filter or filtration systems or chilled water to the normal age of showering or venturi-type filters, cyclone systems or torch burners cannot dispose smoke and odour.

Dense fume is composed by four baking ovens, one embossing unit and the cooling unit. These fumes and organic vapours are sent to the main suction ventilator by the collection channels which are over cooking ovens, embossing and cooling unit. The main suction ventilator ends with a "Combustion Unit" that is operated by natural gas. In the combustion unit, there are two main parts as "burning" and "recuperation". The characteristics of the combustion unit are taken by the ITU report, 2011 and they are given in Table 4.6. In line with ITU report combustion unit design and emission collection lines are shown in Figure 4.2. Through the main suction fan, waste gas is passed in recuperation and the temperature of the gas increased till 300 ° C. Then in the combustion cabin with natural gas burning 900-1000 ° C, the gas is also burned. Natural gas burning unit capacity of combustion units (as front and back of the unit) are 2-40 m^3/hr, and 1-20 m^3/hr with two 400 kW and 200 kW burners which have pre-programmed inverter system. In first incineration cabin (900-1000°C), exhaust gases are burnt through the main burner. At the second combustion unit, which is located on the back burner, waste gas is burnt again and the smoke passed through the full recuperator. Recuperator provides the heat transferring between input flue gas to incinerator and waste gas output of the incinerator so the fuel consumption decreases as 45-50%. After removing from the recuperator, hot combustion gases and fumes in the main suction fan through the heat recuperator go into the atmosphere from stack at 300 ° C. Through system exits and the inside of furnace, extra air is absorbed, large amount of electricity is

consumed because of the large extractors and condensation happens in the system channels.

Table 4.6. Characteristics of the combustion unit (ITU Report 2011).

Burning Unit Characteristics	
Capacity	10,000 Nm^3/h
Gas Inlet Temperature	~ 300 ° C
Disposed yield	99%
Fuel consumption	35-40 m^3/h, 70-75 m^3/h (with recuperator)
Dimension	2.5mx5mx3, 5m (Width x Depth x Height)
Material	outer body of refractory ceramic wool and covered with concrete, St.37, the internal bodies covered with ceramic wool AISI 321
Operating	Temperature and flow control, fully automatic operation
Recuperation Unit Characteristics	
Capacity	10.000 Nm^3/h
Heat Capacity	600.000kcal/h
Gas Inlet Temperature	~95 ^0C
Gas Outlet Temperature	~300 ^0C
Dimensions	1.5m x1.5m x4m (Width x Depth x Height)

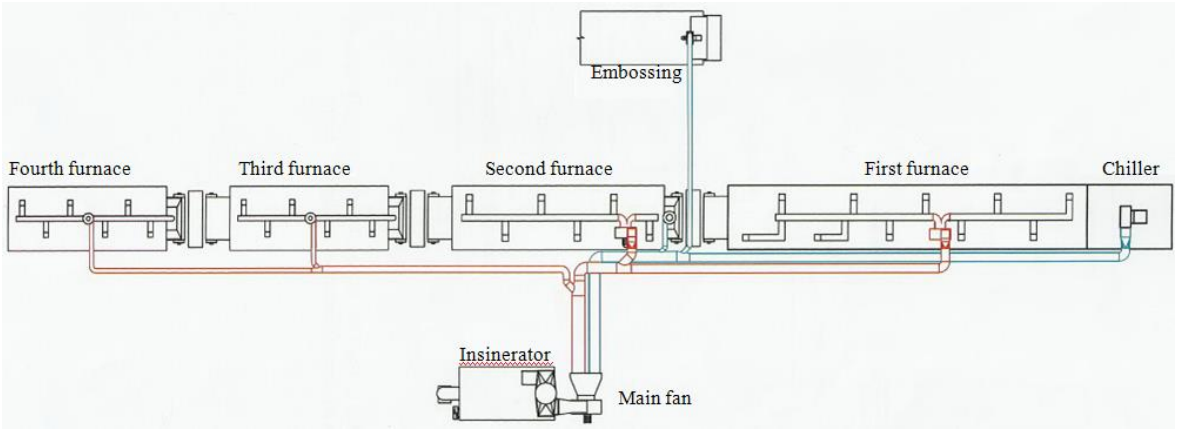

Figure 4.2. Emission collection and treatment system design (ITU Report, 2011).

Characteristics of by-pass stack and combustion system output stacks are shown in Table 4.7. For the identification of working conditions and efficiency of the combustion system, the system temperature, pressure and velocity of the gas were measured. Table 4.8 shows the results of measurements. Measurements were done when the baking ovens that run at full capacity with the formation of dense smoke conditions. All the measurements carried out during the main and second burners that are operating as a 60 m^3 (highest load) natural gas. According to the gas measurement and calculation results, all of the values are shown in Table 4.8 , Table 4.9 and Table 4.10.

Table 4.7. Characteristics of by-pass stack and combustion system flue (ITU Report, 2011).

Parameters	**By-pass Stack**	**Combustion System Flue**
Channel Diameter (m)	1,0 x 0,70	1,20 x 1,20
Channel cross section (m^2)	0,7	1,44
Gas Temperature (° C)	98	260
Gas Velocity (m / sec)	6,1	4,8
Gas Pressure (hPa)	0,3	0,25
Gas Flow Rate (m^3/h)	15.370	23.330
Gas Flow Rate (Nm^3/h)	11.500	12.180

Table 4.8. By-pass stack gas monitoring results (ITU Report, 2011).

Parameter	**1st Measurement**	**2nd Measurement**	**3rd Measurement**
Gas Temperature (° C)	101	98	98
O_2 (%)	20,3	20,4	20,4
H_2O (%)	2,1	2,0	2,2
TOC (Hexane Equivalent, mg/Nm^3)	230	285	310
Unsaturated fats (DOP, mg/Nm^3)	1.250	985	1.390
Characteristics of the collected condensate from the flue gas,	A two-phase, yellowish, cloudy or foul-smelling		

* Measurements were made with an interval of half an hour.

Table 4.9. Combustion system output stack gas monitoring results (ITU Report, 2011).

Parameter	**1st Measurement**	**2nd Measurement**	**3rd Measurement**
Gas Temperature	273	260	259
O_2 (%)	18,3	18,4	18,5
CO_2 (%)	1,5	1,4	1,4
H_2O (%)	2,5	2,4	2,6
CO (mg/Nm^3)	69	108	94
SO_2 (mg/Nm^3)	<1	<1	<1
NO (mg/Nm^3)	28	31	23
TOC (Hexane Equivalent mg/Nm^3)	25	30	24
Unsaturated fats (DOP, mg/Nm^3)	<1	<1	<1
condensate properties	clear, odourless		

* Measurements were made with an interval of half an hour.

Table 4.10. By-pass and combustion system output stack measurement results and removal efficiencies (ITU Report, 2011).

By-pass Stack					
Analysis No	TOC (mg/Nm^3)	TOC (kg/h)	DOP (mg/Nm^3)	DOP (kg/h)	Total (kg/h)
1	230	2,645	1.250	14,375	17,02
2	285	3,277	985	11,327	14,604
3	310	3,565	1390	15,985	19,55
Combustion System Output					
Analysis No	TOC (mg/Nm^3)	TOC (kg/h)	DOP (mg/Nm^3)	DOP (kg/h)	Total (kg/h)
1	25	0,305	<1	-	0,305
2	30	0,365	<1	-	0,365
3	24	0,292	<1	-	0,292
Analysis No	**Efficiency**				
1	98,2 %				
2	97,5 %				
3	98,2 %				
Average	98 %				

According to Table 4.8 by-pass stack measurement results show that synthetic leather embossing oven waste gas fume contains a high proportion of small and large molecular weight organic pollutants. The organic pollutants arise from the organic chemicals used in the artificial leather production process. Because of the baking ovens and embossing input / output openings are open, and the rate of oxygen level was high to be about 20.3% and 20.4% in the by-pass stack (gas composition entering the combustion system). Condensates, which are collected from by-pass stack, are identified as two-phase; yellowish - cloudy and foul-smelling. Under these conditions, output condensate from combustion unit is identified as clear and odourless. The characterization of the by-pass stack flue gas (the hydrocarbon vapours in the combustion system to the output shaft (hexane equivalent), DOP concentrations of organic pollutants and organic contaminant removal efficiency in the waste gas combustion unit results) is given in Table 4.10. As it can be seen in Table 4.10, the organic pollutant removal efficiency average is calculated as 98%. The analyses are performed by TUBİTAK MAM. The analyses results of the synthetic leather facility emission sources after the improvements are given in Table 4.11, Table 4.12, Table 4.13, Table 4.14, Table 4.15, Table 4.16, and Table 4.17.

Table 4.11. Analysis results of KB 1 (Boiler) (TUBİTAK MAM Report, 2012).

Fuel Type	Natural gas				
Fuel Consumption (m^3/h)	117,74				
Nominal Thermal Power (MW)	1,12				
Stack Height (from ground) (m)	17,00				Limit Value
Stack Height (from roof) (m)	4,00				3
Analysis	1st	2nd	3rd	Average	
Gas Temperature (^{0}C)	227	294	203	258	
Gas Velocity (m/sn)	7,3	7,3	7,3	7,3	4
Gas flow rate under Operation Conditions (m^3/h)				14973	
Gas flow rate under Normal Conditions (m^3/h)				6708	
Combustion efficiency (%)	86,1	86,4	88,6	87,0	
The Concentration of Dust (mg/Nm^3)	2,01	1,32	1,88	1,74	
The Concentration of Dust (mg/Nm^3 3 % ref O_2)	2,66	1,90	2,31	2,29±0,66	10
Dust Emission (kg/h)				0,012±0,003	10
The Concentration of CO (mg/Nm^3)	*	*	*	*	
The Concentration of CO (mg/Nm^3 3 % ref O_2)	*	*	*	*	100
CO Emission (kg/h)				*	5
The Concentration of SO_2 (mg/Nm^3)	*	*	*	*	
The Concentration of SO_2 (mg/Nm^3 3% ref O_2)	*	*	*	*	100
SO_2 Emission (kg/h)				*	60
The Concentration of NO (mg/Nm^3)	42	47	38	42	
NO Emission (kg/h)				0,280±0,020	20
The Concentration of NO_2 (mg/Nm^3)	68	74	60	67	
The Concentration of NO_2 (mg/Nm^3 3% ref O_2)	90	106	73	90±5,77	800
NO_2 Emission (kg/h)				0,447	

Table 4.12. Analysis results of Ventilation Shaft 1 (TUBİTAK MAM Report, 2012).

Stack diameter (m)						0,4*0,7
Stack Height from ground (m)						13,2
Stack Height from roof (m)						2
Moisture (%)						2
Gas Velocity (m/sn)						13,6
Gas flow rate under Operation Conditions (m^3/h)						13709
Gas flow rate under Normal Conditions (m^3/h)						11919
Analysis			1st	2nd	3rd	Average
Gas Temperature (^{0}C)			35,0	36,0	35,0	35,3
Dust	mg/Nm^3		1,88	1,58	2,09	1,85 ±0,53
Dust	kg /h		-	-	-	0,022 ±0,006
TVOC	Ppm		30,00	32,00	31,00	31,00
	(mg/Nm^3)		48,21	51,43	49,82	49,82 ±2,75
	2 - Butanone	(mg/Nm^3)	0,0364	0,0329	0,0270	0,0321
		(C-g/Nm^3)	0,0243	0,0219	0,0180	0,0214
	4 - Methyl 2 - pentanone	(mg/Nm^3)	< 0,01	< 0,01	0,01	< 0,01
		(C-g/Nm^3)	<0,0072	< 0,0072	0,0072	< 0,0072
	Hexane	(mg/Nm^3)	< 0,0020	< 0,0020	<0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0017	< 0,0017	< 0,0017	< 0,0017
	isopropyl ether	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0014	< 0,0014	< 0,0014	< 0,0014
	ethyl Acetate	(mg/Nm^3)	0,0249	0,0221	0,0185	0,0218
		(C-g/Nm^3)	0,0136	0,0120	0,0101	0,0119
	cyclohexane	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0017	< 0,0017	< 0,0017	< 0,0017
	n-Heptane	(mg/Nm^3)	0,0027	0,0047	0,0045	0,0040
		(C-g/Nm^3)	0,0022	0,0039	0,0037	0,0033
	1 - Butanol	(mg/Nm^3)	0,0067	0,0051	0,0052	0,0057
		(C-g/Nm^3)	0,0043	0,0033	0,0034	0,0037
	butyl Acetate	(mg/Nm^3)	0,2084	0,1772	0,1607	0,1821
		(C-g/Nm^3)	0,1294	0,1100	0,0997	0,1130
	P – xylene	(mg/Nm^3)	0,0451	0,0528	0,0477	0,0485
		(C-g/Nm^3)	0,0408	0,0478	0,0432	0,0440
	O – Xylene	(mg/Nm^3)	0,0070	0,0071	0,0071	0,0071
		(C-g/Nm^3)	0,0063	0,0064	0,0064	0,0064
TVOC	(kg/h)					0,594 ±0,068
	2 - Butanone	(C kg/h)	0,00034	0,000301	0,00024	0,00029
	4 - Methyl 2 - pentanone	(C kg/h)	< 0,0001	< 0,00001	< 0,0001	< 0,0001
	Hexane	(C kg/h)	< 0,00002	< 0,000023	< 0,00002	< 0,00002
	isopropyl ether	(C kg/h)	< 0,00002	< 0,00002	< 0,00002	< 0,00002
	ethyl Acetate	(C kg/h)	0,00019	0,000165	0,00014	0,00016
	cyclohexane	(C kg/h)	< 0,00002	< 0,000002	< 0,00002	< 0,00002
	n-Heptane	(C kg/h)	0,00003	0,000053	0,00005	0,00004
	1 - Butanol	(C kg/h)	0,00006	0,000045	0,00005	0,00005
	butyl Acetate	(C kg/h)	0,00179	0,001508	0,00136	0,00155
	P – xylene	(C kg/h)	0,00056	0,000656	0,00059	0,00060
	O – Xylene	(C kg/h)	0,00009	0,000088	0,00009	0,00009

Table 4.13. Analysis results of ventilation shaft 2 (TUBİTAK MAM Report, 2012).

Stack diameter (m)						0,9*0,9
Stack Height from ground (m)						13,2
Stack Height from roof (m)						1,5
Moisture (%)						2
Gas Velocity (m/sn)						9,9
Gas flow rate under Operation Conditions (m^3/h)						28771
Gas flow rate under Normal Conditions (m^3/h)						24987
Analysis			1st	2nd	3rd	Average
Gas Temperature (^{0}C)			36,0	35,0	36,0	35,7
Dust	mg/Nm^3		1,83	1,95	0,87	1,15 ±0,44
Dust	kg /h		-	-	-	0,039 ±0,104
TVOC	Ppm		42,00	41,00	40,00	41,00
	(mg/Nm^3)		67,50	65,89	64,29	65,89 ±3,60
	2 - Butanone	(mg/Nm^3)	0,0199	0,0187	< 0,0100	0,0162
		(C-g/Nm^3)	0,0133	0,0125	< 0,0067	< 0,0108
	4 - Methyl 2 - pentanone	(mg/Nm^3)	< 0,01	< 0,01	0,01	< 0,01
		(C-g/Nm^3)	< 0,0072	< 0,0072	0,0072	< 0,0072
	hexane	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0017	< 0,0017	< 0,0017	< 0,0017
	isopropyl ether	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0014	< 0,0014	< 0,0014	< 0,0014
	ethyl Acetate	(mg/Nm^3)	0,0136	0,0127	0,00021	0,0088
		(C-g/Nm^3)	0,0074	0,0069	0,0001	0,0048
	cyclohexane	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0017	< 0,0017	< 0,0017	< 0,0017
	n-Heptane	(mg/Nm^3)	0,0020	0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	0,0016	0,0016	< 0,0016	< 0,0016
	1 - Butanol	(mg/Nm^3)	< 0,0050	< 0,0050	< 0,0050	< 0,0050
		(C-g/Nm^3)	< 0,0032	< 0,0032	< 0,0032	< 0,0032
	butyl Acetate	(mg/Nm^3)	0,0999	0,1275	0,0163	0,0812
		(C-g/Nm^3)	0,0620	0,0791	0,0101	0,0504
	P - xylene	(mg/Nm^3)	0,0286	0,0284	0,0050	0,0207
		(C-g/Nm^3)	0,0259	0,0257	0,0045	0,0187
	O - Xylene	(mg/Nm^3)	0,0044	0,0026	< 0,0020	< 0,0030
		(C-g/Nm^3)	0,0040	0,0024	< 0,0018	< 0,0027
TVOC	(kg/h)					1,646 ±0,104
	2 - Butanone	(C kg/h)	0,00038	0,000364	<0,00019	< 0,00031
	4 - Methyl 2 - pentanone	(C kg/h)	<0,00020	<0,000210	<0,00021	< 0,00021
	hexane	(C kg/h)	<0,00005	<0,000049	<0,00005	< 0,00005
	isopropyl ether	(C kg/h)	<0,00004	<0,000041	<0,00004	< 0,00004
	ethyl Acetate	(C kg/h)	0,00021	0,000202	0,00000	0,00014
	cyclohexane	(C kg/h)	<0,00005	<0,000050	<0,00005	< 0,00005
	n-Heptane	(C kg/h)	0,000047	0,000048	<0,00005	< 0,00005
	1 - Butanol	(C kg/h)	<0,00009	< 0,000095	< 0,00009	< 0,00009
	butyl Acetate	(C kg/h)	0,00175	0,002308	0,00029	0,00145
	P - xylene	(C kg/h)	0,00073	0,000750	0,00013	0,00054
	O - Xylene	(C kg/h)	0,00011	0,000069	< 0,00005	< 0,00008

Table 4.14. Analysis results of ventilation shaft 3 (TUBİTAK MAM Report, 2012).

Stack diameter (m)						1,2
Stack Height from ground (m)						13
Stack Height from roof (m)						1,5
Moisture (%)						2
Gas Velocity (m/sn)						9,1
Gas flow rate under Operation Conditions (m^3/h)						37168
Gas flow rate under Normal Conditions (m^3/h)						32314
Analysis			1st	2nd	3rd	Average
Gas Temperature (^{0}C)			35,0	36,0	35,0	35,3
Dust	mg/Nm^3		3,64	1,49	1,64	2,26 ±0,65
Dust	kg /h		-	-	-	0,079 ±0,023
TVOC	Ppm		35,00	37,00	36,00	36,00
	(mg/Nm^3)		56,25	59,46	57,86	57,86 ±3,17
	2 - Butanone	(mg/Nm^3)	< 0,0100	< 0,0100	< 0,0100	< 0,0100
		(C-g/Nm^3)	< 0,0067	< 0,0067	< 0,0067	< 0,0067
	4 - Methyl 2 - pentanone	(mg/Nm^3)	< 0,0100	0,0168	< 0,0100	< 0,0123
		(C-g/Nm^3)	< 0,0072	0,0121	< 0,0072	< 0,0088
	hexane	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0017	< 0,0017	< 0,0017	< 0,0017
	isopropyl ether	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0014	< 0,0014	< 0,0014	< 0,0014
	ethyl Acetate	(mg/Nm^3)	< 0,002	< 0,002	< 0,002	< 0,0020
		(C-g/Nm^3)	< 0,0011	< 0,0011	< 0,0011	< 0,0011
	cyclohexane	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0017	< 0,0017	< 0,0017	< 0,0017
	n-Heptane	(mg/Nm^3)	0,0020	0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	0,0016	0,0016	< 0,0016	< 0,0016
	1 - Butanol	(mg/Nm^3)	< 0,0050	< 0,0050	< 0,0050	< 0,0050
		(C-g/Nm^3)	< 0,0032	< 0,0032	< 0,0032	< 0,0032
	butyl Acetate	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0012	< 0,0012	< 0,0012	< 0,0012
	P - xylene	(mg/Nm^3)	< 0,0010	< 0,0010	< 0,0010	< 0,0010
		(C-g/Nm^3)	< 0,0009	< 0,0009	< 0,0009	< 0,0009
	O - Xylene	(mg/Nm^3)	< 0,0020	< 0,0020	< 0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0018	< 0,0018	< 0,0018	< 0,0018
TVOC	(kg/h)					1,870 ±0,11
	2 - Butanone	(C kg/h)	<0,00025	<0,00025	<0,00025	< 0,00025
	4 - Methyl 2 - pentanone	(C kg/h)	<0,00027	0,000453	<0,00027	< 0,00033
	hexane	(C kg/h)	<0,00006	<0,00006	<0,00006	< 0,00006
	isopropyl ether	(C kg/h)	<0,00005	<0,00005	<0,00005	< 0,00005
	ethyl Acetate	(C kg/h)	<0,00004	<0,00004	<0,00004	< 0,00004
	cyclohexane	(C kg/h)	<0,00006	<0,00006	<0,00006	< 0,00006
	n-Heptane	(C kg/h)	<0,00006	<0,00006	<0,00006	0,00006
	1 - Butanol	(C kg/h)	<0,00012	<0,00012	<0,00012	< 0,00012
	butyl Acetate	(C kg/h)	<0,00005	<0,00005	<0,00005	< 0,00005
	P - xylene	(C kg/h)	<0,00003	<0,00003	<0,00003	< 0,00003
	O - Xylene	(C kg/h)	<0,00007	<0,00007	< 0,00007	< 0,00007

Table 4.15. Analysis results of incinerator shaft (TUBİTAK MAM Report, 2012).

Stack diameter (m)						0,9
Stack Height from ground (m)						17
Stack Height from roof (m)						4,5
Moisture (%)						7
Gas Velocity (m/sn)						9,8
Gas flow rate under Operation Conditions (m^3/h)						22356
Gas flow rate under Normal Conditions (m^3/h)						8388
Analysis			1st	2nd	3rd	Average
Gas Temperature (^{0}C)			407	401	399	402
Dust	mg/Nm^3		0,73	2,71	2,18	1,87
Dust	kg /h		-	-	-	0,016 ±0,005
CO	Ppm		298	296	264	286
	mg/Nm^3		373	370	330	358
	kg/h		-	-	-	2,996±0,240
SO_2	Ppm		*	*	*	*
	mg/Nm^3		*	*	*	*
	kg/h		*	*	*	*
NO	Ppm		33	33	34	33
	mg/Nm^3		44	44	46	45
	kg/h		-	-	-	0,375±0,030
NO_2	Ppm		34	34	36	35
	mg/Nm^3		70	70	74	71
	kg/h		-	-	-	0,597
TVOC	Ppm		47,00	51,00	67,00	55,00
	(mg/Nm^3)		75,54	81,96	107,68	88,39
	2 - Butanone	(mg/Nm^3)	< 0,0100	< 0,0100	<0,0100	< 0,0100
		(C-g/Nm^3)	< 0,0067	< 0,0067	<0,0067	< 0,0067
	4 - Methyl 2 - pentanone	(mg/Nm^3)	< 0,0100	0,0168	<0,0100	< 0,0123
		(C-g/Nm^3)	< 0,0072	0,0121	<0,0072	< 0,0088
	hexane	(mg/Nm^3)	< 0,0020	< 0,0020	<0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0017	< 0,0017	<0,0017	< 0,0017
	isopropyl ether	(mg/Nm^3)	< 0,0020	< 0,0020	<0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0014	< 0,0014	<0,0014	< 0,0014
	ethyl Acetate	(mg/Nm^3)	< 0,0020	< 0,0020	<0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0011	< 0,0011	<0,0011	< 0,0011
	cyclohexane	(mg/Nm^3)	< 0,0020	< 0,0020	<0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0017	< 0,0017	<0,0017	< 0,0017
	n-Heptane	(mg/Nm^3)	0,0027	< 0,0020	< 0,0020	< 0,0022
		(C-g/Nm^3)	0,0022	< 0,0016	<0,0016	< 0,0018
	1 - Butanol	(mg/Nm^3)	0,0066	< 0,0050	<0,0050	< 0,0055
		(C-g/Nm^3)	0,0043	< 0,0032	<0,0032	< 0,0036
	butyl Acetate	(mg/Nm^3)	< 0,0020	< 0,0020	<0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0012	< 0,0012	<0,0012	< 0,0012
	P - xylene	(mg/Nm^3)	< 0,0010	< 0,0010	<0,0010	< 0,0010
		(C-g/Nm^3)	< 0,0009	< 0,0009	<0,0009	< 0,0009
	O - Xylene	(mg/Nm^3)	< 0,0020	< 0,0020	<0,0020	< 0,0020
		(C-g/Nm^3)	< 0,0018	< 0,0018	<0,0018	< 0,0018
TVOC	(kg/h)					0,743±0,059
	2 - Butanone	(C kg/h)	<0,00015	<0,000150	<0,00015	< 0,00015
	4 - Methyl 2 - pentanone	(C kg/h)	<0,00016	<0,000162	<0,00016	< 0,00016
	hexane	(C kg/h)	<0,00004	<0,000038	<0,00004	< 0,00004
	isopropyl ether	(C kg/h)	<0,00003	<0,000032	<0,00003	< 0,00003
	ethyl Acetate	(C kg/h)	<0,00002	<0,000024	<0,00002	< 0,00002
	cyclohexane	(C kg/h)	<0,00004	<0,000038	<0,00004	< 0,00004
	n-Heptane	(C kg/h)	0,000049	< 0,00004	<0,00004	< 0,00004
	1 - Butanol	(C kg/h)	<0,00009	< 0,00007	<0,00007	< 0,00008
	butyl Acetate	(C kg/h)	<0,00003	< 0,0003	<0,00003	< 0,00003
	P - xylene	(C kg/h)	<0,00003	< 0,0003	<0,00003	< 0,00003
	O - Xylene	(C kg/h)	<0,00007	< 0,00007	<0,00007	< 0,00007

Table 4.16. Total emissions (TUBİTAK MAM Report, 2012).

Emission Source	CO (kg/h)	NO_2 (kg/h)	NO (kg/h)	SO_2 (kg/h)	Dust (kg/h)	TVOC (kg/h)
Hot Oil Boiler Stack	-	0,447	0,280±0,020	-	0,012±0,003	-
Ventilation Stack 1	-	-	-	-	0,022±0,006	0,594±0,068
Ventilation Stack 2	-	-	-	-	0,039±0,011	1,646±0,104
Ventilation Stack 3	-	-	-	-	0,079±0,023	1,870±0,11
Incinerator Stack	2,996±0,240	0,597	0,375±0,030	-	0,016±0,005	0,743±0,059
Total Value	2,996±0,240	1,044	0,655±0,050	-	0,168±0,048	4,853±0,341

Table 4.17. Odour measurement results (TUBİTAK MAM Report, 2012).

Odour Measurement Method	EN 17325			
Sampling Points	Sample 1 OU/m^3	Sample 2 OU/m^3	Sample 3 OU/m^3	Average OU/m^3
In the process line	570	600	510	560

Table 4.18 shows the comparison of the emissions of the synthetic leather facility before and after the improvements. In the facility before the emission collection and treatment systems, indoor air emissions were extremely high and the emissions were at the harmful level in the point of occupational health and safety. The facility is located in the residential area and its emissions and odour also was affecting the public health. The synthetic leather facility did not have a ventilation system and an effective emission collection system. Therefore all of the emissions were staying in the facility for a while and then escaping to the atmosphere through the windows and doors. Basically facility's emissions were not controllable. After the implementation of suggested improvements, an important reduction was observed in the emissions of the facility. Table 4.18 shows the emissions of the facility before and after the improvements. The reduction in the odour is

approximately 78%. The proper collection of the emission sources from the facility and their effect on environment is then started to be controlled.

Table 4.18. Comparison chart of the synthetic leather facility's emissions before and after the improvements.

Type of Pollutant	**Total Emissions Before the Improvements**	**Total Emissions After the Improvements**	**Limit Values**
Dust (kg/h)	*8,400± 2,400	0,168±0,048	10
CO (kg/h)	*148,300±12	2,996±0,240	500
NO_2 (kg/h)	*52,2	1,044	40
VOC (kg/h)	*71,250 ± 8,250	4,853±0,341	30
Avarage Odour (OU/m^3)	2531	560	--

*Calculation of the total emissions before the improvements with %98 removal efficiency

Dust (kg/h): (0,168±0,048) / (2/100) = 8,400±2,400 kg/h

CO (kg/h): (2,996±0,240) / (2/100) =148,300±12 kg/h

NO_2 (kg/h): (1,044) / (2/100) = 52,2 kg/h

VOC (kg/h): (1,425 ± 0,165) / (2/100) = 71,250 ± 8,250

To prevent the emission rates in the synthetic leather facilities there are different systems and technologies. The emission reduction systems investments and operation costs are collected from the market and they are listed in Table 4.19. In line with a cost benefit analysis of the synthetic leather emission treatment systems, it can be said that incineration systems need high operating costs but they are more efficient than wet scrubbers and they need less investment costs than the electrostatic filters. If the incineration system is used with the online temperature measuring system in its burning unit, the system can be controlled easily.

Table 4.19. Investment and operating costs of the emission and odor treatment systems.

System	**Investment Costs (TL)**	**Operating Costs (TL/month)**
Incineration system	150.000	35.000
Carbon Filter	35.000	6.000
Electrostatic Filter	300.000	1.000
Wet scrubber	30.000	Water consumption cost and hazardous waste disposal cost

5. CONCLUSION

Small and medium scale industries account for a high percentage of the total industries and they play a critical role in establishing the environmentally friendly production. This study focuses on the development of an environmentally friendly production strategy for a medium scale synthetic leather facility to reduce its effects on the environment. In the study, the effects of a medium scale synthetic leather facility, having no environmental management system, on the environment were evaluated before and after the application of the proposed strategy to show the improvements in the minimisation of the emissions, solid wastes, hazardous/harmful/toxic wastes, energy consumption, water consumption rates, and odour.

The summary of suggested improvements in the proposed strategy and the conclusions drawn from the results of these improvements are given below:

The results of the study showed that the implementations of the proposed strategy minimized the effects of the focused synthetic leather facility on the environment.

In the synthetic leather production facility, the dye preparation unit was separated from the process line to minimize water consumption. The separation of the painting unit enabled the prevention of extra water consumption and indoor pollution of the facility. In line with energy audits the water leakage points were determined and the loss of water by percolation was prevented in the cooling water systems of the synthetic leather facility. The synthetic leather facility's conventional taps were replaced with the photocell basin taps to reduce the water consumption for the domestic usage. All of these improvements in the water consumption systems led to a 38,5 % reduction of in the water consumption rates. The average monthly water consumption rate of the synthetic leather facility decreased from 65m^3/month to 40m^3/month.

In order to minimize energy consumption, the synthetic leather facility started to do energy audits. The audits determined energy consumption and energy loss points and captured a picture of the operations which caused waste in energy. The synthetic leather

facility layout and equipment inventory were prepared and the facility's construction features, wall and roof materials, insulation levels, door and window sizes were controlled. The major energy consuming equipment and their energy efficiencies were identified. Lightning systems were supported by multiple glazing windows and thus daylight started to be used as an alternative light source to reduce the energy consumption in the lighting system. Mercury containing fluorescent lighting replaced with energy saving LED lighting, or high-pressure sodium or ceramic metal bulb lighting. All of these energy audits and the improvements enabled a reduction from 812.574kwh/year to 569.963kwh/year and led to a 30% reduction in the energy consumption rates. This result shows the energy audits can be the first step to initiate drastic improvements for energy savings.

The synthetic leather manufacturing facility had no waste management system and all types of wastes were collected together as domestic solid waste. In order to separate collection of the hazardous wastes and non-hazardous wastes, waste management action plan and a separate collection were put into practice at the facility. Through the waste management policy; the waste was collected based on its type. The reuse of waste in production cycles as secondary raw material was started. Waste was disposed of by licensed companies, and waste management training for employees were also given in the synthetic leather facility. Both the generation of the waste itself as well as effects of the disposed waste on the environment were minimised.

While the synthetic leather facility's VOC results did not exceed the limit of VOC value which is determined by the Industry Based Air Pollution Control Regulation, the odour level was high throughout the facility. The VOC emissions were creating this pervasive odour. Furthermore, indoor air emissions were extremely high and the emissions were at the harmful level according to occupational health and safety. The facility is located in a residential area and its emissions and odour were affecting public health. The synthetic leather facility did not have a ventilation system or an effective emission collection system. The door and window systems were the only source of ventilation. The facility's emissions were not under control. For controlling the system emissions and reducing the low – value VOCs; waste gas collection and combustion systems, and the new ventilation systems were installed. Since these improvements, the

synthetic leather facility does not have any reduction in the waste gas analysis results, but indeed, it started to prevent high level of indoor air pollution. When the by-pass stack flue gas and combustion system analysis results are compared, there is an emission reduction efficiency of around 98%. Another result is that the facility has had huge odour reduction efficiency approximately 78%. Condensates, which are collected from by-pass stack, are yellowish - cloudy and foul-smelling. On the other hand, output condensation from combustion units is identified as clear and odourless. After the all emission systems' improvements, waste gas emissions and their effect on environment have been brought under control.

In the field of sustainable development, various strategies including practices of environmental technologies can be implemented in various manufacturing industries. Although there is no one perfect strategy for the manufacturing processes, the installation and development of a variety of strategies, techniques and technologies can have an immediate and dramatic impact on the often harmful effects of these industries. The strategies should be continuously evaluated and updated based on the environmental, economic and manufacturing conditions of the facilities. In doing so, these industries can run more efficiently, more cost effectively and more sustainably in a world where protecting the environment is of increasing social and ecological concern. Thankfully we have a variety of environmental measures and analysis that make it possible to determine and perfect the efficiency of new environmental strategies. As these strategies are evaluated and developed, it is our job to implement them throughout all industries to create an environment of sustainable and enduring industry.

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