

**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES**

**LIFE CYCLE ASSESSMENT OF GLOVE
LEATHER
IN ELICO-GLOVING AND HIDE UNIT**

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February 2007

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this thesis entitled “ Life cycle assessment of glove leather in Elico-gloving and hide unit ” is original work of my own, has not been presented for a degree of any other University and that all sources of material used for the thesis have been duly acknowledged.

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LIFE CYCLE ASSESSMENT OF GLOVE LEATHER IN ELICO-GLOVING AND HIDE UNIT

A Thesis Submitted to the School of Graduate Studies of Addis Ababa
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Science in Environmental Engineering.

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ABSTRACT

The leather industry is composed of different production stages and it is characterized by using a large quantity of water and various types of chemicals .The wastes generated are categorized as a high polluting nature and usually are of solid and liquid types.

Currently, except few tanneries in Ethiopia, the majorities are not aware of the environmental impacts associated with their activity. Even they are not willing to have treatment plant because of its cost for erection and running the plant. However, Elico-Gloving and Hide unit (EGHU) constructed the primary treatment plant at a cost of 8 million Birr .The plant is still functional and its running cost is around 550,000 Birr per annum. In addition to this the company is practicing on ISO-14001 .In this paper a study is performed at EGHU by implementing Life Cycle Assessment methodologies. Inventory analysis on the major inputs and out puts of the production processes in the skin tannery and impacts of the related activities are carried out. Based on the adapted impact assessment method the major problems of EGHU are identified. The possible improvement options for the existing problems are suggested. The research result shows that the implementation of the suggested improvement options will have significant benefit for the factory and for the environment. Since practicing on LCA in Ethiopia is at the infant stage, this thesis may serve as source of information to tanneries and other industries on the LCA methodology and on the existing environmental problems of the leather industry.

I INTRODUCTION

The leather production process is composed of several stages associated with the consumption of large amounts of fresh water as well as the generation of liquid and solid wastes. The wastewaters are characterized by significant organic load and remarkably high concentration of inorganic compounds such as chromium, ammonia, sulfide, etc. and leather processing produces chromium bearing solid wastes in variable proportions.

One of the biggest tanneries in Ethiopia is Elico-Gloving and Hide Unit. The company is known world wide with its gloving products. Most of its glove products is exported to Europe and Asia. In order to be competitive in global market the company has been improving the quality of its products by considering the environmental impacts that arise due to the production processes. ISO -14001 certificate is become one of the requirements for products, which are to be exported to the European market. And now the issue becomes important and forced the company to produce eco-friendly products. Complaints from the customers have been raised as the products have abandoned chemicals in them. If conditions proceed as it is the company may lose its customers. Having this in mind effort has been applied by the company to find the cause of customer complaints. However, attractive solution is not yet devised.

Currently the European market establishes an eco-label scheme, which is intended to promote the design, production, marketing and use of products and services with reduced environmental impacts. Eco-label can promote the use of cleaner technologies in any sector that has been traditionally considered very pollutants as that of leather industry so that leather products are on the list of priority products selected or eco-labeling (1).

A useful tool to evaluate the environmental burdens associated with a product, process or activity is Life Cycle Analysis or Assessment (LCA). According to the ISO guide on life cycle assessment principles, LCA means compilation and evaluation of the inputs, outputs and potential environmental impacts of a products system throughout its life cycle. The general categories of environmental impacts needing consideration includes resource use, human health and ecological consequences. LCA is compiled of several

interrelated components; goal definition and scope, inventory analysis, impact assessment and improvement assessment (2,3,4).

For this thesis the LCA approach is based on ISO-14040 standard and focuses on cradle-to-gate approach. In this thesis the environmental impacts of the glove leather will be dealt and then environmental improvement options like BAT (Best Available Techniques), cleaner production options and others will be devised for the exaggerated environmental impacts. To do so all the identification and quantification of the inputs and output flows of the process, energy and materials used wastes released into the environment will be dealt.

II OBJECTIVES

The main objective of this thesis is presented into general and specific aspects.

General objectives of the thesis are

- The introduction of the life cycle thinking into the organization processes
- Practicing the new environmental effect analysis-through LCA
- Providing information to internal and external stakeholders using LCA tool

Specific objectives of the thesis are

- To determine the environmental impact of glove leather product from cradle to gate and then to take proper action so as to improve its environmental impact, where there would be significant impact;
- To improve the environmental conditions of the company by introducing environmental management system.

III METHODS

ISO has standardized the framework of LCA with in the series of ISO-14040. The framework for the life cycle assessment includes:

- The definition of the goal and scope of the project;

- Inventory analysis, impact assessment; and
- Finally the interpretation of the results.

Each of these and other steps are described as follows.

Step 1- Literature and journal review: At this stage the right information in LCA will be gathered and properly enriched;

Step 2- Consultation with the advisor: This is for refining information with the help of the advisor;

Step 3- Defining goal and scope: Defining the purpose, the functional unit, and system boundary and data quality etc. of the considered product;

Step 4-Life cycle inventory (i.e. data collection) and data analysis: The energy carriers and raw materials used, the emissions to atmosphere, water and soil, and different types of land use are identified and quantified at each process, then illustrated in the process flow chart and related to functional basis;

Step 5-Impact assessment: The effects of the resource use and emissions generated are grouped and quantified into a limited number of impacts categories which may then be weighted for importance;

Step 6-Interpretation: The results are reported in the most informative way possible and the need and opportunities to reduce the impact of the product and service on the environment are systematically evaluated;

Step 7-Preparing action plan for the suggested improvement options: Developing an environmental management program to implement the environmental improvement options like BAT (Best Available Techniques), cleaner production options and others will be devised.

IV APPLICATION

The findings of the analysis in this thesis are applicable for the following points:

- Improving the leather product and production process to be competitive in regional, national and international markets;
- Supporting and improving environmental management;
- Deciding the type of raw material to be used for the production of glove leather and the sources of supply of the raw material;
- Assisting to develop internal industry benchmark for environmental performance
- Developing environmental performance indicators;
- Addressing the concerns of customers by adopting Environmental Management System in the company;
- The people who are living around the company will be benefited. This is because the pollutant load of the production effluent will be minimized; and
- Other tanneries that want to have information about LCA application.

1 Life Cycle Assessment

LCA is a methodology for analyzing the environmental interactions of a technological system with the environment (although in principle it could be widened to include health). It becomes a worldwide environmental management tool with the advent of the ISO 14040 international standards. Often referred to as the cradle-to-grave approach (5).

According to ISO 14040, LCA consists of four phases, as presented in Figure 1:1

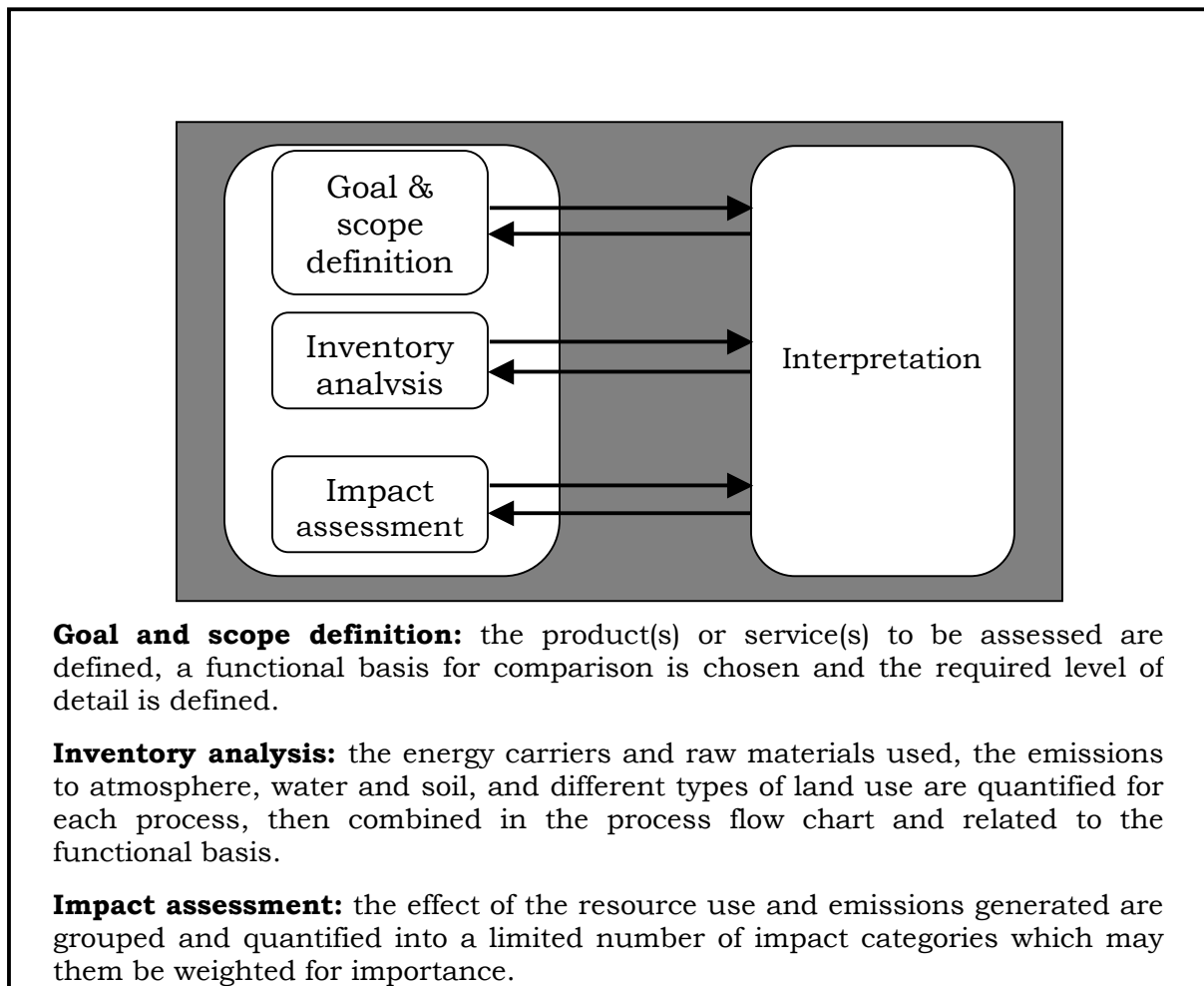


Figure 1.1: the phases of life cycle assessment according to ISO 14040 (5,6)

1.1 Short description of LCIA methods

In relation to LCA there are about 12-impact assessment methods worldwide. This is because combining the subjective and objective aspects and also considering the existing environmental regulation of the country develops the assessment. Some times it may also reflect the political condition of the country. The short description of the 12 methods is presented as follows.

1.1.1 Eco-Indicator 99

The eco indicator 99 does reflect the present state of the art in LCA methodology and application. This of course doesn't mean that all problems are solved. Further developments in environmental science, material technology and LCA methodology will take place and should result in future improvements of the eco-indicators. In the eco-indicators 99 the term environment is defined with three types of damage.

1. *Human health*: Under this category the points included are the number and duration of diseases, and life years lost due to premature death from environmental causes. The effects include are; climate change, ozone layer depletion, carcinogenic effects, respiratory effects and ionizing (nuclear) radiation (7).
2. *Eco-system quality*: Under this category the effects on species diversity, especially for plants and lower organisms. The effects included are eco-toxicity, acidification, eutrophication and land use (7).
3. *Resources*: the points include under this category include the surplus energy needed in future to extract lower quality mineral and fossil resources (7).

The depletion of agricultural and bulk resources as sand and gravel is considered under land use calculate the eco-indicator score, three steps are needed;

1. Inventory of all relevant emissions, resource extractions and land use in all processes;

2. Calculation of the damages these flows cause to human health, eco-system quality and resources; and
3. Weighting of these three damage categories.

The weighting problem is the key problem that is to be solved. Weighting is simplified by:

- Using just three end points, these are human health, eco-system quality and resources.
- Defining these three issues as endpoints that are reasonably easy to understand (8).

The weighting problem has not been solved, but weighting and interpretation of results without weighting has been made easier. The new ideas in the methods are the consistent management of subjective choices using the concept of cultural perspectives. This has lead to a good documentation of the choices and to the publication of three versions, each with a different set of choices (9).

1.1.2 Eco-Indicator 95

The Eco-Indicator method, developed by Pre Consultants under the supervision of the Dutch NOH and implemented in the SimaPro 3.0 LCA software, uses full LCA modules for energy and raw material production and calculates one value per material, which is the weighted sum of ecological impact classes similar to the SETAC proposals (Pre, Goedkoop, 1995). The structure of the evaluation is shown in figure 1.2 (10).

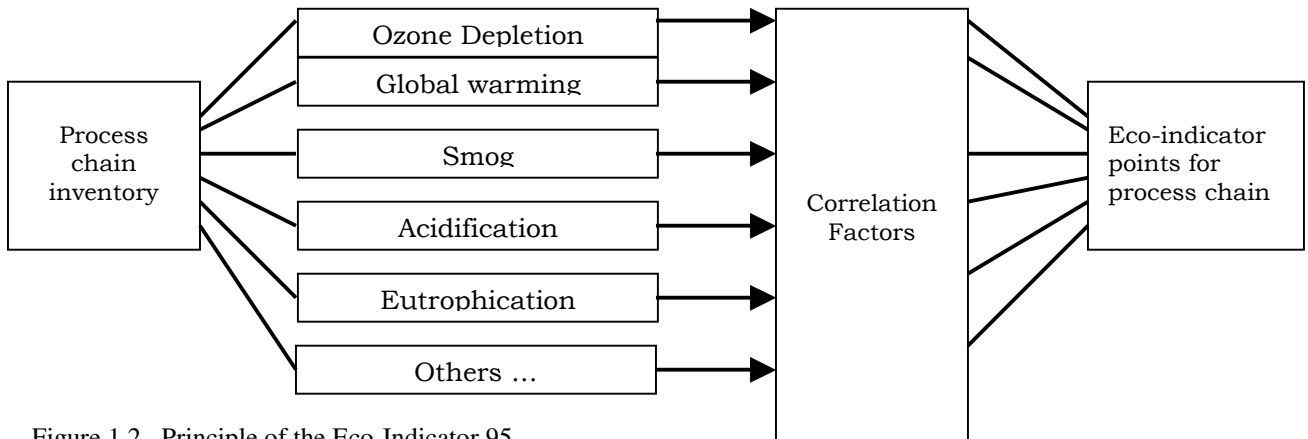


Figure 1.2 Principle of the Eco-Indicator 95

The eco-indicator 95 method encourage using these material assessments without knowing the specifics of the evaluated processes, e.g. a number for copper production

may usually be applied without having to understand the investigated process. When a material is missing in the database, it has to be investigated with the same scope and method by the original database supplier. This is especially complicated for disposal and recycling strategies for products or materials, which are less common or afford special treatment (9).

1.1.3 The Swedish EPS (Environmental Priority Strategy) Model

One method to arrive at one numerical result by evaluation the impact classes specifically by political and social standards has been proposed in Sweden (see figure 1.3)

The principle of the Environmental Priorities Strategy (EPS) is definition of so-called environmental load indices for use of natural resources and energy and pollutant emissions. Based on these inputs, environmental indices of materials and processes are calculated for which the background information originates from an LCA-based inventory of the materials and processes under study. In many cases averages are used for process data, but more accurate regional data may be used instead for a specific sensitivity analysis or when local aspects seems to be important. The speciality of the EPS system is the definition of safeguard subjects, which are represented via willingness to pay for the society (9).

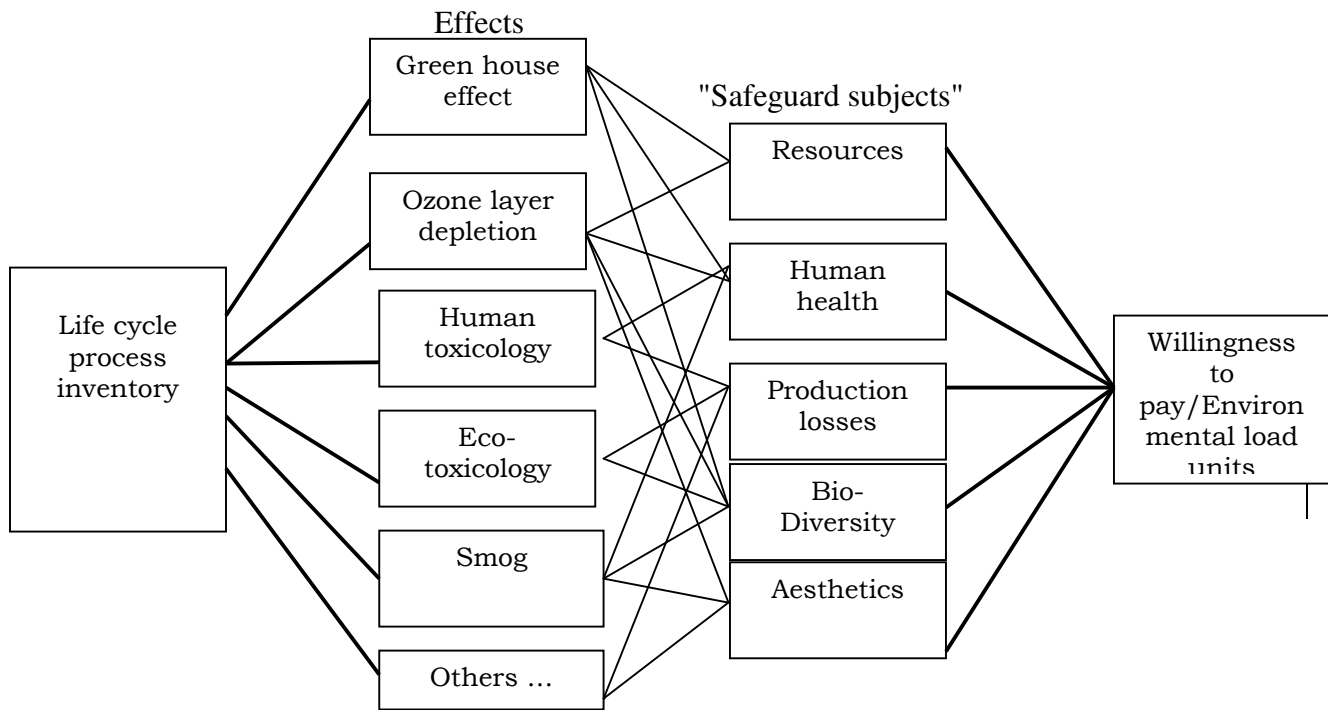


Fig.1.3 EPS-System structural organization

Yet the factors of the EPS model are not very transparent, as they are based largely on local policies or a social value system. The evaluation system does not bring a simplification in comparison to other LCA approaches, but the result can be compressed to only one number, which is linked to both the priorities of the company and of the public (9).

1.1.4 BUWAL (Bundesamt fuer Umwelt, Wald, und Landschaft) Critical Flow Model

The other evaluation method from the Swiss BUWAL is one of the older approaches to produce one environmental number. Here the process emissions are related with factors following a distance-to-target principle and then aggregated together with separate categories for energy and mass of municipal and hazardous waste. The evaluation factors are determined by how much of an emission can be allowed in a certain area compared to what is actually emitted. The 'maximum allowed emission per area' without irreversible

effects is termed the critical flow. The area chosen may bring either a more regional or a more global emphasis to the evaluation factors (9).

The determination of critical and actual flows for all emissions can be quite complicated. For energy and the waste categories the current values for Switzerland were assumed as the critical flows in the original study. For the main emissions (e.g. CO₂, NO₂, SO₂, PO₄³ or SO₄²) into air and water critical flows have been calculated, but again these values are very dependent on national data (9).

1.1.5 EDIP(Environmental Design of Industrial Products) 97 & EDIP 2003

EDIP97 is a thoroughly documented midpoint approach covering most of the emission related impacts, resource use and working environment impacts with normalization based on person equivalents and weighting based on political reduction targets for environmental impacts and working environment impacts, and supply horizon for resources. Ecotoxicity and human toxicity are modeled using a simple key-property approach where the most important fate characteristics are included in a simple modular framework requiring relatively few substance data for calculation of characterization factors (11).

Update through EDIP2003 methodology supporting spatially differentiated characterization modeling, which covers a larger part of the environmental mechanism than EDIP97 and lies closer to a damage-oriented approach. This part of the general method development and consensus program covers investigations of the possibilities for inclusion of exposure in the life cycle impact assessment of non-global impact categories (photochemical ozone formation, acidification, nutrient enrichment, eco-toxicity, human toxicity, noise) (11).

1.1.6 EPS 2000d

The EPS 2000d impact assessment method is the default impact assessment method in the EPS system. It is developed to be used for supporting choice between two product concepts. Category indicators are chosen for this purpose, i.e., they are suitable for assigning values to impact categories. Category indicators are chosen to represent actual

environmental impacts on any or several of five safeguard subjects: human health, ecosystem production capacity, biodiversity, abiotic resources and recreational and cultural values. The characterization factor is the sum of a number of pathway-specific characterization factors describing the average change in category indicator units per unit of an emission, e.g. kg decrease of fish growth per kg emitted SO₂. An estimate is made of the standard deviation in the characterization factors due to real variations depending on emission location etc. and model uncertainty. This means that characterization factors are given for emissions defined by their, location, size and temporal occurrence. Most factors are for global conditions 1990 and represents average emission rates. This means that many toxic substances, which mostly are present in trace amounts, have a low average impact. Weighting factors for the category indicators are determined according to people's willingness to pay to avoid for one category indicator unit of change in the safeguard subjects (11).

1.1.7 Dutch -- Handbook on LCA

The (Dutch) Handbook on LCA provides a stepwise 'cookbook' with operational guidelines for conduction an LCA study step-by-step, justified by a scientific background document, based on the ISO standards for LCA. The different ISO elements and requirements are made operational to be 'best available practice' for each step. The life cycle impact assessment methodology recommended is based on a midpoint approach covering all emission-and resource-related impacts, on which practical and acceptable characterization methods are available (guinea et al., 2002). Best available characterization methods have been selected based on an extensive review of existing methodologies worldwide. For most impact categories a baseline and a number of alternative characterization methods is recommended and for these methods comprehensive lists of characterization and also normalization factors are supplied. Ecotoxicity and human toxicity are modeled adopting the multi-media USES-LCA model developed by Huijbregts (11).

1.1.8 IMPACT 2002+

The IMPACT 2002+ life cycle impact assessment methodology proposes a feasible implementation of a combined midpoint/damage approach, linking all types of life cycle inventory results (elementary flows and other interventions) via 14 midpoint categories to four damage categories (fig.1.4). For IMPACT 2002+ new concepts and methods have been developed, especially for the comparative assessment of human toxicity and ecotoxicity. Human Damage Factors are calculated for carcinogens and non-carcinogens, employing intake fractions, best estimates of dose-response slope factors, as well as severities. The transfer of contaminants into the human food is no more based on consumption surveys, but accounts for agricultural and livestock production levels. Indoor and outdoor air emissions can be compared and the intermittent character of rainfall is considered. Both human toxicity and Ecotoxicity effect factors are based on mean responses rather than on characterizing methods (Eco-indicator 99 and IMPACT 2002+). All midpoint scores are expressed in units of a reference substance and related to the four damage categories human health, ecosystem quality, climate change, and resources. Normalization can be performed either at midpoint or at damage level (11 & 12).

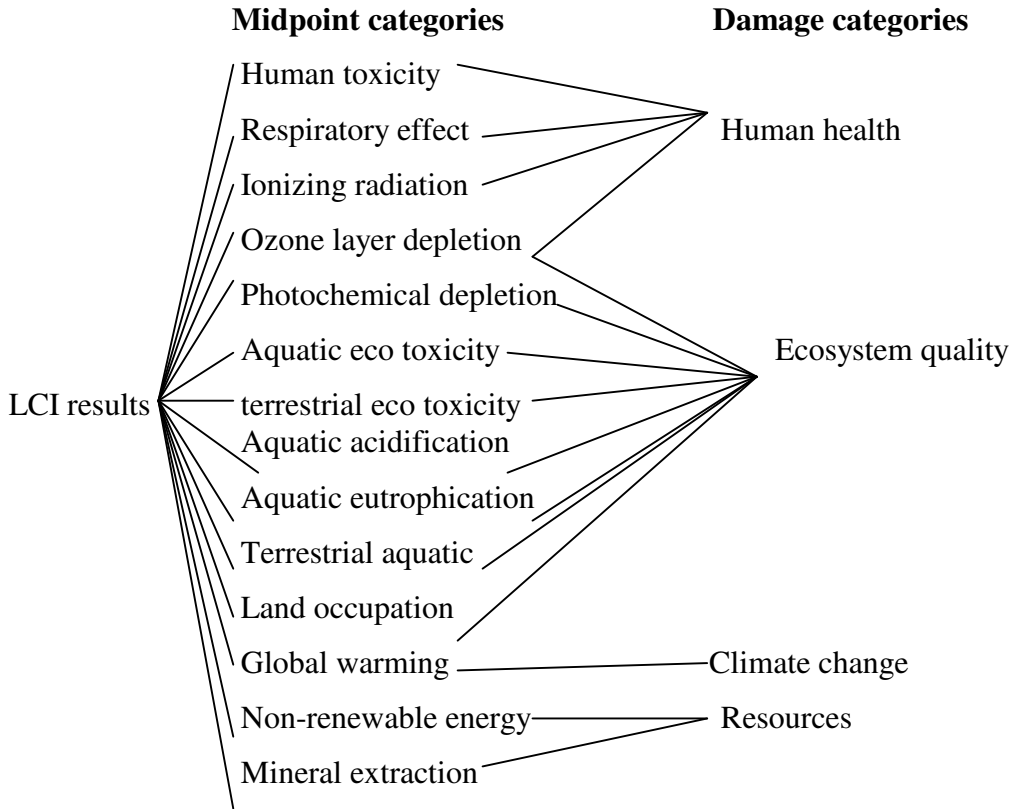


Fig. 1.4 Impact 2002+ structure

1.1.9 JEPIX – Japan Environmental Policy Priorities Index

This method is developed and applied by the JEPIZ Forum, a voluntary initiative of several organizations and private persons from Environmental Accounting, Environmental Management, Eco-Rating and Life Cycle Impact Assessment in Japan. Inspired by the Swiss EcoScarcity method, JEPIX is based on the distance-to-target principle, but in many respects takes different approaches to derive Eco-factors for the weighting of interventions. The method puts more emphasis on a transparent, simple and understandable, but trend-consistent description of the political situations rather than on the preciseness of natural science based modeling. It is designed to indicate, where political pressure is high and therefore new legal requirements are likely to occur and hence to rise environmental costs for industry. Therefore it is considered as complementary to existing LCIA methods that indicate damage to environment and/or society (11).

A first version of JEPIX was published in 2003 as a draft focusing on emissions and addressing 11 focal subjects of Japanese environmental legislation. It provides weighting factors for some 1050 interventions. For substance bound legislation, the weighting is based on annual flows (actual and target), whereas for effect oriented legislation midpoint models such as GWP, ODP, Human Toxicity or POCP are used to derive national flows. As the environmental situation varies substantially across Japan, the weighting factors for some 150 substances are scaled to reflect the situation in each of the 47 prefectures as well as for some 100 rivers, 15 lakes and 3 inland sea areas/bays (11).

The draft version was published in 2003 with support of the Japan Environmental Ministry (MoE), the Ministry for Economy Trade and Industry (METI) and the Ministry for Education and Technology (MEXT).

Since 2003 some 40 leading Japanese Companies (including Komatsu, Canon, TEPCO, Suntory, Fuji Film, All Nippon Airways, J-Power, etc.) are applying this method to evaluate and communicate their environmental performance data and to conduct LCA of products and services. Under the Center of Excellence Program of the Japanese government, the method will be enhanced based on their experience. The final version of JEPIX is expected for publication in 2006. An integration of resources as well as the adoption of newly available data on chemicals is already under development (11).

1.1.10 LIME (Life cycle Impact assessment Method based on End Point Modeling)

LCA National Project of Japan has conducted a study aimed at the development of a Japanese version of the damage oriented impact assessment method called LIME (Life-cycle Impact assessment Method based on Endpoint modeling). In LIME, the potential damage on socio economic impact caused by the utilization of abiotic resources, increase of extinction risk and loss of primary production caused by mining of resources are measured as main damages of resource consumption. Modeling socio-economic impact was based on the concept of user-cost, which accounts for the equity of future generations. The procedure to measure damages of ecosystem is based on studies estimating the risk of extinction of specific species in the field of conservation biology.

Lists of damage factors of mineral resources, fossil fuels and biotic resources like wood material have already prepared and released to the public. The development of these factors enables us to compare and integrate with the damages derived from the other impact categories like global warming and acidification without value judgment of ordinary people (11).

1.1.11 Swiss Ecoscarcity Method (Ecopoints)

The method of environmental scarcity-sometimes called Swiss Eco points method allows a comparative weighting and aggregation of various environmental interventions by use of so-called eco-factors. The method supplies these weighting factors for different emissions into air, water and top-soil/ground water as well as for the use of energy resources. The eco-factors are based on the annual actual flows (current flows) and on the annual flow considered as critical (critical flows) in a defined area (country or region). The eco-factors were originally developed for the area of Switzerland (see references below). There, current flows are taken from the newest available statistical data, while critical flows are deduced from the scientifically supported goals of the Swiss environmental policy, each as of publication date. Later, sets of eco-factors were also made available for other countries, such as Belgium and Japan (11).

The method has been developed top-down and is built on the assumption that a well established environmental policy framework (incl. the international treaties) may be used as reference framework for the optimization and improvement of individual products and processes. The various damages to human health and ecosystem quality are considered in the target setting process of the general environmental policy: this general environmental policy in turn is then the basis for the 'critical flows'. An implicit weighting takes place in accepting the various goals of the environmental policy. The eco-points method contains common characterization/classification approaches (for climate change, ozone depletion, and acidification). Other interventions are assessed individually (e.g. various heavy metals) or as a group (e.g. NM-VOC, or pesticides) (11).

The method is meant for standard environmental assessments, e.g., with specific products or processes. In addition, it is often used as an element of environmental management

systems (EMS) of companies, where the assessment of the company's environmental aspects (ISO 14001) is supported by such a weighting method (11).

1.1.12 The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)

TRACI is an impact assessment methodology developed by the U.S. Environmental Protection Agency that facilitates the characterization of environmental stressors that have potential effects, including ozone depletion, global warming, acidification, eutrophication, troposphere ozone (smog) formation, Ecotoxicity, human health criteria related effects, human health cancer effects, human health no cancer effects, and fossil fuel depletion. TRACI was originally designed for use with life-cycle assessment (LCA), but it is expected to find wider application to pollution prevention and sustainability metrics (11).

To develop TRACI, impact categories were selected, available methodologies were reviewed, and categories were prioritized for further research. Impact categories were selected based on societal consensus concerning the certainties of modeling at this point in the cause-effect chain. Research in the impact categories of acidification, smog formation, eutrophication, human health cancer, human health no cancer, human health criteria pollutants was conducted to construct methodologies for representing potential effects in the United States. Probabilistic analyses allowed the determination of an appropriate level of sophistication and spatial resolution necessary for impact modeling for each category, yet the tool was designed to accommodate current variation in practice (e.g., site-specific information is often not available). The methodologies underlying TRACI reflect state-of-the-art developments and best-available practice for life-cycle impact assessment (LCIA) in the United States (11).

1.2 Practical constraints of life cycle assessments

A continuing concern of LCA methodology development bodies is the time and cost required to complete LCAs. Some have questioned whether the LCA community has established a methodology that is beyond the reach of the majority of potential users. Others

have questioned the relevance of the LCA to the actual decisions that potential users must make. Collection of Life Cycle Inventory (LCI) data can be extremely costly and time consuming and often results in LCA studies being abandoned or proving inadequate because of poor and inconsistent LCI data. Good LCA's demand sound LCI's that subsequently contributes to making good judgments about environmental matters. The build up of a LCI puts together a whole series of smaller process data sets, either for individual processes. In an attempt to facilitate the completion of LCI's numerous industry segments have undertaken and made available 'cradle-to-gate' or 'gate-to-gate' LCI studies. These are prepared by many of the specific industry groupings for the connected processes that are under their control. Such 'block' collections of industry data are known as 'eco-profiles'. A collection of Eco-profiles can then be added together to form a complete LCI. This procedure serves to reduce costs, save time, provide reliable and accurate data and makes LCA studies easier to complete, be more widely applicable, and as a consequence, assists with sound decisions on environmental management by interested parties. The profiles are, however, highly dependent on the contexts in which they were developed and used in different contexts introduces risk of incompatibility (13).

There are a number of organizations marketing eco-profiles in the form of LCA databases however these have been found to vary considerably in:

- Level of detail,
- Flexibility of data manipulation,
- Data quality; and
- Purchase costs.

1.3 Limitations of LCAs

As with any scientific method the LCA methodology suffers from limitations that must be understood. Several basic principles and practicalities remain to be defined:

- Data details differ for each supplier, specific processes used, location, dominant methods of primary protection;

- Analysis of multi-product manufacturing systems provide complex allocation problems;
- The impact assessment stages are not fully developed and cannot provide a full decision support system;
- The impact assessment depends on environmental priorities of the industry segment and data provided; and
- Interpretation is subjective in its ranking of impacts.

In this light LCAs have been shown to rarely produce clear winners and losers but rather serve to detail environmental implications and illustrate tradeoffs (13).

2 Description of the production processes in ELICO-Gloving and Hide unit.

The company has 75 years of experience on leather processing. It started to produce leather in 1924 E.C by the ownership of Armenians in Harar. Then they dismantled the plant and installed it near Akaki river water line (i.e existing place). At that time its name was Darmar Tannery till the ownership transferred to government control. The Tannery was nationalized following a change of government in Ethiopia. Then its name changed to Awash Tannery till it is privatized. Following a change in government and the subsequent liberalization of the economy, Awash Tannery was privatized and came under Ethio-Leather Industry PLC (ELICO). After privatization its name changed to Elico-Awash Tannery as of 1989. Currently it has 700 employees and Hide and Skin Tanneries for the production of hide and skin leathers, respectively. The company uses the Akaki river water for its operation by treating it and also gets its power supply from Ethiopian electric power corporation (EEPCO). For the production of glove leathers of high quality it uses raw sheepskins. To do so the raw skins will pass through different processing stages.

The processing stages are:

- *Beam house operations comprising:* sorting, trimming, soaking, painting and liming, fleshing;
- *Tan yard operations comprising:* delimiting, bating, degreasing, pickling, tanning, samming and setting, shaving;
- *Post tanning operations involves:* Neutralization, bleaching, retanning, dyeing, fatliqouring, drying; and
- *Mechanical finishing operations-*wheel staking and polishing (14).

2.1 Main production processes and related operations

The detail of the operations, chemicals used and the wastes associated to each processing stages in skin tannery are presented as follows.

Skin Beam house operations involve the following processes

- **Soaking:** - This is the process of re hydrating the wet salted skin and dry hide to its natural water content. This can be taken place by immersing the raw material in water having wetting agent and anti septic agent. The associated wastes during soaking are chlorides, sulphates, NH_3 , bloods, dirt and hairs (15,16,17).
- **Liming:** - The main objective of this process stage is to create a condition for removing the hair from the raw skin. Sodium sulphide, sodium Sulphhydrate and lime are the chemicals used for unhairing purpose. Unhaired hair, spills of sulphide and lime sludge is the main waste. The liquor discharged from this operation has high sulphide content and fine hairs that are responsible for high S.S, COD and BOD load(15,16,17).
- **Fleshing:** - At this stage the pelt (i.e. unhaired skin) is fleshed using fleshing machine so as to remove unwanted parts and to clean it for the next operations. If required unnecessary parts will also be trimmed. For this operation the company uses the treated Akaki river water. The wastes from this operation are fleshing and trimmings that contain sulphide(15,16,17).
- **Deliming and bating:** - Here the fleshed pelt of lime is removed by using salts of strong acid like ammonium Sulphate. As a result of the reaction of this chemicals with the lime and sulphide chemicals of the pelt the most dangerous gas will evolve.

This gas is hydrogen sulphide and ammonia gas. To protect employees from the exposure of this gas usually sodium bisulphate is added together with the delimiting agent. However during drain of the drum either this gas may generate and make employees feel discomforts. During bating enzymes are used to improve the open up nature of the leather fiber (15,16,17).

- **Pickling:** - At this stage the pelt is prepared to be changed to leather by carrying out tanning. Salt and sulphuric acid are used .As the pickled pelt is the raw material for glove leather production care has been taken to make it more cleaner. For this purpose before adding the acid the pelt is repeatedly washed by salt and water. Then finally acid is added so that its final P^{H} is <1.0 (15,16,17).

- **Tanning:** - The most widely practiced method of tanning is chrome tanning using chromium Sulphate base salts. The pelt after tanning process will have non-biodegradable nature and then called leather wet blue. Since the chrome uptake rate of the tanned leather is 70% of the input, the rest 30% will be discharged through the effluent. The discharged chrome liquor contains the poisonous pollutant chromium (III) (15,16,17).
- **Samming and shaving:** - So as to reduce the unbounded liquor from the wet blue the leather will be sammed and then shaved to the desired customers order thickness or can be shaved at crust stage in drying form where needed. Chrome containing liquor and wet blue leather shavings and pieces are the major wastes of the samming and shaving operation, respectively(15,16,17).

The process flow chart for the main skin beam house operation are shown if fig. 2.1.

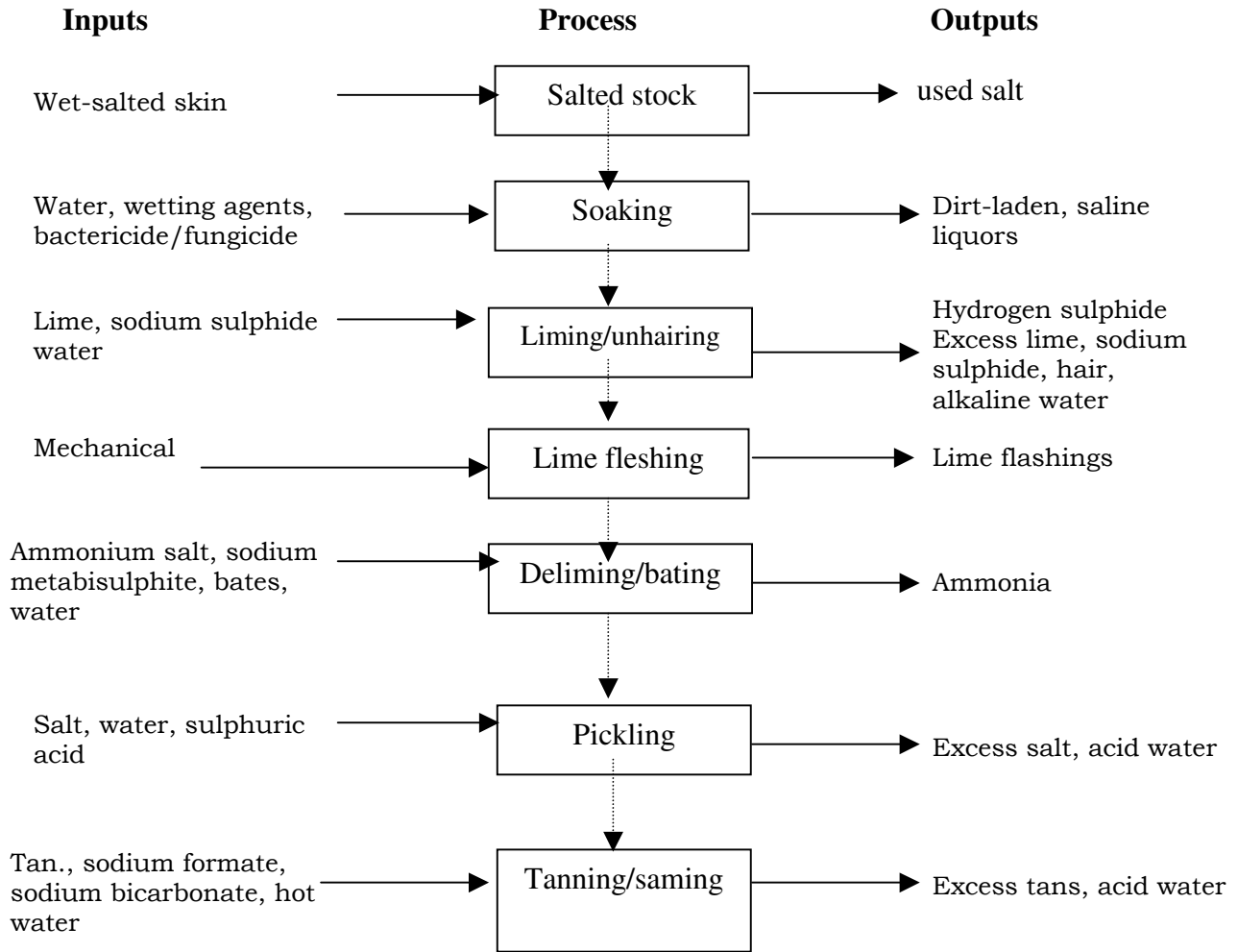


Fig.2.1 Flow chart for skin beam house operation

Skin post-tanning operations involve the following processes and are shown in figure 2.2

- **Neutralisation, Retanning, Fat liquoring and Dyeing:** - At this stage the tanned wet blue leather will be treated with neutralizing agents, synthetic syntans, fat liquors, and dyes and will be converted to dyed crust leather product. Pollutants that contribute to acidity, BOD, COD of effluent are released to the environment (15,16,17).
- **Mechanical operation:** - The wet dyed crust is then pass through the setting out, overhead drying and rotary staking and finally trimming. In relation to this process stages the wastes generated are crust trims and staking dusts (15,16,17).
- **Finishing:** - mechanical operations like wheel staking and polishing and the finally toggling will finish the well-prepared crust leather.

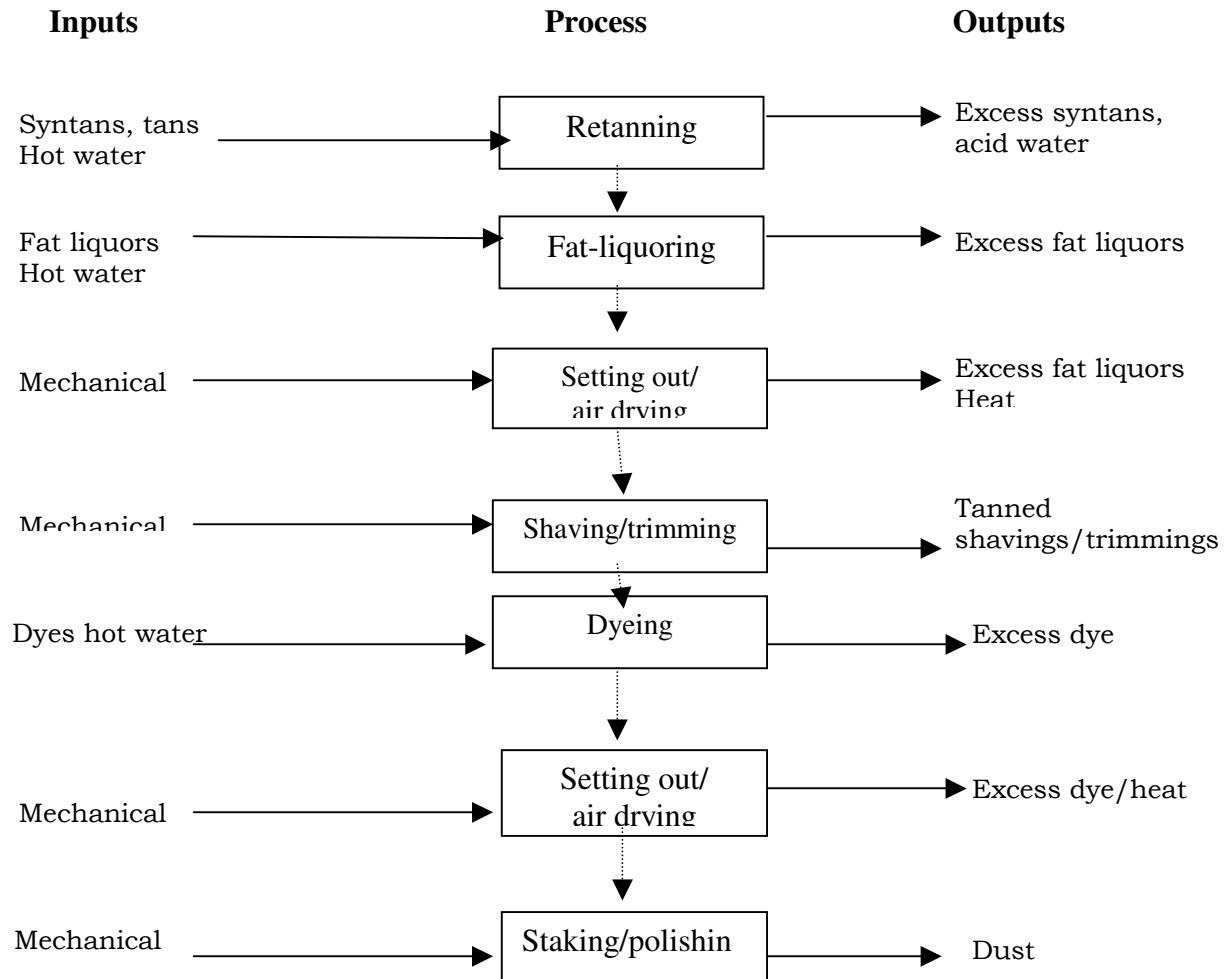


Fig.2.2 Flow chart for skin post tanning operation

Other tannery related operation

- **Effluent treatment:** -there is a Primary effluent treatment plant in the company. During its operation pungent odor and solid wastes and filter cakes generated as waste. There is also chrome recovery unit so as to minimize the chromium discharge.

3 Tannery waste generations in production processes

Leather is a rapidly expanding and highly polluting export sector in Ethiopia. Ethiopia has a natural advantage in terms of its large livestock population, the major input for the leather sector. In order to convert the raw skin into leather it should pass through different processing stages.

The main chemicals used in the various processing stages include sodium chloride, sodium sulphide, sulphuric acid, lime powder, ammonium Sulphate, chromium Sulphate, pigments, dyed and anti-fungus agents.

The tanning industry inevitably produces both liquid and solid wastes. The effluent discharged contains waste material originating from the raw material (skin) and residues of the chemical used in processing. Additionally, environmental damage can result from solid waste if not correctly treated and properly dumped (18).

Quantities of solid waste produced by tanneries depend on the type of leather processed, the source of skins and the techniques applied. On average, at the end of the process about 20% of the weight of the raw skin is (grain side) leather (14).

Solid and effluent waste contains organic substances released from the raw material during processing (blood, mature, hair, fats, proteins, etc (and miscellaneous inorganic and organic chemicals used in processing. The main tannery pollutants at each process stage are listed in table 3.1 (18).

Table 3.1: Tannery operations in sequence and the pollutants resultant in the liquor

Operation	Types of pollution
Soaking	Mainly blood, manure, sand, soluble proteins, salt
Unhairing/liming	Mainly sulphide, high alkalinity, suspended solids (hair & lime), proteins, nitrogenous compounds, COD, BOD
Deliming and bating	Ammonium salts, inorganic and organic acids, enzymes
Pickling	Mainly common salt and strong inorganic acid
Degreasing	Mainly fats, degreasing agents & common salt
Tanning	Mainly Cr ⁺³ salts, Sulphate and carbonates
Retanning + fatliquoring	Cr ⁺³ , tanning agents, fats and oils
Dyeing	Dyestuff, inorganic and organic acids ammonia

Solid wastes generated by mechanical operations are fleshing, chrome shavings, trimmings, rejected finished materials, sludge from effluent treatment (18&20).

Table 3.2 shows the summary of environmental effects caused by tannery pollutants.

The other wastes generated are packing material wastes, spilled chemicals, scrap metal and malfunctioning equipments. All these wastes may generate from soaking to finishing operations (14).

Table 3.2: Summary of environmental effects caused by tannery pollutants(16,18)

Pollution	Symbol	Main negative effect	Impact area
Ammonia	NH ₃	Pungent odor and adverse effects on aquatic life	Water & air
Total Kjeldahl nitrogen	TKN	Causes excessive plant growth & formation of algae	Water & land
Trivalent chrome	Cr ⁺³	- Toxic to human's, aquatic life & crops - At high temp. Oxidizes to chrome VI, which is highly toxic	"
Chloride	Cl ⁻	Harmful to plants & agriculture, corrodes metals	"
Bio chemical oxygen demand	BOD ₅	Depletes dissolved oxygen	Water
Chemical oxygen demand	COD	Depletes dissolved oxygen	Water
Total dissolved solids, sulphates & chlorides	TDS, Cl ⁻ SO ₄	- Harmful to human plants & civil structures - High salinity causes osmotic pressure	Water & land
Oil & grease	O & G	Form surface films on water & shore line deposits which lead to environmental degradation	"
Suspended solids	SS	Can form deposits & create an aerobic condition (odor) which pose a danger to aquatic life	Water
Sulphide	S ²⁻	Odor nuisance at low levels & fatal in high concentrations	Water & air
Sulphate	SO ₄	May cause corrosion of concrete & piping	Water & land

4 Methodology

LCA is composed of several inter related components goal definition and scope, inventory analysis, impact assessment and improvement assessment.

The points considered under each component are described as follows:

4.1 Goal definition and scope

- *Purpose*

The LCA of gloving leather products of ELICO-Gloving and Hide Unit is preformed from "Cradle" to "gate" perspective. The main objective of the study is to make an environmental improvement on the existing glove leather production process. Moreover it serves as a source of information for other tanneries or industries which may be interested to study the impact of their products /processes by applying the LCA methodology. In this study the environmental impact of the *dress glove* and *Silver White* glove products and their production processes will also be analyzed and compared.

- *Functional Unit*

This unit provides a reference to which the inputs and outputs are related (2). The tannery under the study has a capacity to process 1,820,000 pcs wet salted sheepskins per annum. The functional unit chosen is 1 square feet finished glove leather product. Therefore all the emissions are calculated in relation to the production of 1 square feet finished glove leather.

- *System Boundaries*

This term is defined as the interface between the product system and the environment or other product systems(2,14,19). It is essential to define the system boundary when undertaking LCA.Often this is taken as Cradle-to-gate ,gate-to-grave or gate-to-gate(24).For an LCA to be exhaustive ,the system boundaries should encompass all energy and mass flows related to the analysed product(19,20).

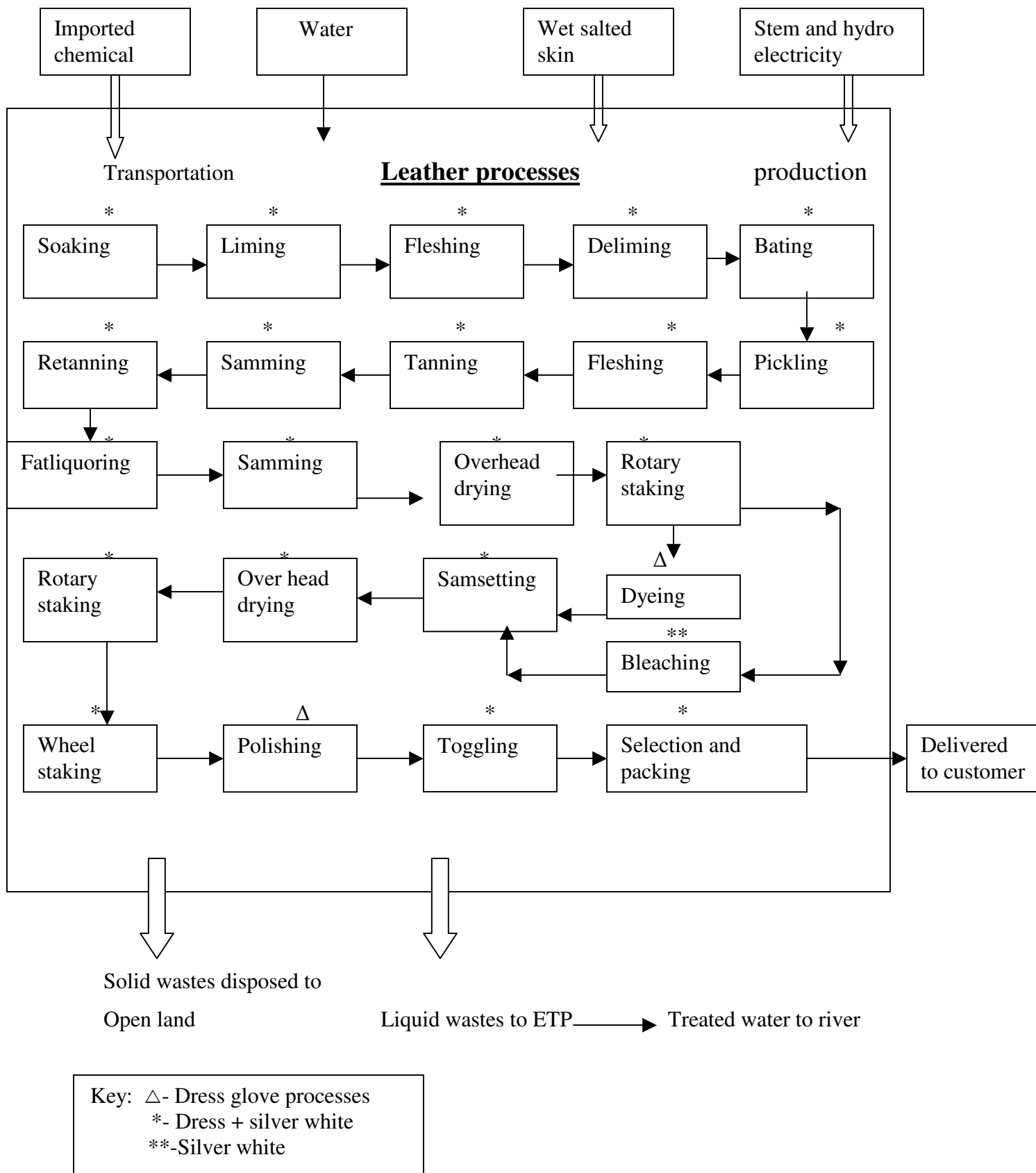


Fig .4.1 System boundary and production process flow chart

The system boundary and the production process flow chart are shown on the chart attached on figure 4.1 . It shows the system boundary and production process flow chart.

The above system boundary incorporates tannery processes for dress glove and silver white leather. Dress glove leather is of different colors and used as dress and hand glove leather for cold season and during some especial occasions. Silver white leather has only silver color and softy nature. It is applicible for wearing during golf playing.

The processes evaluated under this study are beam house, tanning, retanning and dyeing, toggling as well as energy, water, chemical and raw material supply. The efficiency of waste treatment plant including the wastes is also taken into consideration. During the production of the glove leather the polishing and wheel staking process stages are the finishing stages. Because the finished glove products are of full aniline type (no pigment).

In this thesis the impacts as a result of production of chemicals, hydropower electricity generation, gas or oil production and capital goods are excluded. However, the impact during transporting of chemicals from port to gate, and transporting of raw material from supply regions to gate are considered.

As the thesis focuses on cradle to gate approach exclusion is made on what is happening on the delivered product while under the customer control and at its final disposal.

The fate of the chemical containers out of the company gate is also excluded. But the washings from the chemical containers is directly discharged into the effluent treatment plant There fore, no need to discuss about their environmental impact while under the company premises.

The life cycle phases covered in this thesis are explained in table 4.1 below.

Table-4.1: Life cycle boundaries explanation

Life cycle stage	Explanation
Transportation	The transportation of chemicals from port to gate and raw sheep skin from supplying regions to factory gate are considered;
Steam production and consumption	It covers the production of steam using boiler fuel oil; The combustion of fuel oil and the related emissions at each process stage are analyzed;
Leather processes	All the processes to convert raw sheepskin to leather are discussed. Air emissions are neglected as most emissions are to water.
Waste	The emissions to soil as a result of solid wastes are considered.

- *Data Quality*

All the data related to the inputs and outputs of the process were obtained directly from the company between June – August 2006. The standard values used in this thesis are emissions data to produce 1 ton of steam and emissions to air due to performance of a loads 15 ton lorry over 1 km road (21) and the emissions to soil from the sludge production (14).

4.2 Life Cycle Inventory

An analysis of the physical and chemical characterization of wastewater emissions of the leather processes and the effluent treatment plant liquors was performed.

The major tests conducted were Chemical Oxygen Demand (COD) Ammonia (as NH₃), Nitrite (as NO₂), Nitrate (as NO₃), total Kjeldahl nitrogen (as N), Hydrogen Sulphide (as H₂S), phosphate (as PO₄), chromium (as Cr³⁺), Chromium (as Cr⁺⁶).

The Addis Ababa City Water and Sewerage Authority Laboratory conducted the above tests. The samples being analyzed were combined liquor of soaking -liming, deliming- Pickling, Depickling- Tanning, Retanning (for Dress glove), Retanning (for Silver White), Dyeing (for Dress glove), untreated (inlet) and treated (out let) effluent liquors.

The collected samples were representative of the high production time of the company.

Due to lack of measuring instruments the emissions as a result of boiler fuel oil combustion was not measured. However, standard emission values are used to estimate

the possible emissions at each process stage. The company has no instrument to quantify the amount of steam consumed at each process stage. To have a reasonable judgment simple mathematical calculation is used in this thesis.

4.3 Impact Assessment

Impact assessment is a technical quantitative, and/or qualitative process to characterize and assess the effects of the environmental burdens identified in the inventory (2,3,4).

The impact assessment was conducted based on the eco-indicator 95 and impact 2002+ methodology. This is due to the availability of information and data in relation to the above methods. In other methods the methodology applied and their application to developing countries condition is minimal. And also the environmental problems being considered are simply reflecting current condition of the developed countries. The chemicals used by the developed countries are mostly non-harmful due to the strict environmental regulation. Whereas in developing countries the chemical usage is not controlled and susceptible to serious environmental problems. As a result the environmental impacts are many as compared to the developed countries. Of the available LCA methods the above two methods are applicable taking into account the existing problem of the developing countries. In this thesis no discussion made on the land use, noise and fossil fuel depletion as the characterization values are not available and difficult to adapt to the above methodologies.

According to impact 2002+ the environmental impacts are grouped into three damage categories – Human health, eco-system quality and climate change. There are 7 impact categories being considered. These are human toxicity, Photo Chemical Oxidant Formation (POCP-Winter + Summer Smog), eco-toxicity, acidification, and eutrophication & Green house impact. Figure 4.2 shows the adapted impact assessment methods.

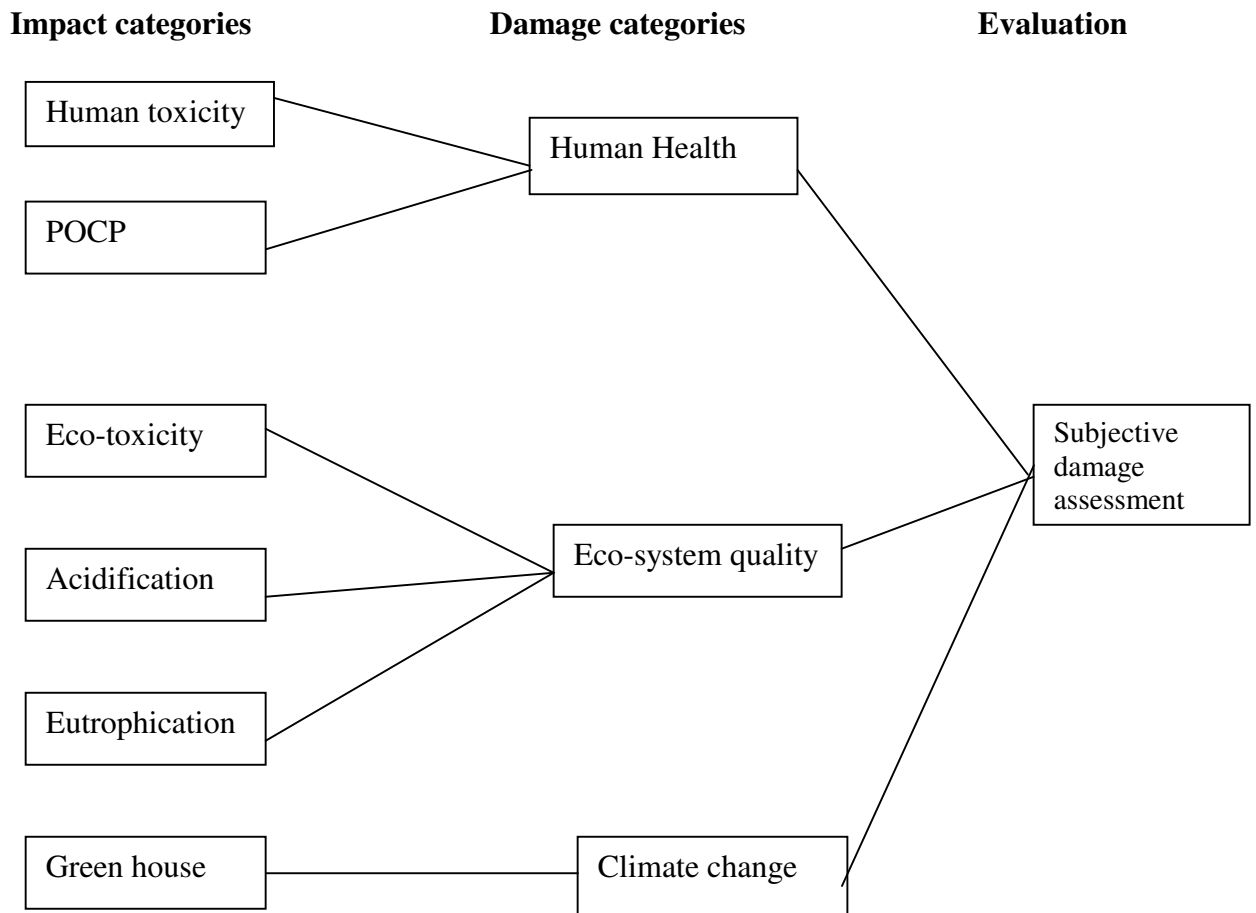


Fig. 4.2- Adapted impact assessment method

The impact categories, the impact reference substances, damage categories and the damage unit are presented in the table 4.2 below

Table 4.2: Impact category reference substance and damage unit

Impact category	Impact reference substance	Damage category	Damage Unit
Human Toxicity	1kg active substance	Human Health	Kg
POCP	Kg ethylene	Human Health	
Eco-toxicity	Kg active substance	Eco-system quality	Kg
Acidification	1 kg SO ₂	"	
Eutrophication	1 kg phosphate	"	
Green House	1 kg CO ₂	Climate change	Kg

4.3.1 Classification and characterization

Classification and characterization are parts of the impact assessment. Classification specifies the choices of environmental problems considered, and characterization quantifies the environmental impacts of the substances involved in the study (2,3,4).

In this thesis classification and characterization are considered separately.

4.3.1.1 Classification

The environmental impacts considered in this thesis are:

- *Global warming (Green house) effect*- measured relative to the effect of 1 kg CO₂
- *Photo Chemical Oxidant Formation (POCP)*- measured relative to the effect of 1 kg ethylene.
- *Acidification potential (AP)*- measured relative to the effect of 1 kg SO₂
- *Human toxicity Potential (HT)*- measured as the human body weight that would be exposed to the toxicologically acceptable limit by 1 kg of the substance.
- *Eco-toxicity, Aquatic (ECA)*- volume of water that would be polluted to a critical level by 1 kg of substance.
- *Eutrophication-Potential (EP)*- measured relative to the effect of 1 kg phosphate

The afore mentioned environmental impacts are discussed below:

- *Global warming (Green House) effect*

Increasing amounts of CO₂ and other green house gases in the earths atmosphere are leading to increased absorption of the radiation emitted by the earth and hence to global warming. CO₂, N₂O, CH₄ and CFC_s all contribute to global warming (21,22).

- *Photo chemical oxidant creation*

Under the influence of UV light, nitrogen oxides react with volatile organic substance (VOC_s), producing the photochemical oxidants that cause smog (21,22).

- *Acidification*

Acid deposition, resulting from the release of nitrogen and sulphur oxides into the atmosphere, on soil and water can lead to changes in soil and water acidity, with effects on both flora and fauna (21,22).

- *Human Toxicity*

Exposure to toxic substance- through air, water or the soil especially via the food chain causes human health problems (21,22).

- *ECO-toxicity*

Toxic substances can damage Flora and fauna. Eco-toxicity is defined for water as aquatic eco toxicity and for soil terrestrial eco toxicity (21,22).

- *Eutrophication*

Addition of nutrients to water or soil increases the production of biomass. In water, this leads to a reduction in oxygen concentration that affects higher organisms such as fish. In both soil and water eutrophication can lead to undesirable shifts in number of species, in eco- systems and thus to a threat to bio diversity (21,22).

4.3.1.2 Characterization values

On the characterization step the values of each of the impact parameters in the inventory table will be multiplied by the characterization values for each impact category. Then segregate each impact category according to the damage category and then add up to determine the over all environmental impact of the glove leather production.

The characterization values used are adapted from eco-indicator 95 and EDIP(Environmental Design of Industrial Products)/UMIP97(Udvikling af Miljoenlige Industri Produkter-1997). See Annex-1 for detail of the characterization values.

4.3.2 Normalization

Normalization intends to perceive the relative magnitude for each environmental indicator under a non-dimensional approach (2,3,4).

The scores for each environmental problem can be normalized in a number of different ways in order to relate them to a reference. In that way, it is possible to relate the environmental impacts of the product under study to global emissions. This can be done by dividing the score of impact parameter by the annual rate of that impact parameter (22).

The global figures used for common environmental problems are given in table 4.3. Due to lack of information that global values have been used instead of local or regional values.

Table 4.3: World values for major impact categories

Impact category	Unit	World
Abiotic depletion	a^{-1}	0.06
Energy depletion	$Gj. a^{-1} \cdot 10^9$	235
Global warming	$Kg. a^{-1} \cdot 10^{12}$	37.7
Photo chemical oxidant formation	$Kg. a^{-1} \cdot 10^9$	3.74
Acidification	$Kg. a^{-1} \cdot 10^9$	286
Human toxicity	$Kg. a^{-1} \cdot 10^9$	576
Aquatic eco toxicity	$m^3 \cdot a^{-1} \cdot 10^{12}$	908
Terrestrial eco toxicity	$Kg. a^{-1} \cdot 10^{12}$	1160
Eutrophication	$Kg. a^{-1} \cdot 10^9$	74.8
Ozone Depletion	$Kg. a^{-1} \cdot 10^9$	11.0

Source- Life cycle assessment, what it is and How to do it, UNEP Publication, 2000

4.3.3 Evaluation

Evaluation permits us to weigh the contribution from different impact categories (2). Each environmental impact is then weighed so that the scores for each problem can be added up. Weighing factors usually differ from country to country, or even within the countries, due to differences in local conditions. Political views also affect the weighing process. Every environmental impact is weighted according to the relative seriousness of that problem (22,23). In this thesis all the impacts are assumed to be the same and treated equally.

5 Application of LCA in ELICO-Gloving and Hide Unit

5.1 Inventory Data

The major data collected to conduct life cycle assessment of the glove leather products of Elico-gloving and hide unit are:

- Raw sheep skin supply
- Input chemical consumption
- Water & steam consumption
- Pollutant emission due to utilization of processing chemicals
- Effluent treatment plant influent & effluent emissions
- Tannery solid waste
- Annual electricity, water and fuel oil consumption

5.1.1 Raw sheep skin supply

The company purchased 1,820,000 wet salted sheepskins from different regions.

The percent share of each region is shown on the following table:

Table 5.1: Distance from Addis Ababa to supplying regions (with in the budget year 2005/06)

Region	Quantity supplied	% Share	Most Common Site	Distance to A.A
Gojjam	839,020	46.10	Addis Kidam	500 km
A.A	473,018	25.99	Merkato	20 "
South Shoa	273,546	15.03	Gumer bole	250 "
Wollo	63,336	3.48	Kombolcha	330 "
North Shoa	58,058	3.19	Tarmabar	175 "
Gonder	56,602	3.11	Debarik	700 "
Wollega	21,112	1.16	Nekemit	340 "
Kaffa- Agaro	19838	1.09	Agaro	350 "
Jimma	15,470	0.85	Jimma	335 "

- Most of the time the raw materials are transported by Isuzu vehicle whose carrying capacity 13,150kg. Its total weight is 15,000 kg and travels 4 km by one-liter oil. The maximum amount of skin being carried by one vehicle is 8,000 pcs.

- The amount of Naphthalene used to preserve 1,000 kg salt is 15 kg.

5.1.2 Input chemical consumption

In order to determine the chemicals input for producing glove leather the 2005/06 budget year data was applied. During this time the skin section of the company produced dress glove leather, silver white and local garment leather. Of these, dress glove and silver white leather shares the maximum and both are export standard products. Chemical consumption to process 1 square feet raw material was calculated by using the standardized process recipe at each process stage. During quantification of the produced products only products that fulfill the company's requirement are considered. The material Input-out put analysis is presented on annex 3. The input chemicals in the major production processes are given in table- 5. 2, 3, 4, 5,6.

Process stage- Soaking- Pickling,

Quantity produced – 8,483,267 ft²

Product type- pickled sheep skin.

Table-5.2: Chemical consumption for soaking-Pickling operation

Chemical name	Consumption g/ft ²	Consumption (kg/annum)
Lime powder	19.76	167,629
Sodium Silicon Fluoride	0.13	1,103
Sodium Sulphide	9.0	76,349
Sodium Sulphydrate	2.6	22,056
Sulphiric acid	3.16	26,807
Preventol- WB	0.17	1,442
Common Salt	38.71	328,387
Eusapon -S	2.64	22,396
Oropon-On ²	0.35	2,969
Pre bating SCS	1.78	15,100
Total	78.3	664,238

Process stage- Tanning-Quantity produced 5,896,261 ft²

Product produced -Wet blue skin

Table-5.3: Chemical consumption for tanning process

Chemical name	Consumption g/ft²	Consumption (kg/annum)
Borron SAF	0.15	884.4
Common Salt	9.33	55,012
Coripol DXA	3.11	18,337.4
Eusapon S	4.66	27,476.5
Imrapel CO-liq.	1.55	9,139
Preventol WB	0.16	942.6
Refined Salt	23.00	135,614
Sodium metabisulphites	2.02	11,910.5
Sodium bicarbonate	6.80	40,095
Sulphuric acid	1.08	6,368.3
Tankrom AB	10.88	64,152
Tergolix AN	0.15	884.4
Total	62.89	370,816.1

Process Stage- Retanning Dress Gloving LeatherQuantity Produced- 5,379,932 ft²

Product Type- Retanned Dress Glove Leather

Table-5.4: Chemical consumption for retanning-Dress gloving leather

Chemical name	Consumption g/ft²	Consumption (kg/annum)
Coripol DXA	3.53	18,991
Coripol MB	3.29	17,699
Coripol MK	3.29	17,699
Formic Acid	0.98	5,272
Oxalic Acid	0.44	2,367
Sodium Bicarbonate	1.50	8,069
Sodium Formate	3.10	16,893
Tankrom AB	3.41	18,583
Total	19.54	105,573

Process stage- 'Retanning' (Bleaching) silver white leatherQuantity produced- 516,329 ft²

Product type- Retanned silver white leather

Table -5.5: Chemical consumption for 'Retanning' silver white leather

Chemical name	Consumption g/ft²	Consumption (kg/annum)
Eupilon –IN	1.47	759
Eupilon-was-1	1.66	857
Blankit AR	0.37	191
Formic acid	0.78	403
Oxalic acid	0.37	191.2
Euderm white DCG	1.10	568.5
Lutan FN	1.10	568.5
PM 4700	0.74	362.5
Ammonia	0.15	77.5
Total	7.74	3,998.2

Process Stage- DyeingQuantity produced- 4,066,960 ft²

Product type- dyed dress glove leather

Table 5.6:-Chemical consumption for dyeing dress glove leather

Chemical name	Consumption g/ft²	Consumption (kg/annum)
Ammonia	0.6	2,440
Catalix GS	0.5	2,033
Eupilon-C	1.1	4,474
PM-4700	0.4	1,627
Eupilon IN	0.6	2,440
Eupilon Was-1	1.4	5,694
Formic acid	3.6	14,641
Invaderm S	0.5	2,003
Tankrom AB	0.8	3,254
Dye stuff	3.78	15,048
Total		53,684

5.1.3 Water & Steam Consumption

The water consumption and the percentage share of boiled water and the boiled water temperature for each process is given in table 5.7:

Table 5.7: Processes water consumption

Process Stage	Water Consumption (m ³ /annum)	% Boiled water	Water temp.	Water type
Soaking- Liming	25,450	-	Cold water	Treated river water
Deliming- Pickling	21,208	50	30-40	Municipal water
Depickling- Tanning	12,913	50	30-40	"
Retanning (Dress glove)	3,336	75	40-60	"
Retanning (Silver White)	1,203	75	40-60	"
Dyeing	7,589	53.5	40-60	"

Out of the total water consumed, 25,450 M³ treated river water was used. The balance 46,249m³ has been taken from municipal water supply;

- Boiler water inlet is 9m³/day for steam production
- The inlet water temperature is 40°C
- The boiler runs 10hr a day
- Of the total finished products, the hide production shares is 41.89% and skin production shares 58.11%

5.1.4 Pollutant emission due to utilization of processing chemicals

In the production of glove leather different types of chemicals are used in each processing stage. As a result each process stage has its own contribution on the overall chemical load of the company effluent. Understanding the chemical load at each stage helps to identify which process stage contributes the highest share for pollution. It is also true for the lowest pollution share. So as to determine the emissions to water samples were collected from soaking to dyeing. Then analyzed by A.A water and sewerage laboratory (AAWSA) and by the Elico-Gloving & Hide Unit laboratory. The laboratory analysis methods being employed by the AAWSA laboratory are presented on Annex-19 .The table 5.8 below shows the chemical load of the production processes.

Table-5.8: Laboratory analysis result of the company effluent

Pollutant type	Unit	Soaking Liming	Deliming Pickling	Depickling Tanning	Retanning (Dress glove)	Retanning (Silver White)	Dyeing (Dress glove)
COD	mg/l	20,030	8,560	4,706	784	193	765
NH ₃	mg/l	216	359.5	66.25	9.6	8.05	31.15
Nitrite NO ₂	mg/l	0.235	0.229	0.067	0.022	0.079	0.036
Nitrate as NO ₃	mg/l	11.75	9.16	3.7	3.2	2.3	2.2
Hydrogen Sulphide as H ₂ S	mg/l	1,579.5	107	-	-	0.025	0.06
Total Nitrogen as N	mg/l	247	752	72.31	9.82	8.17	33.47
Phosphorus as PO ₄	mg/l	19	0.41	2.6	0.084	9.72	4.7
Cr ³⁺	mg/l	-	-	1,285	0.345	0.056	0.048
Cr ⁶⁺	mg/l	-	-	-	-	-	-

5.1.5 Effluent treatment plant (ETP) influent & effluent emission

The company has a primary effluent treatment plant being installed 5 years before. The current pollutant removal efficiency of the plant is presented in the table 5.9 below.

Table 5.9: Pollutant removal efficiency of the ETP

Pollutant type	Unit	Influent result	Effluent result	% Removal efficiency
COD	mg/l	5,300	1,840	65.28
NH ₃	mg/l	103.1	72.7	29.49
Nitrite as NO ₂	mg/l	0.055	0.039	41.82
Nitrate as NO ₃	mg/l	14	1.7	87.86
Total Nitrogen as N	mg/l	180	90	50.00
H ₂ S	mg/l	141	3.05	97.84
PO ₄	mg/l	20.5	4.94	75.90
Cr ³⁺	mg/l	1.2	0.94	18.33

NB: The Company has chrome recovery plant having a chromium removal efficiency of 99.9%.

5.1.6 Tannery Solid Waste

In tannery from the process stages various types of solid wastes are generated. Each waste is designated by its mother process stage name. The waste generated at main process stages are shown on the table 5.10 below.

Table-5.10: Tannery solid wastes

Process stage	Solid waste type	Quantity g/ft ²
Soaking- Liming	Dedusted salt	4.46
	Raw trimming	15.15
	Fleshing	7.86
Deliming- Pickling	Pickle trimmings	7.56
Depickling- Tanning	Wet chrome shavings	4.65
	Dry chrome shavings	13.8
Retanning	Leather trims	0.39
Dyeing	Staking dust	0.79
Effluent treatment	Sludge from ETP	22.3
Selection & packing	Packing material	6.71*10 ⁻³

5.1.7 Electricity, water, benzene, Gasoline and fuel oil consumption

For performing the tannery processes in a better way fulfilling of the required inputs is mandatory. In tannery different types of machineries are used and also the water consumption is too much as compared to other industries except textiles. The processes from the tanning operation to finishing use steam for facilitating the chemical penetration and for drying the leather. For this purpose the company produces steam by using boiler working by fuel oil. For the delivery of chemicals, raw material and for other purpose the company uses vehicles that consume gasoline and benzene. The annual consumption of the above mentioned inputs are tabulated below under table 5.11.

Table-5.11: Annual Input material consumption

Input material	Unit	Annual consumption
Electricity	KWH	792,400
Water	M ³	127,183
Fuel oil	M ³	434.84
Gasoline	lt	105,534(for skin section- 91,182 lt)
Benzene	lt	18,835 (for skin section -13,587lt)

5.2 Inventory Data analysis, classification & characterization

Based on the data gathered and analyzed, interpretations are made. The classification and characterizations have been carried out. The inventory analysis comprises five major parts. These are:

- Emission due to importing of tannery chemicals
- Emission impact due to transporting of raw sheep skins
- Emission due to consumption of steam
- Emission impact due to utilization of processing chemicals
- Emission due to tannery waste

5.2.1 Emission due to Importing of tannery chemical

In the skin section so as to produce glove leathers about 94 chemicals are required. Almost all these chemicals are imported from abroad. When the chemicals reaches the Djibouti port vehicles are used to transport them to the factory gate. In order to determine the quantity of chemicals transported the total chemical consumption of the company was calculated. The total quantity produced and chemical consumption are tabulated on table- 5.12.

For detail information on Input-Output analysis refer annex-3. Most of the chemicals were transported by Isuzu vehicle having carrying capacity of 13,150 kg. Considering the distance from A.A to Djibouti port the total distance traveled by the Isuzu vehicle and the km/ft² are determined and tabulated on tables- 5.12/13/14.

Table 5.12: Chemical consumption of each major process in weight

Process stage	Quantity produced (ft ²)	Chemical consumed (kg)
Soaking-Pickling	8,483,267	664,238
Tanning	5,896,261	370,816.4
Retanning (Silver white)	516,329	3,998.2
Retanning (Dress glove)	5,379,329	105,573
Dyeing	4,066,960	53,684

About 4066960 ft² dyed dress glove leather and 516,329 ft² silver white leather were produced. The total production of these products is 4583289 ft².

To produce 4583289 ft² finished glove leather (i.e. 4,066,960+516,329) a total of 1,198,309.6 kg chemical were used.

It is assumed that the above chemicals were transported from Djibouti port to company gate by Isuzu vehicle whose loading capacity is 13,150 kg. This vehicle including its load has a total weight of 15 ton and can travel 4 km by one liter of oil.

The total distance from A.A to Djibouti to A.A is 1840 km. For return trip its total distance is 1840 km. In order to transport 1,198,309.6 kg of chemicals it required 182 trips. Within 182 trips the vehicles traveled a total of 167,440 km. Let us share this distance to each process stage according to the chemical consumption level.

Table -5.13: Distances allocated for each process stage

Process stage	Chemical weight (kg)	% Share	Distance allocated (km)	Quantity produced ft ²
Soaking- pickling	664,238	55.44	92,829	8,483,267
Tanning	370,816	30.94	51,806	5,896,261
Retanning (Silver white)	3,998	0.33	552.6	516,329
Retanning (Dress glove)	105,573	8.81	14,751.5	5,379,932
Dyeing	53,684	4.48	7,501.3	4,066,960

The km/ft² values calculated by dividing the distance allocated (km) by the quantity produced (ft²) from the data on table 5.13.

The distance traveled in km/ft² for each process stage is tabulated as follows:

Table -5.14: Distances traveled in Km/ft² for each process

Process stage	Km/ft ² (process material)
Soaking- Pickling	0.011
Tanning	8.79*10 ⁻³
Retanning (Silver white)	1.07*10 ⁻³
Retanning (Dress glove)	2.74*10 ⁻³
Dyeing	1.84*10 ⁻³

To produce one square feet finished glove leather 1.85 ft² pickled pelt required. This pickled pelt is used to produced 1.286 sq.ft wet blue and then 1.323 sq.ft Dress glove 1.85 ft² pickled pelt is also required to produce 1 sq.ft Silver white.

For detail see annex-4.

By multiplying the km/ft² values for each process stage by the above-required areas to produce 1ft² finished glove we will get the following results.

Table-5.15: Km shared to produce 1 square feet glove

Process stage	Km shared to produce 1sq.ft finished glove leather
Soaking- Pickling	0.011*1.85 = 0.02 km
Tanning	8.79*10 ⁻³ *1.286 = 1.13*10 ⁻² km
Retanning (Silver white)	1.07*10 ⁻³ *1 = 1.07*10 ⁻³ km
Retanning (Dress glove)	2.74*10 ⁻³ *1.323 = 3.63*10 ⁻³ km
Dyeing	1.84*10 ⁻³ *1 = 1.84*10 ⁻³ km
Total distance	0.03784 km

The expected distance traveled by the Isuzu vehicle to bring chemicals to produce 1sq.ft-finished product is 0.03784 km.

As stated previously the Isuzu vehicle has a total weight of 15 ton and consumes 1 lt fuel oil to travel 4 km. The standard emission by 15 tonne lorry over 1km of road is tabulated as follows:

Table-5.16: Standard emissions values for vehicle

Emissions to air	Kg/15 tonne. Km
CO ₂	0.81
CO	0.002
Hydro carbons (HC)	0.0013
NO _x	0.012
SO ₂	0.00088
Liquid particles in air	0.0008

Source Life cycle assessment, what it is and How to do it, UNEP Publication, 2000

The associated emissions to air by the 15 ton Isuzu vehicle to travel 0.03784 km are:

CO ₂ = 0.81*0.03784 = 0.03065 kg = 30650 mg
CO = 0.002*0.03784 = 7.56*10 ⁻⁵ = 75.68 mg
HC = 0.0013*0.03784 = 4.92*10 ⁻⁵ = 49.2 mg
NO _x = 0.012*0.03784 = 4.541*10 ⁻⁴ = 454.08 mg
SO ₂ = 0.00088*0.03784 = 3.33*10 ⁻⁵ = 33.3 mg
Liquid particles = 0.0008*0.03784 = 3.03*10 ⁻⁴ = 303 mg in air

Emission impacts due to import of processing chemicals is tabulated below under table 5.17:

Table- 5.17: Emission impact due to import of chemicals imported

Pollutant	Unit	Result	Green House effect		Acidification		Eutrophication		Winter smog		Human Toxicity		POCP	
			Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg
CO ₂	mg	30,650	1	30,650										
CO	mg	75.68									0.012	0.908		
HC	mg	49.2	3	147.6									0.398	19.6
NO _x	mg	454.08			0.7	317.9	0.13	59			0.78	354.2		
SO ₂	mg	33.3			1	33.3			1	33.3	1.2	40		
Liquid particles in air	mg	303							1	303				
Total			30,798		351.2		59		336.3		395.1		19.6	

5.3 Emission impact due to transporting of raw sheep skin and due to other transported related activities

The environmental impact by delivering raw sheepskin from different regions and their share in % as well as the distance to A.A is presented in table 5.18

Table-5.18: Total distance per trip from each region

Region	Most common site	Distance to A.A [km]	Total distance per trip [km]
Gojjam	Addis Kidam	500	1,000 km
A.A	Merkato	20	40
South Shoa	Gumer bole	250	500
Wollo	Kombolcha	330	660
North Shoa	Tarma ber	175	350
Gonder	Debarik	700	1400
Wollega	Nekemit	340	680
Kaffa -Agaro	Agaro	350	700
-Jimma	Jimma	335	670

The company purchased 1,820,000 sheep skins from different regions. The quantity supplied from each region is tabulated on table 5.19 and their % share is determined by dividing the quantity supplied by the total supplied -1,820,000 pieces. Finally the number of trips made by Isuzu vehicle is calculated and depicted in the table 5.19 below:

Table -5.19: Total number of trips made for each region

Region	Quantity supplied (Pcs)	Percent Share	Isuzu capacity per trip (pcs)	Total no. of trips made
Gojjam	839,020	46.10	8,000	105
A.A	473,018	25.99	8,000	59
South Shoa	273,546	15.03	8,000	34
Wollo	63,336	3.48	8,000	8
North Shoa	58,058	3.19	8,000	8
Gonder	56,602	3.11	8,000	7
Wollega	21,112	1.16	8,000	3
Kaffa -Agaro	19,838	1.09	8,000	2.5
- Jimma	15,474	0.85	8,000	2

Based on the number of trips made the total km traveled from each region and the associated fuel consumption is presented as follows under table 5.20:

Table- 5.20: Fuel consumption in liter for each region

Region	Km/trip	No. Of trips made	Total km traveled	Fuel consumption (lt) 4km/1litre
Gojjam	1,000	105	105,000	26,250
A.A	40	59	2,360	590
South Shoa	500	34	17,000	4,250
Wollo	660	8	5,280	1,320
North Shoa	350	8	2,800	700
Gonder	1,400	7	9,800	2,450
Wollega	680	3	2,040	510
Kaffa -Agaro	700	2.5	1,750	438
- Jimma	670	2	1,340	335
Total		228.5	147,370	36,843

Of the total gasoline oil consumption about 36,843 liter is for raw sheep skin transport from different regions and the rest 91,182 liter (lt) gasoline oil and 13587 liter (lt) benzene (regular oil) used for other related activities like transport provision for employees, for selling and purchasing activities.

Totally the company had a consumption of 128,025-lt gasolines and 13,587 lt benzene. While this thesis was prepared there was a difficulty of getting the emissions to air by combustion of 1 lt of benzene. However data is available for emissions by combustion of 1 lt of gasoline. Therefore, for simplicity purpose the benzene consumption is added up to the gasoline oil quantity. Gasoline oil as compared to benzene has higher impurities that may result for environmental impact. Combining the benzene consumption to gasoline consumption may not underestimate the environmental impact associated with their consumption. As a result it is assumed that the company consumed 141,612 lt gasoline oil so as to produce 4,583,289 ft². Therefore to produce 1 sq.ft finished glove leather it consumed 0.0309-lt gasoline oil. The vehicle consumes 4 lt to travel 1 km. There fore, the vehicle traveled 0.124 km by 0.0309 lt. Having this in mind one can easily determine the emissions to air as a result of using fuel oil. The standard emission by 15 tonne vehicle over 1km of road is given in table 5.21.

emissions to air by 15 tonne vehicle being traveled 0.124 km are:

$\text{CO}_2 = 0.81 * 0.124$	$= 0.100 \text{ kg} = 100,000 \text{ mg}$
$\text{CO} = 0.002 * 0.124 * 0.124$	$= 2.48 * 10^{-4} \text{ kg} = 248 \text{ mg}$
$\text{HC} = 0.0013 * 0.124$	$= 1.61 * 10^{-4} \text{ kg} = 161 \text{ mg}$
$\text{NO}_x = 0.012 * 0.124$	$= 1.49 * 10^{-3} \text{ kg} = 1,490 \text{ mg}$
$\text{SO}_2 = 0.00088 * 0.124$	$= 1.091 * 10^{-4} \text{ kg} = 109.1 \text{ mg}$
$\text{Liquid particles} = 0.0008 * 0.124$	$= 9.92 * 10^{-5} \text{ kg} = 99.2 \text{ mg in air}$

Emission impacts due to raw sheep skin delivering from different regions of Ethiopia is tabulated as follows:

Table-5.21: Emission impacts due to transporting of raw skins

Pollutant	Unit	Result	Green House effect		Acidification		Eutrophication		Winter smog		Human Toxicity		POCP	
			Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg
CO ₂	mg	100,000	1	100,000										
CO	mg	248							0.012	2.9				
HC	mg	161	3	483									0.398	64.1
NO _x	mg	1,490			0.7	1043	0.13	193.7			0.78	1,162		
SO ₂	mg	109.1			1	109.1			1	109.1	1.2	130.9		
Liquid particles in air	mg	99.2							1	99.2				
Total			100,483		1,152.1		193.7		211.2		1,292.9		64.1	

5.3.1 Emissions due to consumption of steam

As it is known tannery processes involves consumption of steam for chemical processing, dewatering and for further mechanical operation. At least 50% of the leather processing is conducted by using steam. The steam is produced from water by boiling it to a higher temperature using furnace oil. Combustion of furnace oil has its own environmental impact by the emitted pollutants. To determine the quantity of these pollutants, it is necessary to calculate the amount of steam supplied for each process stage. As the company does not have gauges on each section for determining the amount of steam supplied. It is difficult to obtain detailed information on the consumption of steam at each process stage except the total quantity of steam used by the plant. To overcome this information gap effort has been applied to determine the amount of water consumed for each process stage with the boiling temperature. This can provide the indirect quantity of steam supplied to boil.

5.3.1.1 Water consumption

The water consumption per each process stage is calculated using the production process recipes. As for the steam problem, there is also a problem of quantifying the exact amount of water consumed for each process. By applying reasonable assumptions during wetback and drain the following results are obtained in lt/ft^2 . These values are used to calculate the amount of water consumed to produce a certain quantity of a given product.

Table 5.22 gives the details of total water consumption for each process stage.

Table- 5.22: Total water consumption for each process stage

Process Stage	Water Consumption $10^{-3} * \text{m}^3/\text{ft}^2$	Product type	Quantity produced	Total water consumption (m^3/annum)
Soaking- Liming	3	Limed pelt	8,483,267 ft^2	25,450
Deliming- Pickling	2.5	Pickled pelt	8,483,267 ft^2	21,208
Depickling- Tanning	2.19	Wet blue	5,896,261 ft^2	12,913
Retanning (Dress glove)	0.62	Crust for dress	5,379,932 ft^2	3,336
Retanning (Silver white)	2.33	Crust for golf	516,329 ft^2	1,203
Dyeing	1.866	Dyed crust for dress	4,066,960 ft^2	7,589

5.3.1.2 Steam Consumption

The convenient way to determine the steam consumption of each process stage better is first to determine the consumption of water at the skin section. The total steam consumption of the company is calculated as follows:

$$\begin{aligned}
 \text{Water inlet} & \quad 9\text{m}^3/\text{day} = 9\text{m}^3/10\text{hr} = 0.9\text{m}^3/\text{hr} \\
 \text{Water inlet temperature is} & \quad 40^\circ\text{C} \\
 v_f = & \quad 0.0010078 \text{ m}^3/\text{kg} \text{ (Annex-18)} \\
 \rho_f = 1/V_f = & \quad 992.06 \text{ kg/m}^3 \text{ -----(Eq.5.1)}
 \end{aligned}$$

Eq 6.1 calculates the density of the fluid

$$\begin{aligned}
 \rho_f = 1/V_f & = 992.06 \text{ kg/m}^3 \\
 M_{\text{water}} & = \frac{992.06}{0.9} = 1102.3 \text{ kg/hr} = 1.102 \text{ ton/hr}
 \end{aligned}$$

Total working hour per day is 10 hr

$$\text{Then the per day steam production is } 1.102 \frac{\text{ton}}{\text{hr}} * 10 \frac{\text{hr}}{\text{day}} = 11.02 \frac{\text{ton}}{\text{day}}$$

The skin and hide tannery shares amounting to 11.02 ton/day according to their production ratio. Hide production share and skin production share is 41.89% and 58.11%, respectively.

Therefore, the steam consumption of skin and hide section is 6.40 ton/day and 4.62 ton/day, respectively.

Assuming total working days per annum is 280 days, the total steam consumption per annum for skin section is 1792 ton.

Each process stage has its own temperature requirement. The delimiting- tanning process requires 30-40°C, Retanning process 40-60°C and dyeing process requires 40-60 °C. Water volume at average temperature calculated by multiplying the gross water consumption by the % boiled water

The detail of the boiled water consumption on each process stage has been calculated and tabulated as follows under table 5.23:

Table - 5.23: Boiled Water consumption

Process stage	Water consumption (m ³)	% Boil water	Water temp. °C	Temp average °C	Water volume at temp average (m ³)
Deliming- Pickling	21,208	50	30-40	35	10,604
Depickling- Tanning	12,913	50	30-40	35	6,457
Retanning- Dress glove	3,336	75	40-60	50	2,502
Retanning- Silver White	1,203	75	40-60	50	902
Dyeing	7,559	53.5	40-60	50	4,060

For calculating the amount of steam required for boiling the water the following formulas are used:

$$Q_{\text{useful}} = M_{\text{steam}} (h_{\text{steam}} - h_{\text{feed water}}) \text{ ----- (Eq.5.2)}$$

Where h-enthalpy (kj/kg)

$$M_{\text{feed}} + M_{\text{steam}} = V_f^{-1} * V_{\text{water}} = M_{\text{total}} , \text{ -----(Eq.5.3)}$$

Where -V_f=Specific Volume of the saturated fluid (in m³/kg)

-V_{water}=Volume of water (m³)

Steam produced at 5 bars has a temperature of 155°C

Enthalpy of steam = 2753 KJ/kg (Annex-18)

$$M_{\text{steam}} [h_{\text{steam}} - h_{\text{feed}}] = M_{\text{fluid}} * C_p \Delta T, \Delta T = T_2 - T_1 \text{ -----(Eq.5.4)}$$

Where -C_p =Specific heat capacity

i. Process stage – Deliming- pickling

At this process stage the water consumed at 35⁰c is 1060 m³.(Table 5.23) , its specific volume is 0.001006m³/Kg and enthalpy is 146.88KJ/Kg (Annex-18). Its total mass is calculated by using Eqn.5.3.

$$M_f + M_{\text{steam}} = V_f^{-1} * V_{\text{water}} = \frac{1}{0.001006 \text{ m}^3/\text{kg}} \times 10604 \text{ m}^3 = 10541 \text{ ton}$$

The relationship between M_f and M_{steam} is determined by applying Eqn.5.2 and 5.4.

$$M_{\text{steam}} [2753 \text{ kJ/kg} - 146.68] = M_f * 4.186 * [35-20]$$

$$M_f = 41.51 M_{\text{steam}}$$

$$M_f + M_{\text{steam}} = M_{\text{total}} = 10541$$

$$M_{\text{steam}} = 248 \text{ ton}$$

The steam consumed to boil 10604 m³ is 248 ton

ii. Process stage Depickling- Tanning

Water consumption at this stage at 35°C is 6457m³(Table 5.23), its specific volume is 0.001006m³/Kg and enthalpy is 146.68 KJ/Kg (Annex -18)

$$M_f + M_{\text{steam}} = M_{\text{total}} = V_f^{-1} * V_{\text{water}} = \frac{1}{0.001006 \text{ m}^3/\text{kg}} * 6457 \text{ m}^3$$

$$= 6418 \text{ ton}$$

$$M_{\text{steam}} [2753 \text{ kJ/kg} - 146.68] = M_f * 4.18 * [35-20]$$

$$M_f = 41.51 M_{\text{steam}}$$

$$M_f + M_{\text{steam}} = 6418 \text{ ton } M_{\text{steam}} = 151 \text{ ton}$$

The steam consumed to boil 6457m³ is 151 ton

iii. Process stage- retanning Dress glove

Water consumption for this stage at 50°C is 2502 m³ (Table 5.23), its specific volume is 0.001012 m³/Kg and enthalpy is 209.33 KJ/Kg (Annex-18)

$$M_f + M_{\text{steam}} = V_f^{-1} * V_{\text{water}} = \frac{1}{0.001012 \text{ m}^3/\text{kg}} * 2502 \text{ m}^3 = 2472 \text{ ton}$$

$$M_{\text{steam}} [2753-209.33] M_f * 4.186 * [50-20]$$

$$M_f = 20.3 M_{\text{steam}}$$

$$M_f + M_{\text{steam}} = 21.3 M_{\text{steam}} = 24720 \text{ ton}$$

$$M_{\text{steam}} = 116.1 \text{ ton}$$

The steam consumed to boil 2502 m³ is 116.1 ton

iv. Process stage – Retanning – Silver White

Water consumption for this stage at 50°C is 902 m³ (Table 5.23)

$$M_f + M_{\text{steam}} = V_f^{-1} * V_{\text{water}} = \frac{1}{0.001012 \text{ m}^3/\text{kg}} * 902 = 891.3 \text{ ton}$$

$$21.3 M_{\text{steam}} = 891.3 \text{ ton} \quad M_{\text{steam}} = \underline{41.8 \text{ ton}}$$

v. Process stage – dyeing – Dress glove

Water consumption for this stage at 50°C is 4060 m³ (Table 5.23)

$$M_f + M_{\text{steam}} = V_f^{-1} * V_{\text{water}} = \frac{1}{0.001012 \text{ m}^3/\text{kg}} * 4060 \text{ m}^3 = 4012 \text{ ton}$$

$$21.3 M_{\text{steam}} = 4012 \text{ ton}$$

$$M_{\text{steam}} = \underline{188.4 \text{ ton}}$$

The quantity of steam consumed for each process stage is tabulated as follows:

Table- 5.24: Steam consumption per annum for each process stage

Process stage	Product type	Steam consumed (ton)/annum
Deliming- Pickling	Pickled skin	248
Depickling- Tanning	Wet blue skin	151
Retanning- Dress glove	Dress glove crust	116.1
Retanning-Silver White	Silver white crust	41.8
Dyeing	Dyed Dress glove	188.4
Total		745.3

The total consumption of steam in skin section is 1,792 ton, assuming 10% loss, the toggling m/c consumed (1,792-10% (1,792) – 745 = 867.8 ton steam.

The toggling m/c has a capacity of utilizing 140 kg steam per hour. The over all annual consumption by working 20 hr a day is 784 ton steam. The rest amount 83 ton is considered as steam loss due to mechanical problem of the machine.

5.3.1.3 Emissions to air

For determining the emissions to air and water by the production of 1 tonne of steam standard values (11) are used.

Emissions to air by the production of 1 tonne steam using furnace oil are:

CO ₂ =162 kg/tonne
CO = 0.04 kg/tonne
HC = 2.0 kg/tonne
NO _x = 0.5 kg/tonne
SO ₂ = 0.14 kg/tonne
Particles= 0.0012 kg/tonne
Emissions to water = Oil = 0.0025 kg/tonne

In order to determine the emissions due to steam consumption, the consumption has been converted to kg/ft². The values are calculated and tabulated as follows under table 5.25:

Table- 5.25: Steam consumption in kg/ft²

Process stage	Quantity produced (ft ²)	Steam consumption ton/annum	Steam consumed kg/ft ²
Deliming- Pickling	8,483,267	248	0.0292
Depickling- Tanning	5,896,261	151	0.0256
Retanning- Dress glove	5,379,932	116.1	0.02158
Retanning-Silver White	516,329	41.8	0.0809
Dyeing	4,066,960	188.4	0.04632
Togglng	4,583,283	867.8	0.1893

So as to produce 1 sq/ft finished glove the company needed 1.85 sq.ft pickled skin, 1.286 sq.ft wet blue skin and 1.323 sq.ft crust and 1 sq.ft dyed crust. This means by starting with 1.85 sq.ft pickled skin possible to produce the above products with the designated area till reaches to final finished glove leather of 1 sq.ft.

1.85, 1.286, 1.323 and 1 shall multiply the steam consumption calculated above for deliming-Pickling, Depickling-Tanning, Retanning (Dress + Silver White) and dyeing, respectively.

As a result the real steam consumption at each process stage to produce 1 sq.ft finished glove leather is depicted as follows under table 5.26:

Table- 5.26: Real steam consumption for each process stage

Process stage	Real steam consumption [kg/ft ²]
Delimiting- Pickling	0.054
Depickling- Tanning	0.0329
Retanning- Dress glove	0.02855
Retanning-Silver White	0.10703
Dyeing	0.04632
Togging	0.01893

The environmental impact of using steam for the production process is shown on table - 5.27 and the related impacts of oil to aquatic life are further tabulated on table 5.28 and 5.29.

Table 5.27: Environmental impacts by usage of steam during production processing

Pollutant	Green House effect	Acidification	Eutrophication	Winter smog	Human Toxicity	POCP
Soaking-Liming	-	-	-	-	-	-
Delimiting-Pickling	9.03	0.029	3.9*10 ⁻³	7.66*10 ⁻³	9.15*10 ⁻³	0.04
Depickling-Tanning	5.497	0.0156	2.1*10 ⁻³	4.64*10 ⁻³	0.018	0.026
Retanning (Dress glove)	4.77	13.8*10 ⁻³	1.82*10 ⁻³	4.034*10 ⁻³	0.0158	0.022
Retanning- (Silver White)	17.93	0.055	7.02*10 ⁻³	0.069	0.06	0.084
Dyeing (Dress glove)	7.78	0.023	3*10 ⁻³	0.029	0.026	0.035
Togging	31.84	0.087	0.012	0.117	0.102	0.14
Total	76.85	0.22	0.029	0.23	0.231	0.35

Table 5.28: Emissions of oil by steam consumption

Process stage	Steam consumption (kg/ft ²)	Oil emission kg/ton	Oil mg/ft ²
Delimiting- Pickling	0.054	0.0025	0.135
Depickling- Tanning	0.0329	0.0025	0.823
Retanning- (Dress glove)	0.02855	0.0025	0.714
Retanning- (Silver White)	0.10703	0.0025	0.267
Dyeing (Dress glove)	0.04632	0.0025	0.116
Togging	0.1893	0.0025	0.473

Table 5.29: Environmental impacts of oil to aquatic life

Process stage	Oil emissions (mg/ft ²)	Eco-toxicity aquatic (ECA) equivalence factor (m ³ /kg)	Multiplied characterization result (m ³ /kg) (ECA)
Deliming- Pickling	0.135	5,000	0.675
Depickling- Tanning	0.823	5,000	0.412
Retanning- (Dress glove)	0.714	5,000	0.357
Retanning- (Silver White)	0.267	5,000	1.338
Dyeing (Dress glove)	0.116	5,000	0.579
Toggling	0.473	5,000	2.366
		Total	5.727

5.3.2 Emission impacts due to utilization of processing chemicals

During the production of glove skin around 37 major chemicals and 57 dyestuffs are used. The emissions associated with these chemicals are discussed as follows:

The unit of measurement of the pollutants is in mg/lt. To determine their impacts these units shall be converted to mg/ft². To do so it is better to determine the amount of water needed to produce 1 square feet finished glove leather.

As stated previously 1 square feet finished glove leather needs 1.85 sq/ft pickled skin, 1.286 sq.ft wet blue skin and 1.323 sq.ft crust and 1 sq/ft dyed crust. The water consumption shall be determined by multiplying the rough water consumptions (**A** Values, on table 6.30) by 1.85, 1.286, 1.323 and 1(**B** Values, on table 6.30) for Deliming – Pickling, Depickling- Tanning, Re-tanning (Dress + Silver White) and dyeing, respectively.

Table 5.30 Real water consumption in lt/ft²

Process stage	Rough water consumption (lt/ft ²) (A)	Product type	Required area to produce 1 sq.ft finished glove (B)	Real water consumption lt/ft ² A * B
Soaking- Liming	3	Limed pelt	1.85	5.55
Deliming- Pickling	2.5	Pickled pelt	1.85	4.63
Depickling- Tanning	2.19	Wet blue	1.286	2.82
Retanning- (Dress glove)	0.62	Crust (Dress)	1.323	0.82
Retanning- (Silver White)	2.33	Crust (Silver White)	1.323	3.08
Dyeing (Dress glove)	1.866	Dyed	1	1.866

These calculated values (lt/ft²) helps to convert the emissions associated with each process stage. The table 5.31,thus shows the laboratory analytical tests results of the emissions to water ,and the table 5.32 shows the emissions to water in mg/ft².

Table 5.31: Laboratory analysis test results of the emissions to water

Process stage	Unit	POLLUTANTS							
		COD	NH ₃	Nitrite as NO ₂	Nitrates as NO ₃	Hydrogen Sulfide, H ₂ S	Total Nitrogen	Phosphors as PO ₄	Cr ³⁺
Soaking- Liming	mg/lt	20,030	216	0.235	11.75	1,579.5	247	19	-
liming- Pickling	mg/lt	8,560	359.5	0.229	9.16	107	752	0.41	-
Depickling- Tanning	mg/lt	4,706	66.25	0.067	3.7	-	72.31	2.6	1285
Retanning- (Dress glove)	mg/lt	784	9.6	0.022	3.2	-	9.82	0.084	0.345
Retanning- (Silver White)	mg/lt	193	8.05	0.079	2.3	0.025	8.17	9.72	0.056
Dyeing (Dress)	mg/lt	765	31.15	0.036	2.2	0.06	33.47	4.7	0.048

Table 5.32: Emissions to water in mg/ft²

Process stage	Unit	POLLUTANTS							
		COD	NH ₃	Nitrite as NO ₂	Nitrates as NO ₃	Hydrogen Sulfide, H ₂ S	Total Nitrogen	Phosphors as PO ₄	Cr ³⁺
Soaking-Liming	mg/ft ²	113,169.5	1,198.8	1.304	65.2	8,766.2	1,370.9	105.5	-
Deliming-Pickling	mg/ft ²	39,632.8	1,664.5	1.06	42.4	495.4	3,481.8	1.89	-
Depickling-Tanning	mg/ft ²	13,270.9	186.8	0.189	10.43	-	203.9	7.33	3623.7
Retanning-(Dress glove)	mg/ft ²	642.9	7.87	0.018	2.62	-	8.05	0.069	0.28
Retanning-(Silver White)	mg/ft ²	594.4	24.8	0.24	7.08	0.077	25.16	29.94	0.172
Dyeing (Dress)	mg/ft ²	1,427.5	58.1	0.067	4.11	0.11	62.46	8.77	0.09

NB: Emissions to water by each process stage in mg/ft² (i.e. the mg/ft² results are obtained by multiplying the mg/lit values by lt/ ft² values calculated and depicted in the previous table 5.30)

The effluent discharged from each process stage is directed to the treatment plant, which is of primary effluent treatment type. The treating capacity of the plant is determined by analyzing the influent and effluent chemical load. The detail of the laboratory analysis and the related removal efficiency is depicted as follows under table 5.33:

Table- 5.33: Removal efficiency of the treatment plant

Pollutant	Unit	Influent result	Effluent result	% Removal efficiently
COD	mg/lit	5,300	1,840	65.28
NH ₃	mg/lit	103.1	72.7	29.49
Nitrite (NO ₂)	mg/lit	0.055	0.032	41.82
Nitrate (NO ₃)	mg/lit	14	1.7	87.86
Total Nitrogen	mg/lit	180	90	50.00
H ₂ S	mg/lit	141	3.05	97.84
PO ₄	mg/lit	20.5	4.94	75.90
Cr ³⁺	mg/lit	1.2	0.98	18.33 *

NB: * The primary effluent treatment plant of the company has chrome recovery unit having 99% chromium removal efficiency. The above mentioned removal efficiency for chromium is for primary effluent treatment plant.

Before calculating the environmental impact of the pollutants, better to consider the treating efficiency of the treatment plant. That is the laboratory test results shall be reduced by the % removal efficiency (Table -5.33). The adjusted laboratory test results and the associated emissions are shown on annex 5 to 17. The following table 5.34 shows the total environment impact during leather processing by the use of tannery chemicals.

Table 5. 34: Total environment impact during leather processing by the use of tannery chemicals

Pollutant	Unit	Green House effect	Acidification	Eutrophication	Winter smog	Human Toxicity	POCP	Eco-toxicity
Soaking-Liming	mg	-	1,595	1,457.2		147.9	-	1.79
Deliming-Pickling	mg	-	2,210.4	1,422.2		8.56	-	0.1
Depickling-Tanning	mg	-	248.6	189.6		6,066.9	-	20450
Retanning-(Dress glove)	mg	-	10.53	8.47		0.48	-	1.59
Retanning-(Silver White)	mg	-	33.6	22.94		0.34	-	0.97
Dyeing (Dress glove)	mg	-	77.37	39.70		0.168	-	0.48
Total		-	4,175.5	3,140.1		6,224.3	-	20454.9

5.3.3 Emissions due to tannery wastes

During skin leather production different types of wastes are generated. Most of these wastes are of solid waste types. The quantity of solid wastes generated during glove leather production is determined and depicted as follows under table 5.35:

Table-5.35: Chemical content in solid waste in g/ft²

Process stage	Solid waste type	Quantity g/ft ²	Hazard name	Chemical content (g/ft ²)
Soaking-Liming	Dedusted salt	4.46	Naphthalene	0.0669
	Raw trimmings	15.15	-	-
	Fleshing	7.86	-	-
Deliming-Pickling	Pickle trimmings	-7.56		
Depickling-Tanning	Wet-chrome shaving	4.65	Cr ⁺³	0.21
	Dry-chrome shavings	13.8	Cr ⁺³	0.686
Retanning	Leather trims	0.39	Cr ⁺³	0.019
Dyeing	Staking dust	0.79	Cr ⁺³	0.039
Effluent treatment	Sludge from ETP (*)	22.3	NH3	0.178
			N	0.925
			P	7.81*10 ⁻³
			Cr ⁺³	0.65
			Al	0.558
			Ca	1.789
			S	0.859
Selection & packing	Packing material	6.71*10 ⁻³	-	-
Total		76.97		

NB: - Due to lack of information of equivalence factor for chromium (+3) emission to soil the impact as a result of chromium is excluded.

-(*) Based on the standard sludge composition shown on table -5.36.

Table 5.36: Standard Sludge Composition

Chemical character	Min %	Max %	Average
Water content	55	75	65
Organic matter	40	75	57.5
Inorganic matter	25	60	42.5
Organic carbon	21	38	29.5
Ammonium	0.1	1.6	0.8
Nitrogen (organic)	1.3	7.0	4.15
Substance extractable by DCM	0.06	0.4	0.23
Phosphate	0.01	0.06	0.035
Cr ⁺³	0.8	5.0	2.9
Aluminum	0	5.0	2.5
Iron	0.6	12	6.3
Calcium	1.0	15	8
Sulphur	0.7	7	3.85

Data source: European commission, integrated pollution prevention & control (IPPC) reference document-on BAT for the tanning of the Hide & Skin. (14)

5.3.4 Emissions impacts to soil as a result of sludge production

The pollutants existing in the solid sludge are expected to emit to soil. Most of the emissions to soil are of eutrophication type, shown under the table 5.37 below .

Table-5.37: Emission impact due to sludge

Pollutant	Emission (g/ft ²)	Equivalence factor in kg PO ₄ /kg	Eutrophication result mg PO ₄
Ammonia	0.178	0.33	58.74
Total Nitrogen	0.925	0.42	388.5
Phosphorus	7.8*10 ⁻³	3.06	24
Total			471.11

As the sludge produced has a moisture content of 50% most of the pollutants are considered as if existing in liquid medium. Therefore the above tabulated values can also be taken as emissions to water due to transfer of liquor to soil media.

5.3.5 Emissions to water due to preservative agent- naphthalene

During preservation of sheepskin, naphthalene is used together with salt. This naphthalene is discharged to river water at soaking operation. As naphthalene has human toxicity (HT) and Eco-toxicity aquatic (ECA) potential its impact should be determined and calculated as follows. For preservation purpose the company uses 15kg naphthalene in 1000 kg salt. The amount of salt consumed in one square feet sheepskin is 4.46 g, which makes the share of 1.5%. As a result in 4.46 gm dedusted salt there will be 0.067 g of naphthalene. Therefore the amount of naphthalene in g/ft² is 0.067 naphthalene consumption= 0.067 g/ft².

The equivalence factors for Eco-toxicity aquatic potential (ECA) and human toxicity potential (HT) are 8-80 m³/kg and 1.2-2 kg/kg, respectively.

To be on safe side the maximum values for ECA and HT are taken, for the naphthalene consumption and have been shown under table 5.38.

Table -5.38: Emission impact due to naphthalene consumption

Process stage	Naphthalene consumption g/ft ²	ECA equivalence factor m ³ /kg	ECA B m ³ /ft ²	HT equivalence factor kg/kg	HT mg/ft ²
Soaking - Liming	0.067	80	5.36*10 ⁻³	2	134

5.4 Overall environmental impact of the company

The total impact that arises as a result of raw sheep skin transporting and processing, importing and using tannery chemicals, steam production, sludge production and naphthalene consumption which is shown on table 5.39

Table 5.39: Overall environmental impact of the company

Impact Source	Green House effect (mg)	Acidification (mg)	Eutrophication (mg)	Winter smog (mg)	Human Toxicity (mg)	POCP (Summer smog (mg))	Eco-toxicity (mg)
Import of processing chemicals	30,798	351.2	59	336.3	395.1	19.6	-
Transporting of raw sheep skin and other related activities	100,483	1,152.1	193.7	211.2	1,292.9	64.1	-
Steam consumption	76.85	0.22	0.029	0.23	0.231	0.35	5.73*
Utilization of processing chemicals	-	4,175.5	3,140.1	-	6,224.3	-	20,454.9
Sludge production from ETP	-	-	471.11**	-	-	-	-
Naphthalene consumption during preservation	-	-	-	-	134	-	$5.36 \cdot 10^{-3}$
Total (mg)	131,357.9	5,679	3,840	547.7	8,046.5	84.1	20,460.6
(kg)	0.13	$5.68 \cdot 10^{-3}$	$3.84 \cdot 10^{-3}$	$5.48 \cdot 10^{-4}$	$8.05 \cdot 10^{-3}$	$8.4 \cdot 10^{-5}$	0.0205

NB: * emission to water

** emission to soil

6 Normalization

The next step after classification and characterization is the normalization step. The idea of normalization is to analyze the respective share of each impact to the overall damage by applying normalization factors. In this thesis the global figures are considered for the classifications being discussed.

6.1 The over all emission impact of the company

The overall emission impact values is normalized to the global value so as to determine the normalized score (Table 6.1)

Table6.1: Normalized score value of the overall company impact

Environmental problem type	Unit	Company emission (A)	Unit	World value (B)	Unit	Normalized score $A/B * 10^{-15}$
Green house effect	Kg	0.13	$Kg \cdot 10^{12}$	37.7	Kg	3.45
Acidification	Kg	$5.68 * 10^{-3}$	$Kg \cdot 10^9$	286	Kg	19.86
Eutrophication	Kg	$3.84 * 10^{-3}$	$Kg \cdot 10^9$	74.8	Kg	51.34
POCP (Winter+summer Smog)	Kg	$6.32 * 10^{-4}$	$Kg \cdot 10^9$	3.74	Kg	168.98
Human Toxicity	Kg	$8.05 * 10^{-3}$	$Kg \cdot 10^9$	576	Kg	13.98
Eco Toxicity	m^3	0.0205	$m^3 \cdot 10^{12}$	908	m^3	0.023

6.1.1 The Dress Glove and Silver White Glove Leathers Environmental Impact

The Dress and Silver White glove leather production processing steps are the same from soaking to tanning. However they differ on 'retanning' (bleaching) and dyeing processing steps.

The Silver White leather production does not include the dyeing process stage. The environmental impact of the two products considering only the 'retanning' (bleaching) and dyeing process stage and steam consumption is presented as follows:

Dress glove leather processing chemicals and steam consumption are tabulated here.

Table 6.2: Emission impact of the dress glove leather

Impact Source	Green House effect	Acidification	Eutrophication	Winter smog	Human Toxicity	POCP	Eco-toxicity
Steam consumption Dyeing	7.78	0.023	3*10 ⁻³	0.029	0.026	0.035	0.597
Chemical consumption Dyeing	-	77.37	39.70	-	0.168	-	0.48
Total (mg)	7.78	77.393	39.703	0.029	0.194	0.035	1.077
Total (kg)	7.78*10 ⁻⁶	77.393*10 ⁻⁶	39.703*10 ⁻⁶	2.9*10 ⁻⁸	0.194*10 ⁻⁶	3.5*10 ⁻⁸	1.077*10 ⁻⁶

The normalization of the values mentioned under dress glove leather is tabulated as follows:

Table 6.3: Normalized score values for dress glove leather

Environmental problem type	Unit	Company emission (A)	Unit	World value (B)	Unit	Normalized score A/B*10⁻¹⁹
Green house effect	Kg	7.78*10 ⁻⁶	Kg.10 ¹²	37.7	Kg	2.06
Acidification	Kg	77.39*10 ⁻⁶	Kg.10 ⁹	286	Kg	2706
Eutrophication	Kg	39.70*10 ⁻⁶	Kg.10 ⁹	74.8	Kg	5308
POCP (Winter + summer Smog)	Kg	6.4*10 ⁻⁸	Kg.10 ⁹	3.74	Kg	171.1
Human Toxicity	Kg	0.194*10 ⁻⁶	Kg.10 ⁹	576	Kg	3.77
Eco Toxicity	m ³	1.077*10 ⁻⁶	m ³ .10 ¹²	908	m ³	0.01186

Silver white leather processing chemicals and steam consumption are tabulated here.

Table-6.4: Emission impact of the silver white leather

Impact Source	Green House effect	Acidification	Eutrophication	Winter smog	Human Toxicity	POCP	Eco-toxicity
Steam consumption Re-tanning (Bleaching)	17.93	0.055	7.02*10 ⁻³	0.069	0.06	0.084	1.338
Chemical consumption Re-tanning (Bleaching)	-	33.6	22.94	-	0.34	-	0.97
Total (mg)	17.93	33.66	22.95	0.069	0.40	0.084	2.31
Total (kg)	17.93*10 ⁻⁶	33.66*10 ⁻⁶	22.95*10 ⁻⁶	69*10 ⁻⁹	4*10 ⁻⁷	8.4*10 ⁻⁸	2.31*10 ⁻⁶

The normalization of the above-tabulated values is presented as follows:

Table 6.5: Normalized score values for silver white leather

Environmental problem type	Unit	Company emission (A)	Unit	World value (B)	Unit	Normalized score (A/B)*10⁻¹⁹
Green house effect	Kg	17.93*10 ⁻⁶	Kg.10 ¹²	37.7	Kg	4.76
Acidification	Kg	33.66*10 ⁻⁶	Kg.10 ⁹	286	Kg	1,176.9
Eutrophication	Kg	22.95*10 ⁻⁶	Kg.10 ⁹	74.8	Kg	3,068.2
POCP (Winter+summer Smog)	Kg	1.53*10 ⁻⁷	Kg.10 ⁹	3.74	Kg	409.1
Human Toxicity	Kg	4*10 ⁻⁷	Kg.10 ⁹	576	Kg	6.94
Eco Toxicity	m ³	2.31*10 ⁻⁶	m ³ 10 ¹²	908	m ³	0.0254

7 Evaluation

After normalization the next activity is evaluation (weighing). Evaluation can be done by considering the sensitiveness of each environmental impact, e.g. through experts opinion or by treating the problems equally. By plotting the normalized score of dress glove leather and silver white leather the following figures are obtained, as is given under the figure 7.1.

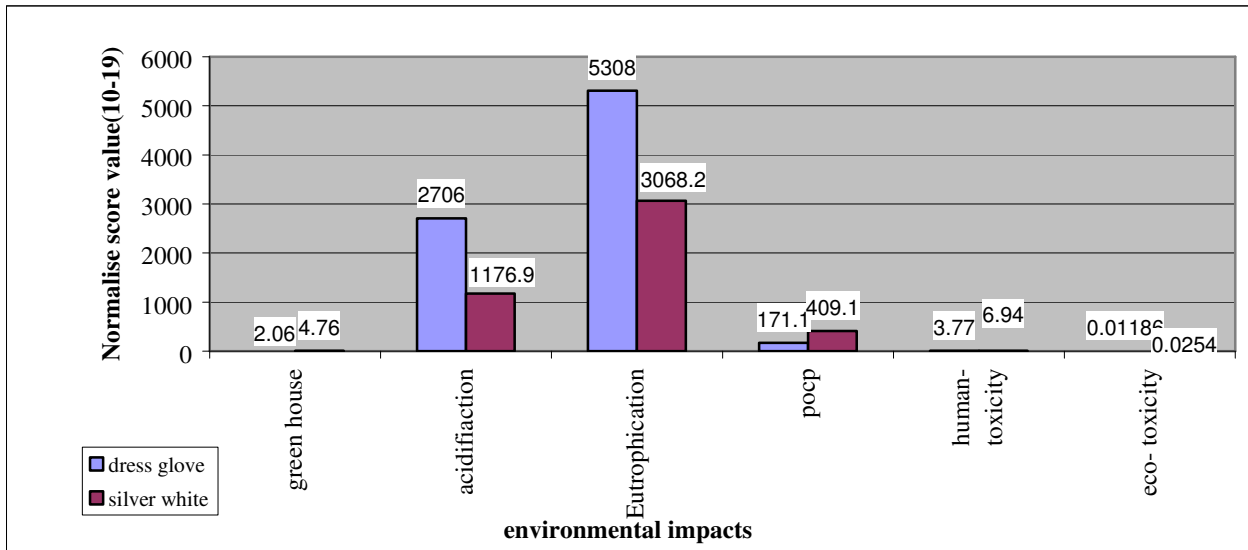


Fig. 7.1 Dress glove and silver white leather environmental effect

7.1 Overall company impact

Of the six major environmental problems POCP scores the highest value and Eco toxicity scores the least (fig7.2). In general the company shall give serious attention on minimizing the environmental problems like POCP, Eutrophication, Acidification and human toxicity, giving priority to them according to the order .If we break down the above problems in accordance with the products type definitely it will be easy to find a solution. Also the figure 7.2 ,figure 7.3,and figure 7.4 show overall company effect, for dress glove leather (dyeing operations) and for silver white leather (retanning-bleaching operations),the environmental impact values, respectively.

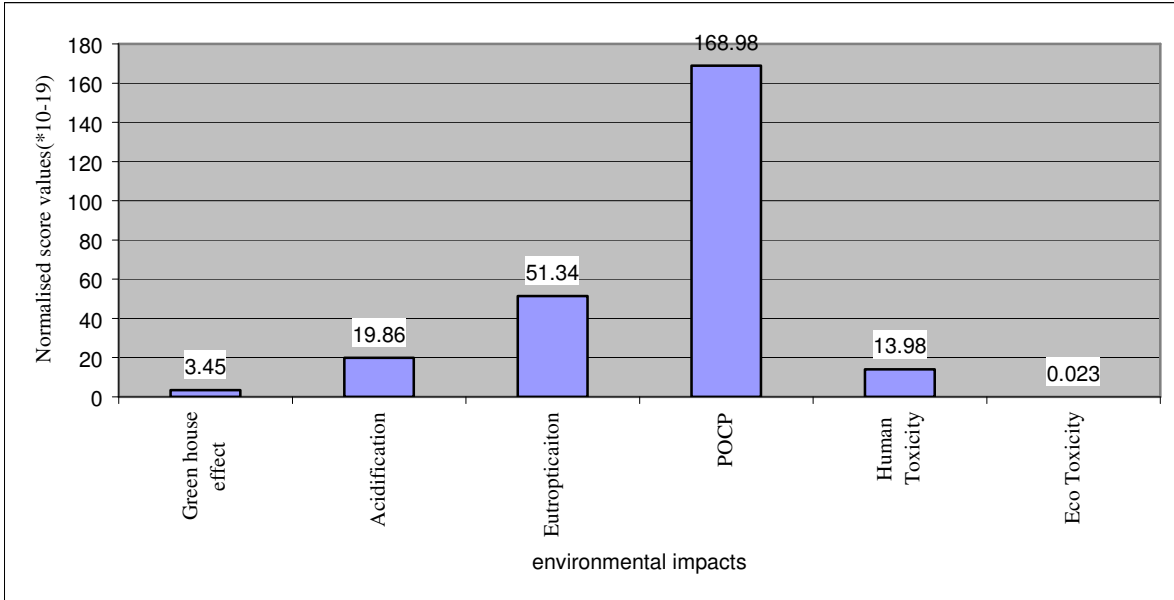


Fig.7.2- Overall company effect (*10⁻¹⁵)

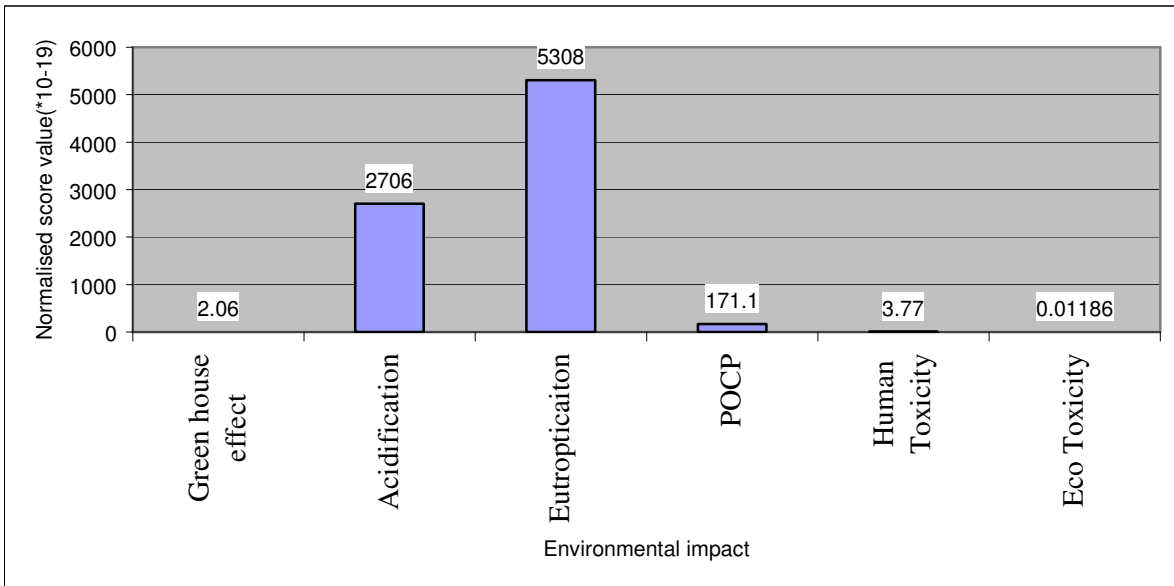


Fig 7.3- For Dress glove leather (dyeing operation) (*10⁻¹⁹)

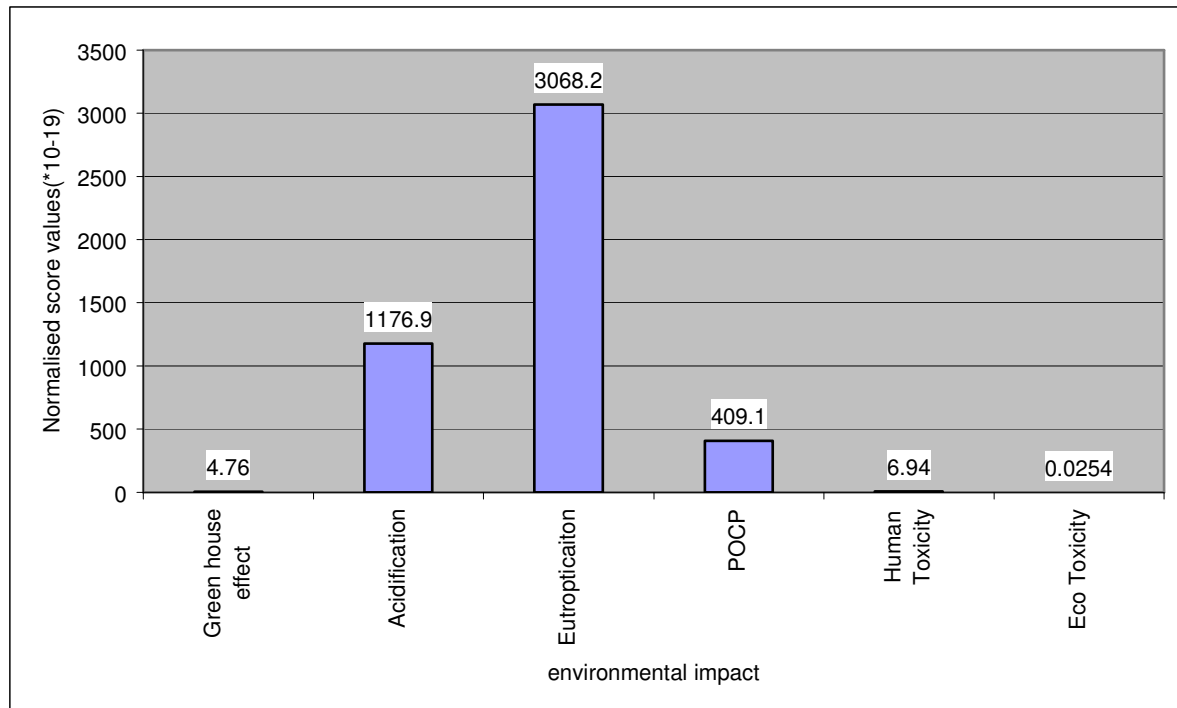


Fig.7.4- For silver white leather ('Retanning' (bleaching) operation) (*10⁻¹⁹)

7.2 Dress glove and Silver White

Dress glove leather is one of the main products of the company. It is used for hand glove making and for dressing purpose. It is mostly exported to USA and Europe. Comparing the re-tanning and dyeing process stages of dress glove leather with Silver White re-tanning stage, the following observations are made

- Dress glove leather has higher Eutrophication, Acidification and human toxicity impact (fig. 7.1 and 7.3);
- Silver White has higher POCP and Green House effect; and
- In general Dress glove leather has higher environmental impact than Silver White leather. (fig.7. 1 and 7.4).

By taking separate action on the two products the overall environmental impact of the company can be improved.

8 Improvement Assessment

In this thesis the damage categories employed are human health, ecosystem quality and climate change. The damage categories are calculated as follows.

- Human Toxicity = 13.98×10^{-15}
- POCP = 168.98×10^{-15}

$$\text{Human health} = \text{Human Toxicity} + \text{POCP} = 182 \times 10^{-15}$$

- Eco-Toxicity = 0.023×10^{-15}
- Acidification = 19.86×10^{-15}
- Eutrophication = 51.34×10^{-15}

$$\text{Ecosystem quality} = \text{Eco-Toxicity} + \text{Acidification} + \text{Eutrophication} = 71.22 \times 10^{-15}$$

- Green House effect = 3.45×10^{-15}

$$\text{Climate change} = \text{Green House effect} = 3.45 \times 10^{-15}$$

From the above three damage categories the company has higher human health impact to the environment. The three damage categories will be depicted on the figure below in bar chart form (figure 8.1).

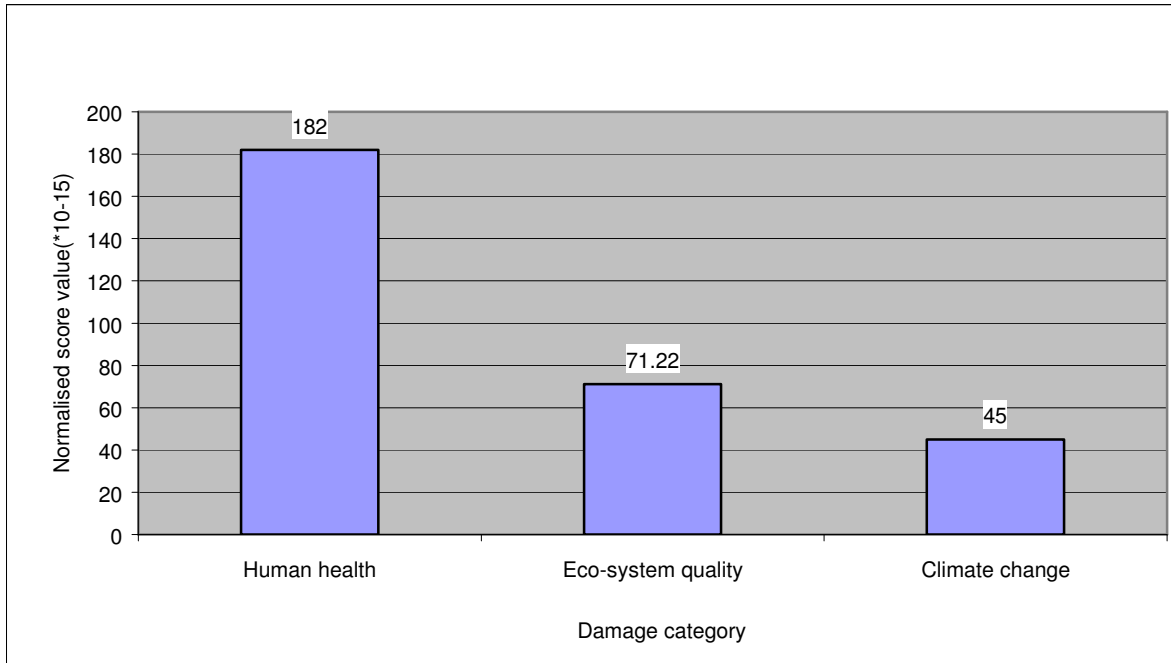


Fig. 8.1 The three damage categories impact level (*10⁻¹⁵)

As shown above, the company needs to give priority for human health impact and then for the next damage categories during preparing environmental management program.

Moreover, it is clearly indicated in the normalized score values the company has serious impact on POCP & Eutrophication. Then Acidification and Human toxicity take the next position. At last but not the least are green house effect and eco toxicity. For each environmental impact the main sources and the remedial solutions will be dealt.

8.1 POCP and Green House Effect

The main source for having higher share of POCP and Green House Gas are transporting of raw sheepskins and import of processing chemicals. As these sources are out of the company's control, it is very difficult to take corrective action. However, by providing awareness program to the major suppliers and freight service provider improvement will be expected. Such as utilization of vehicle with low environmental impacts and avoiding using of old vehicles. The company may use different communication systems to arise the awareness of its staff through different means like brochure, informal discussion, e-mail or telephone or fax. Figure 8.2 below shows the relative merits of POCP effect of the company activity.

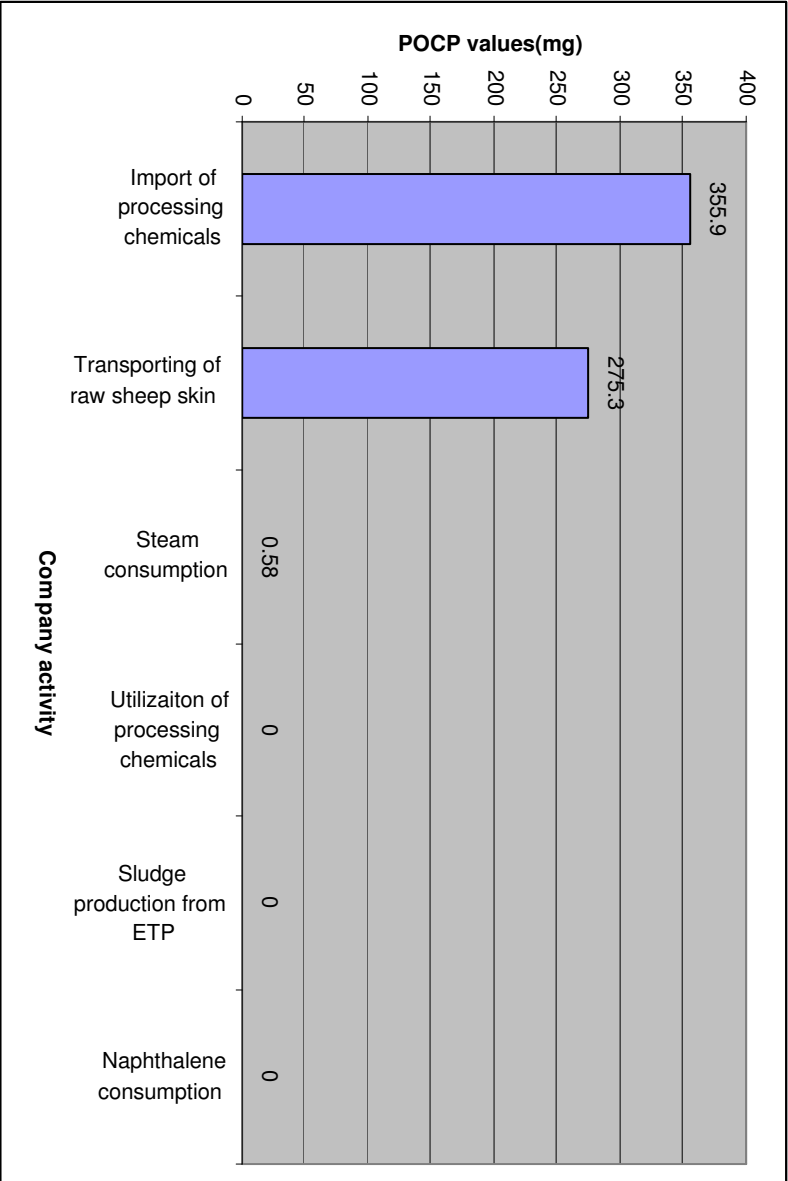


Fig. 8.2 : POCP effect of the company activity

Figure 8.3, on the similar comparison, shows the Green house effect on the company activities below.

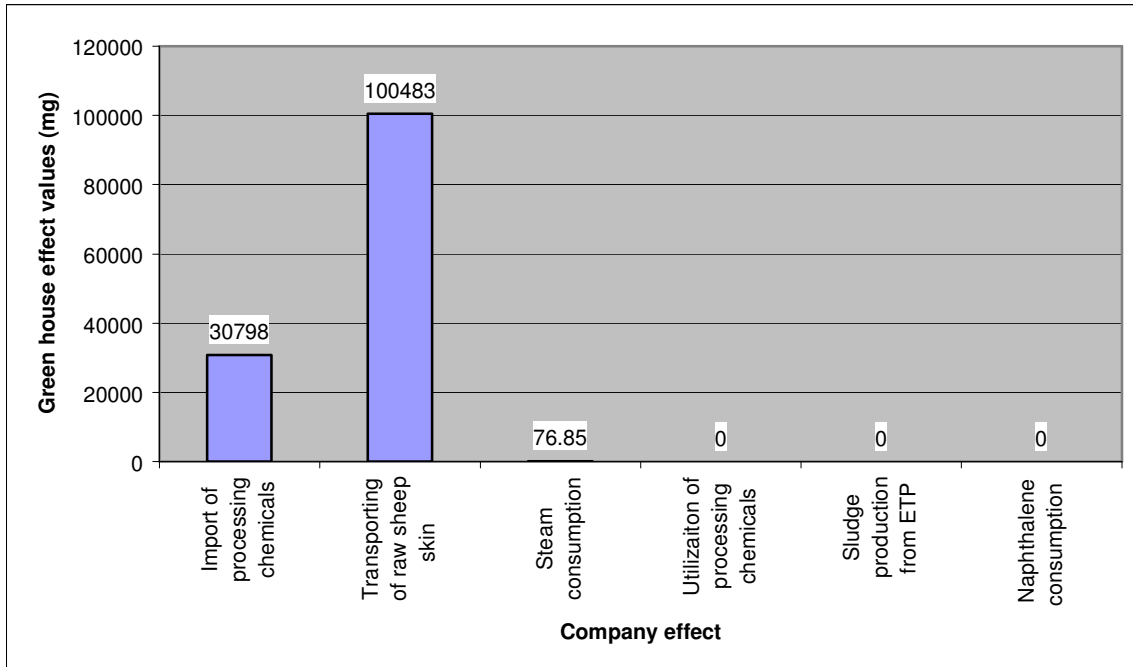


Fig.8.3 Green House Effect of the company activity

8.2 Eutrophication

Highest value of Eutrophication is observed as a result of consumption of processing chemicals. When traced back to the main production process stages for such highest value of eutrophication the main source are Soaking- Liming & Deliming- Pickling processes. Figure 8.4 shows the eutrophication effect of the company activity below.

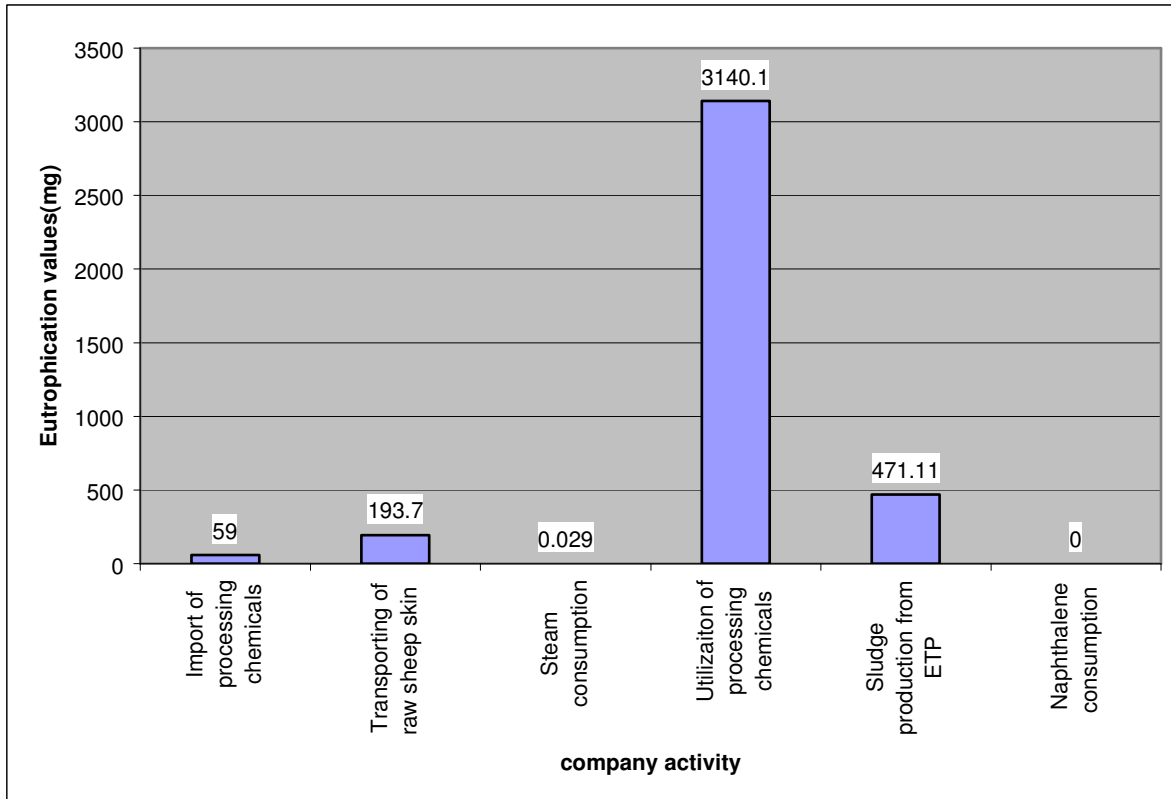


Fig 8.4 Eutrophication effect of the company activity

Eutrophication results due to emission of ammonia, COD, Nitrate, Phosphate & Phosphorus to air & water. So as to improve these emissions remedial solutions expected to be implemented are suggested as follows:

8.2.1 Solution- Green Fleshing

Fleshing skins in green or soaked state is a useful procedure for producing chemical-free solid residues and it allows a more rapid and uniform penetration of chemicals into the skin. Green fleshing requires a well-set machine, where blades are exactly adjusted to avoid a further fleshing step after liming (14).

Green fleshing can be complicated or made impossible if dung, dirt etc, are not sufficiently removed by washing and soaking (14).

If green fleshing is suitably applied before the consumption of chemicals and water in the beam house are reduced by 10-20%. Consequently the wastewater volume in the unhairing/liming step is also reduced. Green fleshing allows a more rapid and uniform penetration of chemicals into the skin (14,18).

8.2.2 Solution- Reducing Sulphide Consumption During Liming

Lime unhairing is the largest contributor of pollution in tanneries. A total substitution of the Sulphide used as an unhairing agent is currently not possible in practice, but they can be reduced considerably. Enzymes and amines can be added to facilitate the unhairing and reduce the consumption of Sulphides (18).

When enzymes are used the water consumption increases because an additional finishing step is required to block the enzymatic activity and the saved hair is not suitable for the production of felt (18). But the suspended solids, COD, BOD and nitrogen amount are expected to be reduced from the existing effluent load.

During liming process the company is started to use enzymes to facilitate soaking and liming process. In the long run effort will be made to reduce the Sulphide consumption.

8.2.3 Solution- Salt free/reduced pickling

Through the use of newly developed salt-substitute non-swelling acid (such as Sulphone)(18), salt-free systems, based on non-swelling polymeric sulphuric acids are available. Another reference quotes the possibility of a partial substitution of chloride by using e.g. Aromatic sulphonic acids. Use of these acids results in reduction of the chloride and sulphates in the discharge liquor (14).

8.2.4 Solution -Optimizing the float

A short pickle float will reduce the salt consumption for the pickling, and reduce the water consumption and subsequently the volume of effluent generated. The float can be reduced to 50-60%, which means that 0.5-0.6 M³ water per tonne fleshed pelts is used (14).

8.2.5 Solution- Reducing the consumption of the degreasing agent

Eusapon is used as degreasing agent during pickling operation. Based on the trial conducted by varying the concentration the product did not show quality deterioration till it reaches 50 % reduction. There fore, reducing the current consumption by 50% will reduce its impact by half. This can be decided by conducting further trial or by using other degreasing agent having higher concentration.

8.3 Acidification

The utilization of processing chemicals is the cause of high acidification values at soaking liming and deliming pickling operations. The solutions suggested on eutrophication also include solution for acidification problems. Figure 8.5 shows the acidification effect on the company activity ,given below.

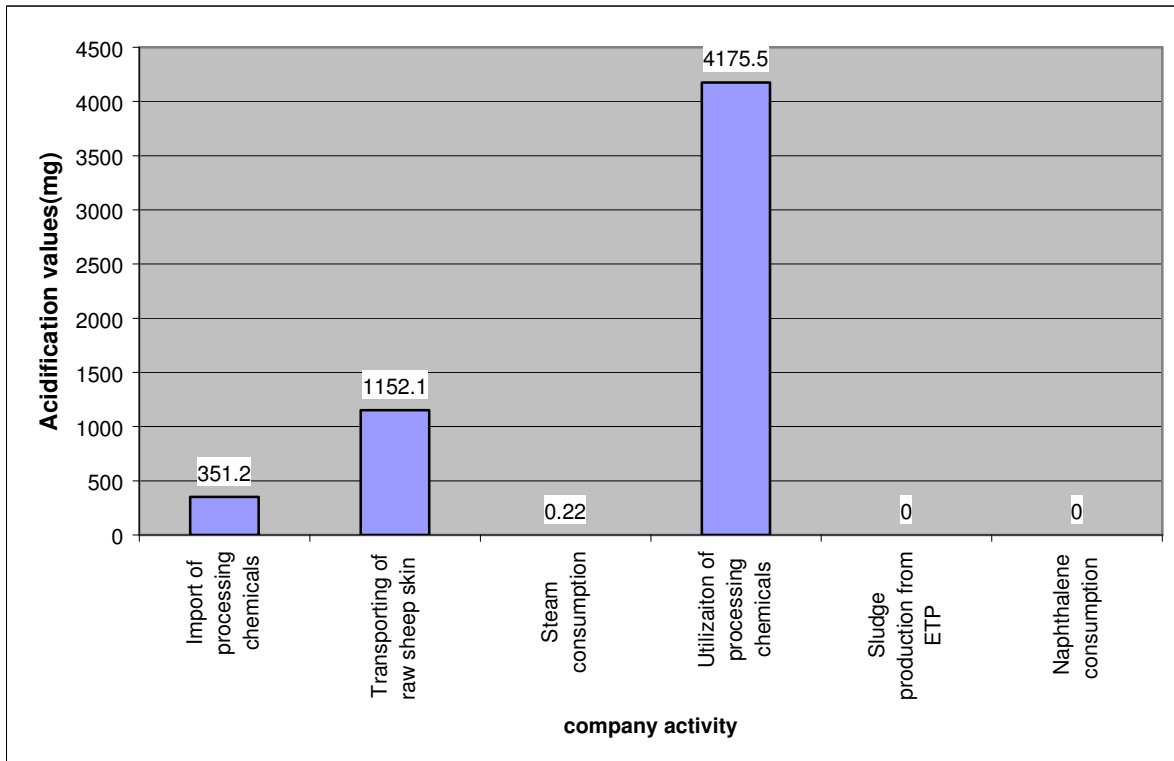


Fig.8.5 Acidification effect of the company activity

8.4 Human Toxicity

The main source for human toxicity is again the chemical consumption during production processing. Depickling-Tanning is the main source for the severe occurrence of Human Toxicity. The emissions responsible for human toxicity are Cr^{3+} , Nitrite, Nitrate, H_2S & phosphorus. Of these Cr^{3+} plays a significant role on maximizing the human toxicity potential. Figure 8.6 shows the Human Toxicity effect on the company activities.

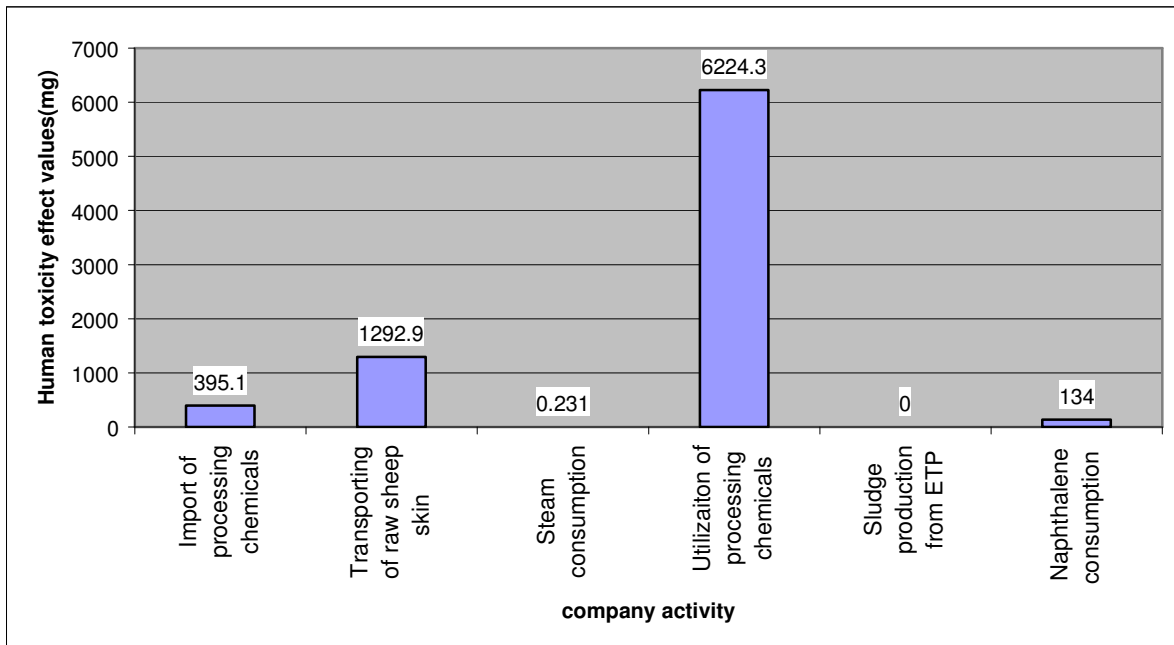


Fig 8.6 Human Toxicity effect of the company activity

The remedial solution to minimize its emission to water is suggested as follows:

8.4.1 Solution: Increasing efficiency of chrome tanning

The 'classic' chrome tanning carried out in long floats is characterized by poor exhaustion, 30-50% of the chrome applied being lost with the wastewater. BLC (British Leather Chemists) reports that an average of 40% of the chrome input may be discharged (14).

To improve the exhaustion of conventional tanning systems the following actions are relevant.

- The 80% chrome uptake can be achieved by altering the physical parameter-temperature rise from 20°C to 50°C , P^{H} from 3.5 to 4.5 of the tanning operation (14);

- The tanning agents are modified so that a low basicity tanning powder penetrates first on the cross section. Then a high basicity chrome powder is added and the temperature is increased (14); and
- Use special chrome agents (aromatic dicarbon acids) e.g. adipin or phthalic acid, aldehyde carbon acids, e.g. glyoxylic acid, which enhance the number of links available for the binding of chrome in the collagen structure (14). Using of these agents help to reduce the existing emission by 97% to 99%.

8.5 Eco- toxicity

Due to utilization of tannery chemicals about 20,454-mg/ft² Eco-toxicity has been observed. About 20,450 mg/ft² Eco-toxicity is contributed by the Depickling-tanning process followed by the contribution of soaking liming (1.79 mg/ft²) and retanning (Dress glove) [1.59 mg/ft²]. The main contributors for eco-toxicity are H₂S, Cr³⁺, and naphthalene. The figure 8.7 below shows the eco-toxicity impact values on the company activity.

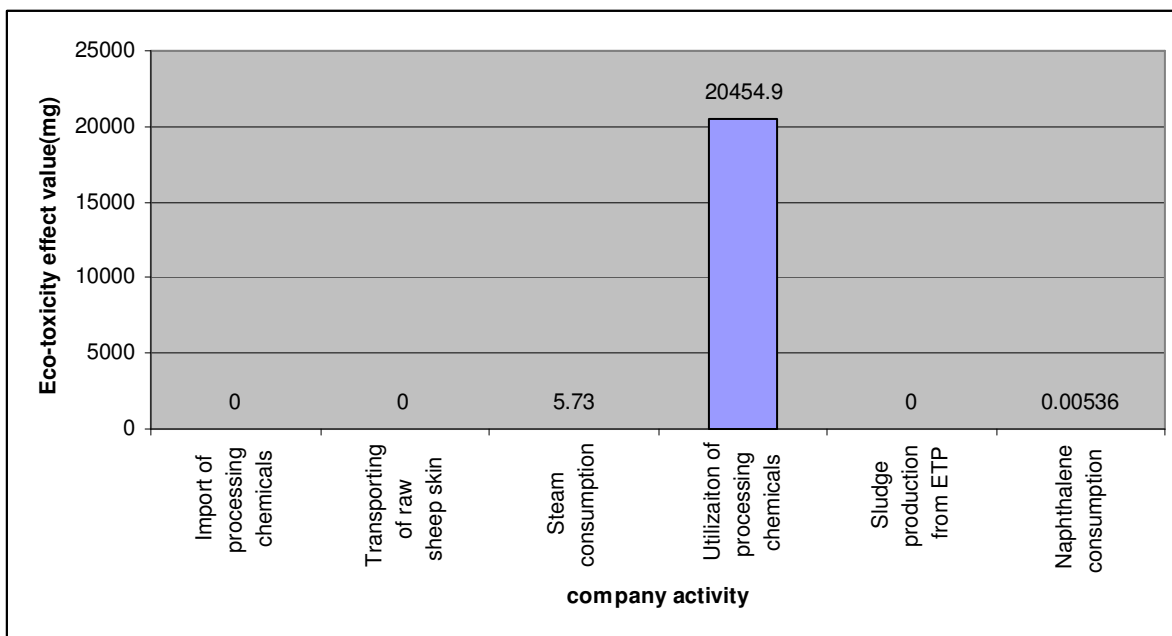


Fig 8.7 Eco toxicity impact of the company activity

In order to improve emissions of H₂S, Cr³⁺ and naphthalene, measures should be taken to reduce their consumption amount.

The possible remedial solutions for reducing H_2S , Cr^{3+} emissions are discussed under eutrophication and human toxicity. Moreover for minimizing emission of naphthalene during raw sheep skin preservation the remedial solution is presented below:

8.5.1 Solution: Avoid use of naphthalene for raw skin preservation

Biocides may be used in the curing, soaking, pickling, tanning & post tanning processes. Halogenated organic compounds e.g. bronopol, thiadialine, have been used for long time in tanneries and halogenated biocides are still sold. Sodium or potassium-di-methyldithiocarbonate is considered to be a more environmental friendly bactericide, due to its lower persistency and toxicity levels (IPPC). According to BLC (British Leather Chemists) the use of e.g. 0.05% (of the weight of raw skins) bronopol can offer adequate protection. In Italy its concentration vary from 0.1 of to 0.5% depending on the type and concentration of the commercial products (14)

Use of newly developed anti septic (thie-cyanomethyl thio benzothazole TCMB, isothiazolone, chloracetamide) available from several commercial firms is also suggested(18).

Therefore the company shall replace the naphthalene by the above-mentioned chemicals or replace it by sodium carbonate & borax mixture if they are not costlier.

8.6 Dress glove leather and Silver White leather

Comparing the two products normalized score values; Dress glove leather seems to have more polluting nature. (The detail is shown on fig 7.1 under Evaluation)

Dress glove has highest polluting nature than silver white on Eutrophication, Acidification and Human Toxicity. Where as silver white is on POCP and green house effect.

8.6.1 Dress glove leather

Main contributor for polluting nature of dress glove leather is the dyeing operation. During dyeing different kinds of dyestuffs are utilized to produce products of different colors. The dyestuffs used have powdering nature. The other contribution comes from the retanning operation.

In order to minimize the environmental impact of the dress glove leather improvement options like dyeing process stage improvement, improving fatliquoring operation and minimizing the chemical consumption during dyeing are suggested. Of these on the last improvement option trial was conducted by taking 52 crust skins. The trial started by reducing the existing chemical consumption by 25 %. The result obtained is similar with the quality obtained by normal operation. The detail of the result is shown on table 8.4. The next trial focused to minimize the chemical & water consumption by 50%. By so doing the product quality is not affected and similar to the normal product quality .The detail of the test result is shown on table 8.3. By reducing the consumption further by 75% ,the result obtained is not satisfactory because it had made the product to have dry feeling and poor dye penetration. The detail of the result is shown on table 8.5.

From the above trials the last optimized result is obtained by the 50 % chemical and water consumption reduction. This also results minimizing the existing environmental impact by 50%. By conducting further trial it is expected to reduce more than 50 % up to 30 %. The detail of the trial for 50 % chemical reduction and the other suggested solutions are presented as follows

8.6.2 Solution- Minimizing the Chemical and Water Consumption During Dyeing of Dress Glove Leather

i. Resources employed

- Recipe used - Dyeing – Black - Normal
- Recipe No. - R & D.s 22/2/06
- Trial date - 6/6/06 – 28/6/06
- No. of skins consumed - 12+40= 52
- Skin type - 0.4-0.5 mm, Grade 1-3 & 5th
-0.6-0.7 mm, Grade 1-3 & 5th

ii. Methodology employed

The method followed to conduct the chemical reduction is simply reducing existing chemical percentage by 50%. As a controlling sample skins with the normal chemical dosage were

also processed. At the completion of each trial the softness of the leathers, stretchiness, penetration and color shade were evaluated against the normal processed skin.

iii. Limitations

During cost calculation due to availability of information the saving on purchasing processing cost are excluded.

iv. Observation

From the laboratory test result the following observations are made:

- The 50% reduction processes results for more or less similar skins quality with the normal processed skins.
- The chemical reduction results for imparting softness to the leather except for the higher thickness of lower grade dyed crust.
- Stretchiness (elongation) of the skins in general shows improvement. i.e. their stretchiness is reduced as compared with the normal processed skin.
- Color shade of the processed skins becomes more or less similar to the normal shade.
- There is also complete penetration of dyestuffs.

v. Potential impact on saving

Analysis has been done based on the cost saving of the 2005/06-budget year plan.

In 2005/06, 80% of the crust (4,066,960 ft²) have been processed in to black dress glove leather which is equivalent to 3,253,568 ft² (Here all of them are expected to be 'normal' i.e. not water repellent)

For calculating the chemical consumption the average weight and area of a skin are taken as 130 gm and 4.58 ft², respectively.

The detail of the chemical cost calculation is presented as follows:

1. Normal operation

The total crust being dyed is 4,066,960 ft². Based on this value the total chemical consumption is calculated.

Table 8.1 shows chemical consumption at dyeing stage by normal operation.

Table 8.1: Chemical consumption at dyeing stage by normal operation

S.N	Chemical name	Actual consumption g/ft ²	Total consumption kg	Cost Br/kg	Total cost (Birr)
1	Ammonia	0.6	2,440	92.65	226,066
2	Eupilon IN	0.6	2,440	21.74	53,046
3	Luganil black NT	4.256	17,308	72.12	1,248,253
4	Luganil black CN	1.135	4,616	78.39	361,848
5	Lurazon black VB	0.852	3,465	44.95	155,752
6	Lurazol black PL	0.567	2,306	41.87	96,552
7	Formic acid	3.6	14,640	6.75	98,820
8	Catalix GS	0.5	2,033.4	23.33	47,439
9	Tankrom AB	0.8	3,253.4	10.399	33,832
10	Water	1,761.57	7,163,718	3*10 ⁻³	21,491
	Total				2,343,099

Total dyeing chemical cost = 2,343,099 Birr/year

2. *Chemical consumption reduction by 50 %.*

Table 8.2 shows chemical consumption at dyeing stage by chemical reduction of 50% from the normal operation .

Table 8.2: Chemical consumption at dyeing stage by chemical reduction by 50 %

S.N	Chemical name	Actual consumption g/ft ²	Total expected consumption kg	Cost Br/kg	Total expected cost (Birr)
1	Ammonia	0.3	1,220	92.65	113,033
2	Eupilon IN	0.3	1,220	21.74	26,523
3	Luganil black NT	2.13	8,662	72.12	624,703
4	Luganil black CN	0.57	2,308	78.39	181,708
5	Lurazon black VB	0.43	1,749	44.95	78,618
6	Lurazol black PL	0.28	1,139	41.87	47,690
7	Formic acid	1.8	7,320	6.75	49,410
8	Catalix GS	0.25	1,017	23.33	23,727
9	Tankrom AB	0.4	1,627	10.399	16,919
10	Water	1,000.25	4,068,903	3*10 ⁻³	12,207
	Total				1,174,538

Total dyeing chemical cost by 50% reduction method is equivalent to 1,174,538 Birr.

Therefore, the company may save 1,168,561 Birr per annum by applying the 50% reduction method.

vi. *Other related benefit*

1. *The weight of the skin is expected to be lighter than the previous skin weight.*

This is shown as follows:

- Avg. skin weight= 130 g
- Maximum chemical load= 12.911 g (by normal operation)
- Final weight = 142.911 g/pcs (normally processed skin)
- Maximum chemical load = 6.45 g (by 50% reduction)
- Final weight = 136.45 g/pcs (by 50% reduction)

By assuming all the chemicals added remain in the skin with exception of water the modified product shows a weight reduction by 6.461 g/pcs or 1.41 gm/ft². Through out the 2005/06 budgets the expected weight reduction for the 3,253,568 ft² will be 4,589.80kg. The transport(delivery) weight will also be minimized by 4,589.80kg. In financial terms it may be equivalent to 20,080 Birr.

2. *The treatment cost for treating 2,476 m³ will be reduced by 7,428.07 Birr*

- Total water to be consumed by normal operation 573.4m³/year
- By applying the 50% reduction method the expected water consumption reduction will be 2,476 m³/year. This value is calculated by multiplying the water reduction 0.761 g/ft² and the total production 3,253,568 ft².
- The existing treatment cost = 3 Birr/m³
- Finally the treatment cost will be = 7,428.07 Birr/year
- The company may save 7,428 Birr with in the 2006/07 budget year

3. *The company can be competent in international market even by reducing its existing selling price by 0.17 Birr/ft² and thus get a benefit out of it if it produces black dress glove leather above the planned quantity.*

NB: By normal operation the chemical cost = 0.57 Birr/ft²

By 50% reduction process chemical cost = 0.396 Birr/ft²

vii. Conclusion

By summing up all the direct & indirect saving the company may have a total saving of 1,168,561 Birr/annum. The physical characteristics of the modified leather are the same with the normally produced leather. This is clearly shown on the table 8.3 below.

Table 8.3 shows the test result observed by reducing the chemical and water consumption by 50 %.

Table 8.3: Laboratory test result of the normally produced and chemical reduced products (50 % reduction)

Thickness (mm)	Grade	Softness (mm)		Penetration		Elongation (%)		Color shade compare with the normal shade
		Normal	50% reduction	Normal	50% reduction	Normal	50% reduction	50% Reduction
0.4-0.5	3 rd	5.1	4.7	Ø(full)	Ø(full)	50	48	Same
0.4-0.5	5 rd	4.7	4.3	Ø	Ø	46	40	Same
0.6-0.7	3 rd	4.6	4.6	Ø	Ø	71	54	Same
0.6-0.7	5 rd	5.1	4.6	Ø	Ø	57	42	Same

Table 8.4 shows the test result observed by reducing the chemical and water consumption by 25 %.

Table 8.4: Laboratory test result of the normally produced and chemical reduced products (25% reduction)

Thickness (mm)	Grade	Softness (mm)		Penetration		Elongation (%)		Color shade compare with the normal shade
		Normal	25% reduction	Normal	25% reduction	Normal	25% reduction	25% Reduction
0.4-0.5	3 rd	5.1	5	Ø(full)	Ø(full)	50	49	Same
0.4-0.5	5 rd	4.7	4.6	Ø	Ø	46	43	Same
0.6-0.7	3 rd	4.6	4.3	Ø	Ø	71	66	Same
0.6-0.7	5 rd	5.1	5.1	Ø	Ø	57	55	Same

Table 8.5 shows the test result observed by reducing the chemical and water consumption by 75 %.

Table 8.5: Laboratory test result of the normally produced and chemical reduced products (75% reduction)

Thickness (mm)	Grade	Softness (mm)		Penetration		Elongation (%)		Color shade compare with the normal shade
		Normal	75% reduction	Normal	75% reduction	Normal	75% reduction	75% Reduction
0.4-0.5	3 rd	5.1	4.4	Ø(full)	partial	50	40	lighter
0.4-0.5	5 rd	4.7	4.0	Ø	partial	46	40	lighter
0.6-0.7	3 rd	4.6	4.3	Ø	partial	71	50	lighter
0.6-0.7	5 rd	5.1	3.8	Ø	partial	57	40	lighter

8.6.3 Solution- Improving the fat liquoring operation

Fat liquors are a significant cause of wastewater contamination, especially in the production of soft leathers, which require large amounts of fat liquor. Improvements can be achieved by higher exhaustion thus reducing the COD levels in the waste water by careful selection of the type of fat liquor to be used can also reduce the pollution load related either to organic solvents (solvent-based fat liquors), or to chlorinated organic compounds (chlorinated fat liquors) which increase the AOX levels (14).

8.6.4 Solution- Dyeing process stage improvement

Achievable techniques and technologies to reduce the impact on the environment of dye stuff and of the dyeing process are:

- To minimize the input of chemicals used, both dyestuff and auxiliary;
- To select dyestuff and auxiliary with lower environmental impact, e.g. substitute poorly exhausting dyestuff with high exhausting ones, substitute dyestuff containing high levels of salts with dyestuffs containing a limited amounts of salts, etc;
- To avoid the use of ammonia as penetrating agent, as ammonia can be substituted completely in most cases;
- To substitute powder dyestuffs with liquid ones, to reduce dust emissions;
- Ammonia can usually be substituted completely by auxiliaries such as dye Penetrations; and

- A small number of dyestuffs used in the leather industry are halogenic and can result in the emission of AOX (Absorbable Organic Halogen (x)). Where possible halogenic dyestuffs should be replaced to avoid the release of AOX. The use of vinyl sulphone reactive dyes is considered general practice and reduces the AOX load (14).

8.7 Silver White Leather

The environmental impact of silver white is high in relation to POCP and Green House effect. The main contributors to this serious environmental impact are steam consumption and use of bleaching agents like Imprapel co-liquid and the oxidant sodium meta bisulphate. As compared to dress glove leather impact, silver white has higher environmental impact as a result of steam consumption. This is due to high quantity of steam consumption during processing.

The improvement options suggested are improving the condition of the existing boiler and minimizing the quantity of steam consumed by certain percentage as did on the dress glove leather. The other option is to replace Imprapel co-liquid by other bleaching agent who do not have serious environmental impact or who have other type of active ingredient than chlorine type.

The detail for the suggestion made to improve the boiler efficiency is depicted as follows:

8.7.1 Solution: - Improving the existing condition of the boiler

For the production of steam the company uses boiler working with furnace oil. The boiler has rated capacity of 4000 kg lt/hr at 12 bar and it is fire tube type. The boiler started to function before 7 years.

On January 2006 experts from metal products development center came to the company and evaluated the boiler efficiency. As a result the boiler efficiency is found to be 63.5% . At the time of purchase from the technical data sheet its efficiency was 82% currently it is expected to be below 63.5%.

The above figure was determined by applying simple calculation

$$\text{Boiler efficiency } (\eta) = \frac{Q \times (H-h)}{8 \times \text{GCV}} * 100 \text{ ----- (Eq. 8.1)}$$

- Quantity of steam generated per hour (Q) approximately 9m³ water/day = 1.125 m³/hr = 1125 lt/hr
- Quantity of fuel used per hour (q) 875 lt/day = 109.38 lt/hr
- The working pressure and superheat temperature
- Bar = 0.5 MPa
- The temperature of feed water 40°C
- Type of fuel and gross calorific value of the fuel (GCV)
= 41.8 MJ/L
- Enthalpy of steam at 0.5 MPa & , H = 2748.7 kg/kg
- Enthalpy of feed water at 40°C h= 167.57 kg/kg

By using eqn.8.1 the boiler efficiency is calculated as follows:

$$\eta = \frac{1125 \text{ lt/hr} [2748.7-167.57] \text{ kj/kg} * 100}{109.38 \text{ lt/hr} * 41.8 \text{ Mj/L}}$$

$$= 63.5\%$$

Comparing the previous efficiency (i.e. 82%) the existing efficiency is reduced minimum by 22.6%. If the company implements the following recommendations, the existing emissions to air will be reduced at least by 29.1% as the boiler efficiency improved by 29.1 %.

- Attempt should be made to provide the lowest excess air level possible for efficient operation.
- Tube deposits and fouling on external surfaces seriously affect heat transfer from the hot combustion gases to the waterside passages, thereby reducing efficiency.
There fore the boiler tubes shall be cleaned on regular base.
- Install continuous excess oxygen analyzer to automatically adjust burner air fuel ratio.

- Where economically justified, install automatic viscosity controllers on fuel oil systems both to ensure good atomization and to permit mixing various grades of fuel oils. The most consideration is to have proper viscosity.
- Periodically check thermostat setting at oil pre heater.
- Have good house practice for boiler operation.

8.7.2 Solution- Upgrading the effluent treatment plant

There are two basic levels of effluent treatment – primary treatment and combined treatment.

i . Primary treatment – Primary treatment which includes sludge treatment

The final effluent will remain high in BOD and COD values, with little ammonia nitrogen abatement, but upgrading of effluent characteristics can be achieved by lagooning to encourage natural biological action (facultative lagooning)(18).

ii . Combined treatment- Primary treatment, including sludge dewatering followed by Secondary treatment (3).

The final effluent will have lower residual BOD and COD values and much reduced ammonia nitrogen content, as shown in figure 8.6 below (18):

Table 8.6: Removal efficiency of primary and combined treatment unit

Parameter	Expected Removal %	
	Primary Treat	Combined Treat
COD	50-60	94-95
BOD	40-50	90-95
Sulphide	94-97	100
Trivalent chrome	96-98	100
Ammonia Nitrogen	10-15	80-90
Average	61	94.4

On average the removal efficiency of the primary treatment unit is 61%. Where as the combined treatment unit is 94.4%. That means by installing secondary treatment plant the existing pollutant removal efficiency will be improved by 54.8%.In the same phenomenon the existing emissions to water will be reduced by 54.8%.

The term of secondary treatment refers to the removal of the organic substances via biological processes. Suspended and colloidal solids are removed by flocculation and adsorption while soluble matter is removed by bio sorption (18,24).

The primary (physico-chemical) treatment alone generally fails to produce a final tannery effluent with in the required standards for discharge into surface waters, therefore, a successive biological treatment step is usually necessary. The secondary treatment may be aerobic, facultative or anaerobic. In the tannery effluent treatment only the first two processes are of practical use (18,24).

The aerobic process most widely used is extended aeration (or total oxidation) with 2-3 days of retention time. Facultative (or preferably aerated/facultative) lagoons are also utilized especially in hot climatic regions where abundant land is available (18).

8.7.1.1 Solution- Secondary treatment plant design

Proposed treatment method- Extended Aeration

The proposed method of secondary treatment unit is shown in figure 8.8 below.

The unit comprised the aeration and clarifier units.

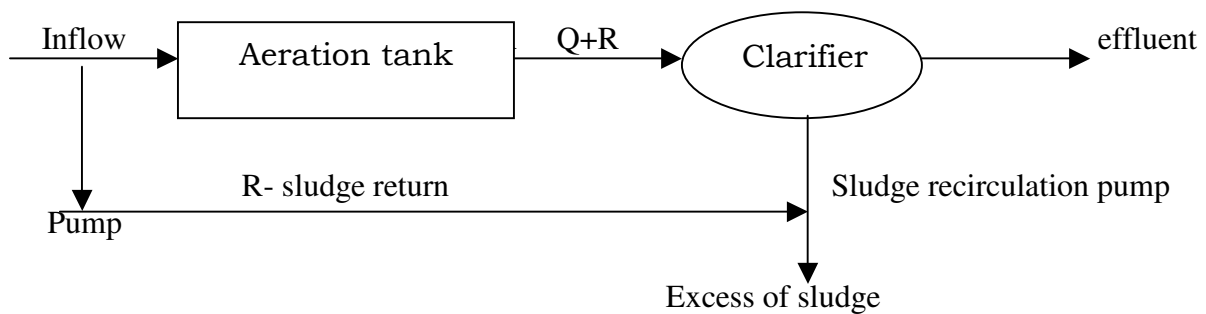


Fig 8.8 - Secondary effluent treatment plant unit

8.7.1.1.1 Design of aeration and clarifier tank

The design values used for the design purpose are shown below:

- $Q_{\max} = 40 \text{ m}^3/\text{hr}$ (from sedimentation to aeration tank), $Q_{\max} = 560 \text{ m}^3/\text{day}$
- $\text{BOD}_5 = 2000 \text{ mg/l}$ (liquor BOD_5 influent)
- Temp. during cold month = 10°C
- BOD_5 out let = 200 mg/l (expected)

- Growth yield (Y) = 0.5 mg V_{ss}/mg BOD₅
- Ammonia concentration (N₀-N₁)=45
- Average TKN=60mg/l
- Maximum TKN=90 mg/l
- Fixed suspended solids=50 mg/l (S_o avg.)
- Non-biodegradable volatile suspended solids=75 mg/l (S_o max.)
- Inlet NH₃ concentration=73 mg/l
- Out let NH₃ concentration (expected) =32 mg/l
- Solids content inlet=2000mg/l
- Solids content outlet=100mg/l

1. Mean solids retention time

$$\theta_s = 3.05 (1.127)^{20-T} \text{-----(Eq.8.2)}$$

Where θ_s =mean solids retention, days and
T=Temperature (°c)

The mean solids retention time is calculated by using Eq. 8.2

$$\theta_s = 3.05 (1.127)^{20-10}$$

$$= 10 \text{ days}$$

2. Hydraulic retention time

$$\frac{V}{Q} = \frac{\theta_s}{X_1} * \frac{Y(S_0-S_1)}{1+K_d \theta_s} \text{-----(Eq 8.3)}$$

Where Q=Flow rate in m³/day
X₁=mixed -liquor suspended solids concentration

θ_s =Mean solids retention time in days

Y=Growth yield

S₀-S₁=Inlet -Out let Solids content

k_d=Decay constant in days⁻¹

For $X_1 = 2000 \text{ mg/l}$ at $\left. \begin{array}{l} K_d = 0.18 \text{ day}^{-1} \\ K_d = 0.48 t_s^{-0.415 (1.05)^{T-20}} \end{array} \right\} T = 20^\circ\text{C}, \alpha = 0.77$
 $t_s = 10 \text{ days}$

Eq. 8.3 is used to calculate the hydraulic retention time as follows:

$$\frac{V}{Q} = \frac{10}{2000} * \frac{0.5(2000-100)}{1 + 0.18 * 10}$$

$$= \underline{1.69 \text{ days}}$$

Volume of aeration tank = $1.69 \text{ days} * 560 \text{ m}^3/\text{days}$
 $= 947 \text{ m}^3 \longrightarrow$

Depth = 3m
 $L/W = 2 \quad L = 2W$
 $L.W.D = 947$
 $2W^2(3) = 947$
 $W = 12.6 \text{ m}$
 $L = 25.2 \text{ m}$

Let Depth = 3 m

$$\phi^2 = \frac{4V}{3.14 H} = \frac{4 * 947}{3.14 * 3}$$

$$\phi = \underline{20.05 \text{ m}}$$

\therefore aeration tank dimension

Depth = 3.2m (3m useful height)

$$\phi = \underline{20.05 \text{ m}} \quad (\text{if circular})$$

3. Clarifier thickener area

i. Surface area for clarification

$$A = \frac{Q_{\max}}{q_L} \text{----- (Eqn.8.4)}$$

Where $-q_L =$ Limiting surface over flow rate (Lt^{-1})

$-Q_{\max} =$ Peak flow rate of clarified effluent

By experience the limiting surface over flow rate is 50 m/day

The surface area for clarification is determined by using Eq. 8.4

$$A = \frac{560 \text{ m}^3 / \text{day}}{50 \text{ m} / \text{day}} = 11.2 \text{ m}^2 = \text{Surface area for clarification}$$

ii. *The surface area for thickening*

$$A = \left(\frac{(Q + Q_R) X_1}{G_L} \right) \text{----- (Eq.8.5)}$$

Where X_1 = mixed liquor suspended solids
Concentration (ML^{-3})

G_L = limiting solids loading ($\text{ML}^{-2} \text{ t}^{-1}$)

Use a limiting solids loading of 70 kg/m²-day ,a value that has been shown by experience to result in conservative design.

Eq.8.5 helps to determine the surface area for thickening as follows:

$$\begin{aligned} A &= \frac{560 + 420(2000)}{70 \text{ kg} / \text{m}^2 \text{ day} * 10^{-3}} \\ &= \underline{\underline{28 \text{ m}^2}} \end{aligned}$$

For the area required for thickening, Depth usually = 3m

Based on the area calculated the Diameter = 6.0 m

Of the two areas the surface area required for thickening (28 M²) is greater than the surface area for clarification (11.2 M²).

Therefore, the clarifier thickener area to be provided = 28 m²

Sludge should be pumped at flow rate = 40m³/hr assuming 14 working hours per day to pump 560 m³ in a day.

∴ Install pumps whose capacity = 40m³/hr

4. Aeration- Capacity Required

Since nitrification is a process objective, sufficient dissolved oxygen to meet peak ammonia load is calculated as follows:

$$R_{O_2} = a \frac{Q_{max} S_{o max}}{Q_{av} S_{oav}} Q (S_o - S_1) + b \frac{(Q_{max} N_{oma} x)}{Q_{av} N_{oav}} Q (N_o - N_1) - \frac{C Q V (S_o - S_1)}{1 + k_d \theta_s} \text{-----(Eq. 8.6)}$$

Where - R_{O_2} = rate of oxygen utilization (MT^{-1})

S_o, S_1 = Concentration of the carbon substitute in the influent and effluent, respectively (ML^{-3})

N_o, N_1 = Concentration of ammonium in the influent and effluent (ML^{-3})
(73,32)

a, b, c = Oxygen equivalent ratios, 1.47, 4.57, 1.42, respectively

Q_{max}, Q_{avg} = maximum and average discharge rate (560, 373)

$S_{O max}, S_{O avg}$ = maximum and average suspended solids concentration (75, 50)

$N_{O max}, N_{avg}$ = maximum and average concentration of ammonia (90, 60)

The total amount of oxygen is determined by applying Eq. 8.6

$$\begin{aligned} R_{O_2} &= 1.47 (2.25) (560) (1900) + 4.57 (2.25) (560) (41) \\ &\quad - \frac{1.42 (560) (0.5)(1900)}{1 + 0.18 (10)} \\ &= 146 \text{ kg } O_2/\text{hr} \end{aligned}$$

Assuming mechanical surface aerators will be used with an expected aerator performance of 1.25 $kg O_2/KWH$

$$P = \frac{10^3 * R_{O_2}}{NV} \text{----- (Eq. 8.7)}$$

Where - P = Power level, W/m^3

- R_{O_2} = Oxygen utilization rate, $Kg O_2/\text{hr}$.

- N = expected aeration performance, $Kg O_2/KWH$

- V = volume of aeration basin, m^3

Eqn.8.7 determines the power required for aerator performance

$$P = \frac{10^3 * 146}{1.25(1.69)(560)} = 129.5 \text{ w/m}^3$$

Then the air flow rate is calculated by Eqn.9.8 by inserting the power calculated by Eq 8.7.

$$\begin{aligned} \text{Air flow rate} = Q_a &= 9.74 * 10^{-4} P \text{ ----- (Eq.8.8)} \\ &= 9.74 * 10^{-4} * 129.5 \\ &= 0.126 \text{ m}^3 \cdot \text{air/m}^3 \cdot \text{min} \\ &= \underline{\underline{7.56 \text{ m}^3 \text{ air} \\ \text{m}^3 \cdot \text{hr}}} \end{aligned}$$

The power level required to maintain the mixed liquor suspended solids in suspension (X_1)

can be estimated with formula: $P = 0.004 X_1 + 5$ ----- (Eq. 8.9)

$$\begin{aligned} P &= 0.004 * 2000 + 5 \\ &= 13 \text{ w/m}^3 \end{aligned}$$

Since the power consumption for providing the solution the required oxygen level is greater than making the mixed liquor suspended solids in suspension, Oxygen requirements control .

There fore, aerator capacity = $129 (1.69) (560 * 10^{-3})$

$$= \underline{\underline{122.08 \text{ KW}}}$$

5. Recycle capacity to be installed

Assuming recycle capacity equal to 0.75 times the wastewater flow rate (Q), the rate of return of recycled liquor (Q_R),

$$\begin{aligned} Q_R &= 560 \text{ m}^3/\text{d} * 0.75 \\ &= 420 \underline{\underline{\text{m}^3/\text{d}}} \end{aligned}$$

6. Solids quantities to be produced

So as to determine the size of the sludge-conditioning tank 1000 ml of the flocculated liquor was taken and tested for complete sedimentation time. This test will help to determine the quantity of sludge settled in 1000 ml within 2 hr retention time in the sedimentation (clarifier) tank. The laboratory test result is given in table - 8.7 below.

Table 8.7: sludge quantity tests

Retention time Minute	Amount of sludge		
	Test 1	Test 2	Average
30 ¹	39 ml	32 ml	35.5 ml
60 ¹	32 ml	27 ml	29.5 ml
90 ¹	30 ml	25 ml	27.5 ml
120 ¹	28 ml	23 ml	25.5 ml

For the sludge pumped after 2 hr retention time the quantity of sludge produced will be 25.5 ml/1000 ml. Amount of liquor in sedimentation tank is 560m³. Therefore the sludge produced is expected to be 14m³.

By making the sludge conditioning tank size 15 m³ its dimension will be height 3m (3.2m total depth) and diameter of tank 2.5m.

Finally the supernatant liquor will be discharged to the river and some sludge returned back mixing with the influent to aeration tank. Filter pressing then dewater the excess sludge.

9 Result Discussion and conclusion

9.1 Result Discussion

Under this thesis the environmental impact of the Elico - Gloving and Hide Unit is conducted by using life cycle Assessment method. As the Life Cycle Assessment (LCA) method deals with the complex interactions of a product or service, it attempts to predict the overall environmental burdens associated with the product or the related activities (5).

LCA would determine the energy and raw material utilization and solid, liquid and gaseous emissions generated at each stage of life cycle .Generally as stated before the second-generation impacts of the system are ignored (25).In order to conduct LCA successfully one has to pass through the 4 main phases. These phases are goal definition and scope assessment, inventory phase, impact assessment phase and interpretation or improvement phase. As the Company is export oriented it is mandatory to give priority for improving the environmental activities. To do so the goal and scope of LCA defined and the major production related activities are considered. These are raw sheep skin supply, input chemical consumption, water & steam consumption, pollutant emission due to utilization of processing chemical, and chemical transporting from port to company gate. The required data in relation to the fore mentioned activities were collected. The next step after collecting data is conducting impact assessment .In LCA the production system is examined from an environmental perspective using category indicators such as global warming, acidification and eutrophication etc. The usual practice of conducting impact assessment by LCA involves the following components. These are

- Selection of impact categories, category indicators and characterization models.
- Assignment of LCI results -the environmental loads are classified according to the impact categories.
- Calculation of the category indicator results(characterization)
- Normalization -expressing category indicators relative to a standard eg.tones of CO₂ equivalent.
- Grouping, sorting and possibly ranking of the impact categories.
- Weighting-expressing the subjective importance of an impact category, often the categories are sorted by theme or damage category (6).

Taking into account the above points damage base impact assessment method is devised by combining the impact 2002 + and eco -indicator 95 method.

Eco-indicator 95, developed by pre -consultants, uses full LCA modules for energy and raw material production and calculates one value per material, which is the weighted sum of ecological impact classes (9,10).

The IMPACT 2002+ life cycle impact assessment methodology proposes a feasible implementation of a combined mid point /damage approach ,linking all types of life cycle inventory results via 14 mid point categories to four damage categories. These four damage categories are human health, eco-system quality, climate change and resources (12).

The tannery industry is one of the polluting industries in Ethiopia. The main pollutants emitted during leather processing are Ammonia (NH_3),Total Kjeldahal Nitrogen(TKN),Trivalent Chrome (Cr^{+3}),Chloride(Cl^-),Bio-Chemical Oxygen Demand(BOD_5),Chemical Oxygen Demand(COD),Oil and grease ,Sulphide(S^{-2}) and sulphate(SO_4^{-2}). These pollutants one way or the other way may be responsible for the major impact categories mentioned in the adapted method of assessment.

The damage categories incorporated in this paper are human heath, eco-system quality and climate change. The improvement assessment shows that the company has higher impact on human health, then on eco-system quality and climate change. The main environmental impacts that favors for eco-system quality impact are eco-toxicity, Acidification and eutrophication. Of these the dominants are eutrophication and acidification. For the case of human health impact, POCP impact takes the lead and then the human toxicity impact. The last but not the least damage category is climate change, which is expressed by the green house effect only.

In general the environmental impacts of the company are POCP, green house effect, Eutrophication Acidification, human toxicity & Eco-toxicity.

In this thesis the skin department activity is only considered. Because most of the skin products are for export purpose and have international acceptance. Of these dress glove leather and silver white leather are selected as they are the dominant products. Because these

two products have the highest market share. Environmental impact of these products is conducted by collecting appropriate data as stated previously. The assessment shows that Dress glove has higher environmental impact than silver white leather. The main contributor for dress glove's and silver white's environmental impact is eutrophication.

The remedial measures recommended under this thesis are mostly substitution of chemicals, simple technological change, process modification, and input chemical reduction. The summary of the recommendations is presented as follows:

- Transporting of raw sheep skins and chemicals are the main contributors for POCP and green house effect. These effects can be minimized by improving the awareness of the company stakeholders of avoiding of use of old vehicles.
- For highest value of eutrophication and acidification, consumption of processing chemicals plays a dominant role. The remedial measures recommended for reducing their impact are green fleshing, reducing sulphide consumption during liming, practicing salt free/reduced pickling, reducing the existing pickle float and finally reducing the consumption of degreasing agent during degreasing operation.
- The main contributor for human toxicity is also chemicals consumption at depickling and tanning operation. The toxicity is mainly due to Cr^{+3} discharge to the environment. In order to minimize the Cr^{+3} release what suggested as a solution is increasing the efficiency of chrome tanning agent fixation. This is by process modification and by using tanning agents having higher exhaustion rate.
- The soaking -liming operation is responsible for higher value of eco-toxicity. This might result due to consumption of naphthalene for preservation purpose. Avoiding usage of naphthalene for raw skin preservation can minimize the eco-toxicity impact of the company.

- As stated above dress glove leather has higher environmental impact than silver white leather. The improvement option suggested is reducing the chemical and water consumption at dyeing process stage by 50 %.
- The other improvement options are using of fatliquors that have high exhaustion rate and improving of the dyeing process stage and the dyestuff types.

The main contributor for highest environmental impact of silver white leather is steam consumption and use of bleaching agents. These will increase the POCP and green house effect of the silver white leather production. Improving the efficiency of the existing boiler and reducing the steam consumption and replacing or reducing the existing bleaching agents are proposed as improvement options.

- Based on the removal efficiency of the company treatment unit, upgrading it to secondary unit is recommended as a solution.

9.2 Conclusion

Based on the LCA method environmental improvement options from chemical substitution to technological change are devised for ELICO-Gloving and Hide Unit. Most of the suggested improvements are low cost type and focuses on chemical substitution/process modification/chemical consumption reduction.

In this thesis about 13 major improvement options are devised. Of these options, 2 options are devised for improving the POCP and green house effect of the company, 9 for acidification and eutrophication, and for human toxicity and eco toxicity each one. The majority of the improvement options are less costly except upgrading the existing treatment unit to secondary unit. 3 options focuses on chemical consumption reduction, 4 on chemical substitution, 4 on process modification and finally one on awareness raising.

By implementing these options the company will reduce /minimize its environmental impact to the society and may get a saving on its chemical and water consumption.

Practicing on LCA method helps to tackle the environmental problems and to efficiently manage its Environmental Management System (EMS). For the successful implementation of the LCA the company shall internalize this system into its existing management systems. The stakeholders need to have general awareness programme so as to insert Life Cycle thinking in the company. Life cycle thinking implies that every one in the whole chain of a product's life cycle ,from cradle to grave has a responsibility and a role to play ,taking into account all relevant external effects(8). In relation to this the company can prepare Environmental Management Programmes (EMP) and set the environmental performance indicators that can easily be tracked. By so doing improvement is expected on handling the environmental problems of the company.

Since the implementation of the LCA is at the infant stage in Ethiopia and even in the company, this thesis will serve as a tool for guiding what has to be done on LCA and on the major environmental problems of the tannery industry.

During implementation of LCA there are constraints that makes the results efficieint or inefficient. As more time given and sufficient finance allocated for data collection and

analysis, its efficiency will become higher. That is collection of Life Cycle Inventory(LCI) data can be costly and time taking and problem may happen if one or both of them affected(8).The other factor responsible for LCA efficiency is the method of impact assessment .It is advisable to use a method that suitably fit for the production activity to be dealt. If other tanneries start to use LCA they have to consider the constraints that practically faced.

By the discussion made with plant manager, the company is now not in position to implement the suggested improvement options. This is due to the existence of 14 EMP being generated by the company EMS team members. However, agreed to start to implement the possible ones after the execution of 50% of the existing EMP.

10 Reference

- 1) Eslier Science limited, Prof. Don Huisingh, Journal of cleaner production-Volume Number 5, UK(1999)
- 2) International Organization for standards (ISO), ISO-14040 Standard, Austria(2000)
- 3) European environmental agency, Allan astrup Jensen, Life cycle assessment A guide to approaches, experiences and information sources, Denmark (August 1997)
- 4) Leiden university, Jeroen B.Guinee, Life cycle assessment, An operational guide to to the ISO-Standard ,The Netherlands (May 2001)
- 5) UNEP ,Helias A. & Martijin Van Rooijen, Life cycle approaches, The road from analysis to practice /Life cycle Initiative, France(2005)
- 6) UNEP, Evaluation of Environmental impacts in life cycle assessment, France(2003)
- 7) Simapro 6-Introduction to LCA with simapro, The Netherlands (September 2004)
- 8) PR'e Consultant, Mark Goedkoop, Eco-indicator 99- Manual for designers, The Netherlands (June 2001)
- 9) N.F.Nissen, Comparison of simplified environmental assessment versus full life cycle assessment (LCA) for the electronics designer ,Germany
- 10) PR'e Consultant, Mark Goedkoop, Eco-indicator 95- Manual for designers, The Netherlands (1996)
- 11) LCA Methods and links-website address ,(2004)

- 12) Swiss Federal Institute of Technology, Oliver Jolliet & Manuele Margni, Impact 2002+ -A new life cycle impact assessment methodology, Switzerland (2003)
- 13) Fridge, Life Cycle Assessment of paper and plastic check out carriers bags
- 14) European Commission, Integrated pollution prevention and control (IPPC) Reference Document on Best Available Technique (BAT) - for the tanning of hide and skins, Spain (May 2001)
- 15) J.H. Sharp house, Hand book of leather technology, UK (1983)
- 16) UNIDO, M. Bosnic & J. Buljan, Pollutants in tannery effluents, (9 August 2000)
- 17) EPA, JRB Associates, Leather and leather products, U.S (February 1982)
- 18) UNIDO, Giuseppe Clonfero, UNIDO Training material -Manual on tannery effluent treatment, Zimbabwe (October 1999)
- 19) University of Santiago, B. Rivela, Journal of chemical engineering department -Life cycle assessment as a tool for improving tannery industry, Spain (2004)
- 20) Maxime Chasnais, Emission Scenario document, (May 2000)
- 21) UNEP, ,Life cycle assessment, What it is and How to do it ,(2000)
- 22) Association of the Dutch Chemical Industry (VNCI, Guide line -Environmental Performance indicators for the chemicals industry- The EPI method, The Netherlands (2001)
- 23) Susan Hankinson, Comparative life cycle assessment Pork versus Tofu , Stockholm (May 2005)
- 24) Clemson university, Linvil G. Rich, Low maintenance mechanically simple WASTE WATER TREATMENT SYSTEM, USA (1980)

- 25) Curtin university of technology, venky Narayanaswamy, Environmental life cycle assessment case studies for Western Austrial Grain products ,Australia(May 2004)
- 26) APHA, AWWA, WEF, 19th edition- Standard method for the examination of water and Waste water, US (1995)

Annexes

Annex -1 Characterization values(2)

Impact category- Global warning, unit kg CO₂				
Emissions to	Substance	Factor	Unit	Data Source
air	CO ₂	1	Kg/CO ₂ /kg	Eco-indicator 95
air	CH ₄	1	"	"
air	N ₂ O	320	"	EDIP/UMIP 97
air	HC	3	"	"
Impact category- Acidification, Unit kg SO₂				
air	Ammonia	1.88	Kg SO ₂ /kg	Eco-indicator 95
"	NO ₂	0.7	"	"
"	NO _x	0.7	"	"
"	SO ₂	1	"	"
"	SO _x	1	"	"
Impact category- eutrophication, Unit kg PO₄				
Soil	Ammonia	0.33	Kg PO ₄ /kg	Eco-indicator 95
Water	"	0.33	"	"
Air	"	0.33	"	"
Water	COD	0.022	"	"
Water	Kjeldhal N	0.42	"	"
Air	Nitrate	0.1	"	"
Soil	Nitrate	0.1	"	"
Water	Nitrate	0.1	"	"
Air	Nitric Oxide	0.2	"	"
Impact category- eutrophication, Unit kg & PO₄				
Water	Nitrite	0.13	Kg PO ₄ /kg	Eco-indicator 95
Air	Nitrite	0.13	"	"
Water	Total N	0.42	"	"
Impact category- eutrophication, Unit kg & PO₄				
Emissions to	Substance	Factor	Unit	Data Source
air	NO ₂	0.13	Kg/PO ₄ /kg	Eco-indicator 95
air	NO _x	0.13	"	"
Soil	NO _x	0.13	"	"
Water	NO _x	0.13	"	"
Soil	Nitrogen, total	0.42	"	"
Water	"	0.42	"	"
Air	"	0.42	"	"
Soil	Phosphate	1	"	"
Air	Phosphate	1	"	"
Water	Phosphate	1	"	"
Water	Phosphorus	3.06	"	"
Impact category- eutrophication, Unit kg & PO₄				
Soil	Phosphorus	3.06	"	"
Air	Phosphorus	3.06	"	"
Impact category Human Toxicity				
air/water	NH ₄	0.02	Kg/kg	"
air/water	CO	0.012	"	"
air/water	Cr+ ₆	4.7*10 ⁴	"	"
water	H ₂ S	0.78	"	"
air/water	NO ₃	0.0099	"	"

Impact category- Global warning, unit kg CO₂				
air/water	NO ₂	0.26	"	"
air/water	NO _x	0.78	"	"
air/water	Phosphate	0.00052	"	"
air/water	SO ₂	1.2	"	"
water	Cr ³⁺	2.05	"	"
water	naphthalene	2	"	"
Impact category-winter smog Unit kg SPM				
Emissions to	Substance	Factor	Unit	Data Source
air	Particulates	1	Kg SPM/kg	Eco-indicator 95
	SO ₂	1	"	"
	SO _x	1	"	"
Impact category- summer smog (POCP) unit kg C₂H₄				
air	HC	0.398	Kg C ₂ H ₄ /kg	Eco-indicator 95
air	CH ₄	0.007	"	"
air	naphthalene	0.761	"	"
Impact category- Eco toxicity aquatic				
water	H ₂ S	6.7*10 ⁻³	M ³ /kg	EDIP/UMIP 97
water	Cr ⁺³	6.914	M ³ /kg	"
water	naphthalene	80	M ³ /kg	"

Annex-2 -Vehicles trips

Vehicle type	Carrying capacity (A)	Chemical transported (B)	Number of trips A/B	Total trip 2*A/B
Isuzu	13150	1198309.6	91	182

- Since the distance from A.A to Djibouti 920 km, the total distance the vehicles traveled a total of 167,440 km. This value is calculated by multiplying the total trip by the distance from A.A. to Djibouti, 920km.
- In order to determine the environmental impact the above 167,440 km shall be Distributed to each process stage according to their % share. Then the distance allocate (km) will be obtained by multiplying the total distance (km) by the % share.

Annex-3- Input-Output Analysis

1,820,000 PCS Raw sheepskin has a total area of 8,483,267 ft². That means
 One piece sheepskin has an area of 4.661 ft².

Product Type	Input	Process stage	Output	Product type
Raw skin	8,483,267	Soaking-Pickling	8,483,267	Pickled skin
Pickled skin	8,483,267	Pickle selection	5,379,932	For wet blue production
			516,329	For silver white
			2,587,006	For lining
Pickled skin	5,379,932	Tanning	5,379,932	Wet blue skin
Wet blue	5,379,932	Retanning	5,379,932	Dress glove crust
	516,329	"	516,329	Silver white glove crust
Dress glove crust	5,379,932	Crust selection	4,066,960	For dyed crust
			1,312,972	For garment(ASA)
Crust for dress glove	4,066,960	Dyeing	4,066,960	Dyed dress glove leather

Annex-4- Quantity of raw material required to produce 1 ft² glove leather

-Glove leather produced by using pickled skin as starting material If that so to produce 4,583,289 ft² glove leather 8,483,267 ft² pickled skin required. Then to produce 1 ft² glove leather 1.85 ft² pickled skin is required. This value is calculated as follows

$$\frac{\text{Pickled skin area}}{\text{Glove leather produced}} = \frac{8,483,267 \text{ ft}^2}{4,066,960 + 516,329} = \frac{8,483,267}{4,583,289} = 1.85$$

-If the starting material is wet blue to produce 4,583,289-ft² glove leather about 5,896,261 ft² wet blue is required.

The wet blue area required to produce 1 ft² glove leather is calculated as follows

$$\frac{\text{wet blue area}}{\text{glove leather area}} = \frac{5,896,261}{4,583,289} = 1.286$$

This mean that to produce 1 ft² glove leather, about 1.286 ft² wet blue skin is required.

-By using dress glove crust leather as starting material, dyed glove leather can be produced.

The crust area required to produce 1 ft² of dyed glove leather is calculated as follows:

$$\frac{\text{Dress glove crust}}{\text{Dyed dress glove leather}} = \frac{5,379,932 \text{ ft}^2}{4,066,960 \text{ ft}^2} = 1.323$$

The above value 1.323 is applicable only for the production of dyed glove leather from natural crust leather.

Annex-5- Adjusted pollutant emission from soaking-liming process

Pollutant	Unit	Laboratory test result (A)	% Removal efficiency (B)	Adjusted test result A(1-B)
COD	mg/ft ²	113,169.5	65.28	39292.5
NH3	mg/ft ²	1,198.8	29.49	845.3
Nitrites as NO ₂	mg/ft ²	1.304	41.82	0.76
Nitrate as NO ₃	mg/ft ²	65.2	87.86	7.9
Hydrogen Sulphide, H ₂ S	mg/ft ²	8,766.2	97.89	189-.3
Total Nitrogen	mg/ft ²	13,70.9	50	685.5
Phosphate, PO ₄	mg/ft ²	105.5	75.90	25.4
Cr ³⁺	mg/ft ²	-	18.33	-

Annex- 6- Adjusted pollutant emission from Deliming-Pickling process

Pollutant	Unit	Laboratory test result (A)	% Removal efficiency (B)	Adjusted test result A(1-B)
COD	mg/ft ²	39,632.8	65.28	13760.5
NH3	mg/ft ²	1,664.5	29.49	1173.6
Nitrites as NO ₂	mg/ft ²	1.06	41.82	0.62
Nitrate as NO ₃	mg/ft ²	42.4	87.86	5.14
Hydrogen Sulphide, H ₂ S	mg/ft ²	495.4	97.84	10.70
Total Nitrogen	mg/ft ²	3481.8	50	1740.9
Phosphate, PO ₄	mg/ft ²	1.89	75.90	0.46
Cr ³⁺	mg/ft ²	-	18.33	-

Annex- 7- Adjusted pollutant emission from Depickling-Tanning process

Pollutant	Unit	Laboratory test result (A)	% Removal efficiency (B)	Adjusted test result A(1-B)
COD	mg/ft ²	13,270.9	65.28	4607.7
NH3	mg/ft ²	186.8	29.49	131.7
Nitrites as NO ₂	mg/ft ²	0.189	41.82	0.11
Nitrate as NO ₃	mg/ft ²	10.43	87.86	1.27
Hydrogen Sulphide, H ₂ S	mg/ft ²	-	97.84	-
Total Nitrogen	mg/ft ²	203.9	50	101.9
Phosphate, PO ₄	mg/ft ²	7.33	75.90	1.77
Cr ³⁺	mg/ft ²	3,623.7	18.33	2959.5

Annex- 8- Adjusted pollutant emission from Retanning (dress glove) process

Pollutant	Unit	Laboratory test result (A)	% Removal efficiency (B)	Adjusted test result A(1-B)
COD	mg/ft ²	642.9	65.28	223.2
NH3	mg/ft ²	7.59	29.49	5.5
Nitrites as NO ₂	mg/ft ²	0.018	41.82	0.01
Nitrate as NO ₃	mg/ft ²	2.62	87.86	0.318
Hydrogen Sulphide, H ₂ S	mg/ft ²	-	97.84	-
Total Nitrogen	mg/ft ²	8.05	50	4.03
Phosphate, PO ₄	mg/ft ²	0.069	75.90	0.017
Cr ³⁺	mg/ft ²	0.28	18.33	0.23

Annex- 9- Adjusted pollutant emission from retanning (silver white) process

Pollutant	Unit	Laboratory test result (A)	% removal efficiency (B)	Adjusted test result A(1-B)
COD	mg/ft ²	594.4	65.28	206.4
NH3	mg/ft ²	24.8	29.49	17.5
Nitrites as NO ₂	mg/ft ²	0.24	41.82	0.14
Nitrate as NO ₃	mg/ft ²	7.08	87.86	0.86
Hydrogen Sulphide, H ₂ S	mg/ft ²	0.077	97.84	1.66*10 ⁻³
Total Nitrogen	mg/ft ²	25.16	50	12.58
Phosphate as PO ₄	mg/ft ²	29.94	75.90	7.22
Cr ³⁺	mg/ft ²	0.172	18.33	0.14

Annex- 10- Adjusted pollutant emission from Dyeing (Dress glove) process

Pollutant	Unit	Laboratory test result (A)	% removal efficiency (B)	Adjusted test result A(1-B)
COD	mg/ft ²	1427.5	65.28	495.6
NH3	mg/ft ²	58.1	29.49	40.97
Nitrites as NO ₂	mg/ft ²	0.067	41.82	0.039
Nitrate as NO ₃	mg/ft ²	4.11	87.86	0.49
Hydrogen Sulphide, H ₂ S	mg/ft ²	0.11	97.84	2.38*10 ⁻³
Total Nitrogen	mg/ft ²	62.46	50	31.23
Phosphate as PO ₄	mg/ft ²	8.77	75.90	2.11
Cr ³⁺	mg/ft ²	0.09	18.33	0.07

Annex- 11 adjusted emissions to water in mg/ft²

Process stage	Unit	POLLUTANTS							
		COD	NH ₃	Nitrite as NO ₂	Nitrates as NO ₃	Hydrogen Sulphide, H ₂ S	Total Nitrogen	Phosphors as PO ₄	Cr ³⁺
Soaking- Liming	mg/ft ²	39292.5	845.3	0.76	7.9	189.3	685.5	25.4	-
Deliming- Pickling	mg/ft ²	13760.5	1173.6	0.62	5.14	10.70	1740.9	0.46	-
Depickling- Tanning	mg/ft ²	4607.7	131.7	0.11	1.27	-	101.9	1.77	2959.5
Retanning- (Dress)	mg/ft ²	223.2	5.5	0.01	0.318	-	4.03	0.017	0.23
Retanning- (Silver White)	mg/ft ²	206.4	17.5	0.14	0.86	1.66*10 ⁻³	12.58	7.22	0.14
Dyeing (Dress)	mg/ft ²	495.6	40.97	0.039	0.49	2.38*10 ⁻³	31.23	2.11	0.07

Annex- 12: Environmental impacts due to emissions of pollutant during soaking- liming process stage

Pollutant	Unit	Emissions	Green House effect		Acidification		Eutrophication		Winter smog		Human Toxicity		POCP		Eco Toxicity	
			Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg
COD	mg	39292.5					0.022	864								
NO ₃	mg	845.3			1.88	1589	0.33	279								
Nitrites as NO ₂	mg	0.76			0.7	0.53	0.13	0.09			0.26	0.19				
Nitrates NO ₃	mg	7.9			0.7	5.5	0.1	0.79			0.0099	0.08				
Hydrogen sulphide, H ₂ S	mg	189.3									0.78	147.7			9.45*10 ⁻³	1.79
Total Nitrogen	mg	685.5					0.42	287.9								
Phosphorus as PO ₄	mg	25.4					1	25.4			0.00052	0.013				
Cr ³⁺	mg	-									2.05	-			6.914	-
Total			-		1595		1457.2		-		147.9		-		1.79	

NB: ρ_{H₂S} = 1.5 kg/m³

Annex 13: Environmental impacts due to emissions of pollutant during Deliming- Pickling

Pollutant	Unit	Emissions	Green House effect		Acidification		Eutrophication		Winter smog		Human Toxicity		POCP		Eco Toxicity	
			Kg/k g	mg	Kg/k g	mg	Kg/k g	mg	Kg /kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg
COD	mg	13760.5					0.022	302.7								
NO ₃	mg	1173.6			1.88	2206.4	0.33	387.3								
Nitrites as NO ₂	mg	0.62			0.7	0.43	0.13	0.081			0.26	0.16				
Nitrates NO ₃	mg	5.14			0.7	3.6	0.1	0.51			0.0091	0.051				
Hydrogen sulphide, H ₂ S	mg	10.70									0.75	8.35			9.45*10 ⁻³	0.10
Total Nitrogen	mg	1740.9					0.42	731.2								
Phosphorus as PO ₄	mg	0.46					1	0.42			0.00052	2.39*10 ⁻⁴				
Cr ³⁺	mg	-									2.05	-			6.914	-
Total			-		2210.4		1422.2		-		8.56		-		0.10	

Annex - 14 Environmental impacts due to emissions of pollutant during Depickling-Tanning process stage

Pollutant	Unit	Emissions	Green House effect		Acidification		Eutrophication		Winter smog		Human Toxicity		POCP		Eco Toxicity	
			Kg/k g	mg	Kg/k g	mg	Kg/k g	mg	Kg /kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg
COD	mg	4607.7					0.022	101.4								
NO ₃	mg	131.7			1.88	247.6	0.33	43.5								
Nitrites as NO ₂	mg	0.11			0.7	0.08	0.13	0.014			0.26	0.03				
Nitrates NO ₃	mg	1.27			0.7	0.89	0.1	0.13			0.0099	0.013				
Hydrogen sulphide, H ₂ S	mg	-									0.78	-			9.45*10 ⁻³	-
Total Nitrogen	mg	101.9					0.42	42.8								
Phosphorus as PO ₄	mg	1.77					1	1.77			0.00052	9.2*10 ⁻⁴				
Cr ³⁺	mg	2959.5									2.05	6066.9			6.914	20450
Total			-		248.6		189.6		-		6066.9		-		20450	

Annex 15 Environmental impacts due to emissions of pollutant during Retanning (Dress glove)

Pollutant	Unit	Emissions	Green House effect		Acidification		Eutrophication		Winter smog		Human Toxicity		POCP		Eco Toxicity	
			Kg/k g	mg	Kg/k g	mg	Kg/k g	mg	Kg /kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg
COD	mg	223.2					0.022	4.91								
NO ₃	mg	5.5			1.88	10.3	0.33	1.82								
Nitrites as NO ₂	mg	0.01			0.7	7*10 ⁻³	0.13	1.3*10 ⁻³			0.26	2.6*10 ⁻³				
Nitrates NO ₃	mg	0.318			0.7	0.22	0.1	0.032			0.0099	3.15*10 ⁻³				
Hydrogen sulphide, H ₂ S	mg	-									0.78				9.45*10 ⁻³	-
Total Nitrogen	mg	4.03					0.42	1.69								
Phosphorus as PO ₄	mg	0.017					1	0.017			0.00052	8.84*10 ⁻⁶				
Cr ³⁺	mg	0.23									2.05	0.47			6.91	1.59
Total			-		10.53		8.47		-		0.48		-		1.59	

Annex 16 Environmental impacts due to emissions of pollutant during Retanning (Silver White)

Pollutant	Unit	Emissions	Green House effect		Acidification		Eutrophication		Winter smog		Human Toxicity		POCP		Eco Toxicity	
			Kg/k g	mg	Kg/k g	mg	Kg/k g	mg	Kg /kg	mg	Kg/kg	mg	Kg/kg	mg	Kg/kg	mg
COD	mg	206.4					0.022	4.54								
NO ₃	mg	17.5			1.88	32.9	0.33	5.8								
Nitrites as NO ₂	mg	0.14			0.7	0.098	0.13	0.018			0.26	0.04				
Nitrates NO ₃	mg	0.86			0.7	0.60	0.1	0.086			0.0099	8.5*10 ⁻³				
Hydrogen sulphide, H ₂ S	mg	1.66*10 ⁻³									0.78	1.29*10 ⁻³			9.45*10 ⁻³	1.57*10 ⁻⁵
Total Nitrogen	mg	12.58					0.42	5.28								
Phosphorus as PO ₄	mg	7.22					1	7.22			0.00052	3.75*10 ⁻³				
Cr ³⁺	mg	0.14									2.05	0.29			6.91	0.97
Total			-		33.6		22.94		-		0.34		-		0.97	

Annex 17 Environmental impacts due to emissions of pollutant during dyeing

Pollutant	Unit	Emissions	Green House effect		Acidification		Eutrophication		Winter smog		Human Toxicity		POCP		Eco Toxicity	
			Kg/kg g	m g	Kg/kg	mg	Kg/kg g	mg			Kg/kg	mg	Kg/kg	mg	Kg/kg	mg
COD	mg	495.6					0.022	10.9								
NO ₃	mg	40.97			1.88	77.0	0.33	13.52								
Nitrites as NO ₂	mg	0.039			0.7	0.03	0.13	5.07*10 ⁻³			0.26	0.01				
Nitrates NO ₃	mg	0.49			0.7	0.343	0.1	0.049			0.0099	4.85*10 ⁻³				
Hydrogen sulphide, H ₂ S	mg	2.38*10 ⁻³									0.79	1.86*10 ⁻³			9.43*10 ⁻³	2.25*10 ⁻⁵
Total Nitrogen	mg	31.23					0.42	13.12								
Phosphorus as PO ₄	mg	2.11					1	2.11			0.0052	0.011				
Cr ³⁺	mg	0.07									2.05	0.14			6.91	0.48
Total			-		77.37		39.70		-		0.168		-		0.48	

Annex-18- Properties of saturated steam

Temperature °C	Vapor Pressure (Kpa)	Specific volume (m ³ /kg)		Enthalpy (KJ/Kg)		Entropy (KJ/Kg.K)	
		Liquid	Saturated vapor	Liquid (H _l)	Saturated vapor (H _v)	Liquid	Saturated vapor
3	0.7577	0.0010001	168.132	12.57	2506.9	0.0457	9.1562
6	0.9349	0.0010001	137.734	25.20	2512.4	0.0912	9.0773
9	1.1477	0.0010003	113.386	37.80	2517.9	0.1362	9.0003
12	1.4022	0.0010005	93.784	50.41	2523.4	0.1806	8.9253
15	1.7051	0.0010009	77.926	62.99	2528.9	0.2245	8.8524
18	2.0640	0.0010014	65.038	75.58	2534.4	0.2679	8.7814
21	2.487	0.0010026	54.514	88.14	2539.9	0.3109	8.7123
24	2.985	0.0010027	45.883	100.70	2545.4	0.3534	8.6450
27	3.567	0.0010035	38.774	113.25	2550.8	0.3954	8.5794
30	4.246	0.0010043	32.891	125.79	2556.3	0.4369	8.5156
33	5.034	0.0010053	28.011	138.33	2561.7	0.4781	8.4533
36	5.947	0.0010063	23.940	150.86	2567.1	0.5188	8.3927
40	7.384	0.0010078	19.523	163.57	2574.3	0.5725	8.3336
45	9.593	0.0010099	15.258	188.45	2583.2	0.6378	8.2570
50	12.349	0.0010121	12.032	209.33	2592.1	0.7038	8.1648
55	15.758	0.0010146	9.568	230.43	2600.9	0.7679	8.0763
60	19.490	0.0010172	7.671	251.13	2609.6	0.8312	7.9913
65	25.03	0.0010199	6.197	272.06	2618.3	0.8935	7.9096
70	31.19	0.0010228	5.042	292.98	2626.8	0.9549	7.8310
75	38.58	0.0010259	4.131	313.93	2635.3	1.0155	7.7553
80	47.39	0.0010291	3.407	334.91	2613.7	1.0753	7.6824
85	57.38	0.0010325	2.828	355.90	2651.9	1.1343	7.6122
90	70.14	0.0010360	2.361	376.92	2660.1	1.1925	7.5445
95	84.55	0.0010397	1.9819	397.96	2668.1	1.2500	7.4791
100	101.35	0.0010435	1.6729	419.04	2676.1	1.3069	7.4159
105	120.82	0.0010475	1.4194	440.15	2688.8	1.3630	7.3549
110	143.27	0.0010516	1.2102	461.30	2691.5	1.4185	7.2958
115	169.06	0.0010559	1.0366	482.48	2699.0	1.4734	7.2387
120	198.53	0.0010603	0.8919	503.71	2706.3	1.5276	7.1833

Annex-19 AAWSA Laboratory analysis methods

S.No.	Parameter	Methods of Analysis	Remark
1	Ammonia as NH ₃	Ammonia Nessler	Dr.4000 Spectro photometer for measurement
2	Nitrite as NO ₂	Diazotization	"
3	Nitrate as NO ₃	Chromo tropic acid	"
4	Total Kjeldahal Nitrogen	Kjeldahal apparatus	"
5	Hydrogen Sulphide as H ₂ S	Methylene Blue	"
6	Chromium as Cr ⁺³	1,5 Diphenyl Carbohydrazied	"
7	Chromium Total	Alkaline Hypobromite Oxidation	"
8	BOD ₅	Azid Modification of winkler (Burette titration)	Titration to quantify
9	COD	Dichromate reactor digestion	"
10	Phosphate	Ascorbic acid method	Dr.4000 Spectro photometer for measurement

N.B The above mentioned test methods extracted from APHA, AWWA, WEF, 19th edition- Standard method for the examination of water and Waste water, US (1995) (26).

