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DEVELOPING ANALYTICAL FRAMEWORK THAT ACCOUNTS THE
ENVIRONMENT, SOCIAL AND ECONOMIC ASPECTS OF A PRODUCTION
SYSTEM (THE CASE OF ETHIOPIAN LEATHER INDUSTRIES)

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Abstract

Using a life cycle Assessment, impacts of a product can be described in technical terms by assessing and quantifying inputs and outputs during the various stages of a product's life cycle. Techniques such as Environmental cost Accounting (ECA) and Social Auditing (SA) create opportunities to describe impacts of products in social and economic terms. By combining these tools we can finally derive at a comprehensive approach to decision making. This report tries to prescribe an analytical frame work that combines tools and techniques such as LCA, ECA and SA to yield a robust and comprehensive approach in the analysis of environmental impacts. In addition case study leather industries in Ethiopian context are discussed to illustrate how such an approach can be applied and its potential improvement for sustainability by reducing environmental stress and creating economic benefit in a social balanced way.

ACRONYM

LCA	Life Cycle Assessment
ECA	Environmental Cost Accounting
SA	Social Auditing
LCIA	Life Cycle Impact Assessment
LCI	Life Cycle Inventory
ODP	Ozone Depletion Potential
LLPTI	Leather and Leather Products Technology Institute
CML	Centre for Environmental Studies
EDIP	Environmental Design of Industrial Products
SS	Suspended Solid
BOD	Biological oxygen demand
DOC	Dissolved Organic Carbon compound
VOC	Volatile Organic Carbon compound
NMVOC	Non methane Volatile Organic Carbon compound

Contents	Page
 CHAPTER ONE	
INTRODUCTION	
1.1 BACKGROUND	1
1.2 STATEMENT OF THE PROBLEM.....	2
1.3 PURPOSE OF THE STUDY	2
1.4 THEORETICAL BASIS.....	2
1.5 APPLICATIONS	3
1.6 THESIS STRUCTURE.....	4
 CHAPTER TWO	
LITRATURE REVIEW	
2.1 LIFE CYCLE ASSESSMENT.....	5
2.2.1 THEORETICAL FOUNDATION OF LCA.....	5
2.1.2 USES OF LIFE CYCLE ASSESSMENT.....	6
2.1.3 LIFE CYCLE ASSESSMENT PROCEDURES	8
2.1.3.1 GOAL AND SCOPE DEFINITION.....	8
2.1.3.2. INVENTORY ANALYSIS	9
2.1.3.3. LIFE CYCLE IMPACT ASSESSMENT	10
2.1.3.4 LIFE CYCLE INTERPRETATION	17
2.1.4 LIMITATION OF LIFE CYCLE ASSESSMENT.....	21
2.2 ENVIRONMENTAL COST ACCOUNTING	22
2.2.1 PROCEDURES FOR ASSESSMENT OF ENVIRONMENTAL COST ACCOUNTING	23
2.2.2 LIMITATION OF ENVIRONMENTAL COST ACCOUNTING.....	27
2.2.3 APPLICATIONS OF ENVIRONMENTAL COST ACCOUNTING.....	27
2.3 SOCIAL AUDITING.....	28
2.3.1 METHODOLOGY OF SOCIAL AUDITING	29
2.2.3 SOCIAL ACCOUNTABILITY REQUIREMENTS AND STANDARDS	31
 CHAPTER 3	
INTEGRATING LIFE CYCLE ASSESSMENT WITH ECONOMIC AND SOCIAL MODELS.....	
	41
 CHAPTER 4	
CASE STUDY FOR ETHIOPIAN LEATHER INDUSTRIES	
4.1 INTRODUCTION	34
4.2 LEATHER PROCESSING.....	34
4.3 LIFE CYCLE ASSESSMENTS FOR LEATHER PROCESSING	39
4.3.1 METHODOLOGIES	39
4.3.1.1 GOAL DEFINITION AND SCOPE.....	39

4.3.1.2	LIFE CYCLE INVENTORIES.....	42
4.3.1.3	IMPACT ASSESSMENT.....	42
4.3.2	INVENTORY DATA	42
4.3.3	DATA ANALYSIS AND INTERPRETATION	55
4.3.4	CONCLUSION.....	62
4.4	ENVIRONMENTAL COST ACCOUNTING FOR LEATHER PROCESSING.....	63
4.4.1	ENVIRONMENTAL COST CATEGORIZING.....	63
4.4.2	MATERIAL FLOW BALANCE.....	64
4.4.3	PROCESS FLOW CHARTS	65
4.4.4	CONCLUSION.....	68
4.5	SOCIAL AUDITING FOR LEATHER INDUSTRIES	68
4.5.1	AUDITING THE THREE LEATHER INDUSTRIES.....	68
4.5.2	MEASURING USING SOCIAL ACCOUNTABILITY REQUIREMENTS...	74
4.5.3	CONCLUSION.....	75
4.6	INTEGRATING THE THREE MODELS.....	75
4.6.1	IDENTIFYING AND TAKING A MEASURE TO MINIMIZE THE KEY IMPACTS	75
 CHAPTER 5		
CONCLUSION AND RECOMMENDATION		
5.1.	CONCLUSSION.....	79
5.2	RECOMMENDATIONS FOR FUTURE WORK	80
	REFERENCE.....	81
ANNEX 1	DAMAGE FACTOR AND ASSESSMENT FOR ECO-INDICATOR 99 METHOD	84
ANNEX 2	ISO 14000 STANDARDS ON LCA	87
ANEEX 3	ENERGY CONSUMPTION OF GAREMENT MANUFACTURING FROM SHEEPSKIN.....	88

List of Figures

Figure 2.1: Life cycle inventories accounting for material use, energy, wastes, emissions and by products over all of the stages of a product's life cycle.	10
Figure 2.2 General representation of the EI 99 methodology. The white boxes refer to procedures; the other boxes refer to intermediate results.	16
Figure 2.3: Overall scheme of the IMPACT 2002+ framework, linking LCI results via the midpoint categories to damage categories, based on Jolliet et al. (2003a)	17
Figure 2.4: Frame work of Life Cycle Assessment	19
Figure 2.5: Process flow charts :(SOURCE Environmental management acc. Procedure and principles).....	26
Figure 3.1: Representation of an integrated model.....	32
Figure 4.1: Leather process flow chart	38
Figure 4.2: System Boundary of the leather processing	41
Figure 4.3: Single score weighted value for beam house operation	56
Figure 4.4: Single score weighted value for tanning house operation.....	57
Figure 4.5: Single score weighted value for post tanning house operation	57
Figure 4.6: Single score weighted value for Finishing operation	58
Figure 4.7: Single score weighted value for Waste treatment	59
Figure 4.8: Single score weighted value for leather per impact category.....	59
Figure 4.9: Single score weighted value for leather	60
Figure 4.10: Shows the LCA network of leather product from the Slaughter house to the gate of the finished leather output with a cut off 9 percent.	61
Figure 4.11: Material flow and cost accounting chart	67

List of Tables

Table 2.1:	Characterization factor for different impact categories	14
Table 2.2	Total Corporate Environmental Costs	23
Table 2.3	Overview on Environmental Cost scheme.....	25
Table 4.1	Inventory data for slaughter house (* Source ecoinvent data base)	44
Table 4.2	Inventory data for Skin preservation	51
Table 4.3	Inventory data for beam house operation	51
Table 4.4	Inventory data for Tanning Operation	53
Table 4.5	Inventory data for Post tanning Operation.....	53
Table 4.6	Inventory data for Finishing Operation	54
Table 4.7	Inventory Data for Waste water treatment operation.....	55
Table 4.8	Environmental cost categories for different companies	63
Table 4.9a	Major input in leather processing.....	65
Table 4.9b	Major output in leather processing	65
Table 4.10	Percentage distribution of workers (company A) in [%].....	69
Table 4.11	Percentage distribution of workers (company B) in [%]	72
Table 4.12	Percentage distribution of workers (company C) in [%]	73

CHAPTER ONE INTRODUCTION

1.1 BACKGROUND

Globalization of markets, companies and products is quickly intensifying national co-dependence. This transformation has grave consequences on environmental and social protection policies, most of which have tended to lag behind in the globalization process.

When environmental policy was acknowledge as new policy area in the 1960s, the original trust focused on setting standards and laying down detailed technical requirements for minimizing pollution from industrial processes. Thus, the emphasis was on technical measures to trim down emissions of pollutions of existing processes through an ‘end-of-pipe’ approach was adequate in reducing emissions of pollutants through one environmental medium, it was often accompanied by an increase of these pollutants in other media. While the process oriented “end-of-pipe” measures were relatively successful for large immobile polluters (large point sources). They were less effective in regulating smaller, mobile or diffused (non-point) sources. Furthermore, the administrative burden involved in monitoring and control of an increasing number of technical prescriptions was excessive.

The focus of environmental policy has then moved towards a more integrated or “holistic” view of environmental problems. Thus it recognizes the fact that environmental challenges posed by globalization are the result of a multitude of factors and players that span the life cycle of a product, and along the entire product supply chain. Therefore, it has become critical to understand relationships between different actors in the economy and how these actors interact in the context of supply-demand and input-output relationships.

Using a Life Cycle Assessment (LCA), impacts of a product can be described in technical terms by assessing and quantifying input and outputs during the various stages of a product’s lifecycle. Techniques such as the Environmental Cost Accounting (ECA) and Social Auditing (SA) create opportunities to describe impacts of products in social and economic terms. By combining these tools we can finally derive at a comprehensive

approach that fully accounts for the environment, social and economic implication of a production system.

1.2 STATEMENT OF THE PROBLEM

Private sectors made decisions usually on activities related to alternative product or product design. Decisions making contexts often addressed by life cycle Assessment must also eventually take the economic consequences of alternative product or product design into account. However, neither the internal nor external economic aspects of decisions are within the scope of LCA methodology. This traditional separation of lifecycle environmental assessment from economic and social analysis has limited the influence and relevance of LCA for decision making, and left uncharacterized the important relationships trade-offs between the economic and life cycle environmental performance of alternative product design decision scenarios.

1.3 PURPOSE OF THE STUDY

The purpose of the study generally is developing a frame work that combines techniques of environmental life cycle assessment, environmental cost accounting and social auditing. This helps in simplifying the decision making process and get a strong and comprehensive approach in the analysis of environmental impacts. Through increasing understanding the environmental, economic and social costs of industrial processes, the research will ultimately contribute to more environmentally friendly production processes that are nevertheless also economical and consider social issues.

1.4 THEORETICAL BASIS

Analyses, whether environmental, economic or social, over the life cycle of a product can be described as models for assessing and quantifying inputs and outputs during the various stages of a product's life; from cradle to grave. The specific techniques of environmental life cycle assessment (ELCA) and environmental cost accounting provide us with such models. The techniques of ELCA, environmental cost accounting, and social audits have been fairly well developed but separately of each other. Yet these three aspects of production are closely inter-related. Considering environmental issues outside

of their economic and social implications would render the implementation of environmental policy unfeasible.

A methodology that integrates the three would contribute to more optimal production decision- that relates sustainable production to economic efficiency (and competitiveness) as well as the preservation of basic social norms.

1.5 APPLICATIONS

It is proposed to apply the analytical framework (developed as part of the research methodology) to the consideration of environmental impacts and global comparative advantage of the leather industries in Ethiopia. The analysis will, of course, not be limited to Ethiopia since the application of the 'life cycle approach' will necessarily require the consideration of these industries' trading partners. For example, even though leather is processed in Ethiopia, most chemical inputs are imported from Germany and leather in various forms (both finished products and semi processed) are exported to such countries as Italy. Thus the life cycle approach would include an analysis of environmental implications of chemical production in Germany, further processing of semi-processed leather in Italy, and disposal in countries that import the final product. Thus, the research will be undertaken in conjunction with efforts to balance environmental, economic and social concerns in the country. As such, it will provide input to this important effort.

The research objectives at the practical level are as follows:

- (i) to highlight the areas in the production processes for leather with a high environmental, economical and social burden through out the production life cycle so that the impacts can be monitored and improvement measures can be taken,
- (ii) To assist certification by internationally accredited institutes for holistic environmental and international labor standards and ethical considerations thus gain access to the more sophisticated markets of Europe and US.

- (iii) To inform policy makers that a policy that takes into account an integrated environmental, economical and social parameters is the driving force behind all company to be competitive in the field of national, regional and international market. It should be integrated in to the company's overall business strategies and should be compatible with the organizational policy such as quality or occupational health and safety. It must therefore be initiated, developed and actively supported at the highest level by the policy makers.

- (iv) To prepare a self -study manual on the basis of an analytical framework developed as part of the research. This will be an important environmental, economical and social analysis, evaluation and improvement-measuring instrument. It is expected that the manual will be used by the Leather and Leather products Training Institute (LLPTI)

1.6 THESIS STRUCTURE

Literature review in chapter two covers the methodology, procedures and limitations of the life cycle assessment, environmental cost accounting and social auditing. Chapter three covers the case study for Ethiopian leather industries where all the three methods are applied independently. Integrating of the three scenarios is covered in chapter four. Chapter five covers the Conclusions and recommendations for future work.

CHAPTER TWO LITRATURE REVIEW

2.1 LIFE CYCLE ASSESSMENT

As environmental awareness increases, industries and businesses have started to assess how their activities affect the environment. Society has become concerned about the issues of natural resource depletion and environmental degradation. Many businesses have responded to this awareness by providing “greener” products and using “greener” processes. The environmental performance of products and processes has become a key issue, which is why some companies are investigating ways to minimize their effects on the environment. Many companies have found it advantageous to explore ways of moving beyond compliance using pollution prevention strategies and environmental management systems to improve their environmental performance. One such tool is called life cycle assessment (LCA). [1]

Life-cycle assessment (LCA) is a methodology for analyzing the environmental interactions of a technological system with the environment [2]. Life cycle assessment is a “cradle-to-grave” approach for assessing industrial systems. “Cradle-to-grave” begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth.

2.2.1 THEORETICAL FOUNDATION OF LCA

The foundational issue is one that will inevitably be raised whenever there is disagreement among parties: between industry and the environmental movement, for example, between individual industrial sectors and companies, or between consumer organizations and the government. While noted earlier, LCA must be focused on unambiguous and transparent reporting of data, assumptions, and methods. However, it is now clear that this does not suffice [3].

Some differences in data may be caused by differences in the scope, geographical boundaries, and so on, of the LCA under review. There are also differences that may be

argued to originate from differences in attitude. The use of quantitative safety factors for toxic mechanisms that are poorly understood provides another instance where diverging frames of the various parties may lead to disagreement on the findings of an LCA [4].

At the same time, though, it also points a way to possibly validating the results of an LCA. Bringing cases to a hypothetical decision point then leads us to consider a series of crucial questions. The first is: does LCA speak the truth? Or does an LCA only provide a certain measure of the truth? How can we ensure that assertions made by or with an LCA have certain truth content? The purposes of LCA, the questions posed in an LCA, the methodological means of achieving answers to these questions, the principles that underlie the modeling of the economy-environment interaction are all logically related and deserve coherent treatment.

According to ISO 14040, Life Cycle Assessment (LCA) is a method for assessing the environmental aspects and potential impacts associated with a good or a service delivered, by:

- Compiling an inventory of relevant input and output of a product system (i.e. the Life Cycle Inventory (LCI));
- Evaluating the potential environmental impacts associated with those inputs and outputs (i.e. the Life Cycle Impact Assessment (LCIA));
- Interpreting the results of the inventory analysis and impacts assessment phases in relation to the objective of the study.[5]

2.1.2 USES OF LIFE CYCLE ASSESSMENT

LCA is designed as a decision-making tool for designers, regulatory agencies, and business organizations. It is used to evaluate the environmental impacts of products and process and also identifies a section within a product or process's life cycle where the greatest reduction in resource requirements and emissions can be achieved [6]

According to a survey of organizations actively involved in life-cycle studies, the most important goal of life-cycle studies is to minimize the magnitude of pollution [7]. Other

goals include conserving non-renewable resources, including energy; ensuring that every effort is being made to conserve ecological systems; developing alternatives to maximize the recycling and reuse of materials; and applying the most appropriate pollution prevention or abatement techniques. As discussed in this section, life-cycle studies have been applied in many ways such as developing, improving, and comparing products.

Product Comparison

The most widely used function of life-cycle studies is for the purpose of comparing products or services. This kind of study has received a great deal of attention. These studies are often sponsored by organizations that have a high interest in the results of the studies, most often for decision making purposes.

Strategic Planning

One of the important functions life-cycle studies is to provide guidance in long-term strategic planning concerning trends in product design and materials [8]. By their nature, life-cycle studies include environmental impacts whose costs are external to business (e.g., acid rain formation) as well as internal (e.g., the cost of waste generation). Assessing these external costs is a key to strategic environmental planning, as regulations tend to internalize what are currently external costs of doing business.

Public sector uses

Life-cycle studies are also heavily used in the public sector [9]. Policymakers report that the most important uses of life-cycle studies are

1. Helping to develop long-term policies regarding overall material use, improving resource conservation, and reduction of the environmental impacts and risks posed by materials and processes throughout the product life cycle,

2. Evaluating resource effects associated with source reduction and alternative waste management techniques, and
3. Providing information to the public about the resource characteristics of products or materials

Process Design

For a designer, it has been a serious question on how to accommodate various constraints such as economic, technologic and environmental ones to the design and operation of cleaner and greener processes. Earlier design approaches were economics- centered and based on cost-benefit analysis. These approaches attempt to trade off environmental and economic assets with an aim to maximize differences between socioeconomic benefits of an activity against the financial and environmental liabilities [10]. Such practices ultimately seek to attach a monetary value to the environment and are therefore fraught with difficulty.

Generally, process choices (including choices of feed materials for the process) are likely to have more impact over the life cycle of the process than production of the equipment itself.

2.1.3 LIFE CYCLE ASSESSMENT PROCEDURES

2.1.3.1 GOAL AND SCOPE DEFINITION

Goal and Scope definition is the first phase of the LCA process that defines the purpose and method of including life cycle environmental impacts into the decision-making process. In this phase, the following items must be determined: [1].

- The type of information that is needed to add value to the decision-making process, and
- How accurate the results must be to add value, and how the results should be interpreted and displayed in order to be meaningful and usable.

The goal and scope definition of the LCA project will determine the time and resources needed. The defined goal and scope will guide the entire process to ensure that the most meaningful results are obtained. Every decision made throughout the goal definition and scoping phase impacts either how the study will be conducted, or the relevance of the final results.

The following points should be defined in the goal and scope definitions of the LCA, which leads to get a meaningful result of the study.

- Defining the object of study, including defining the functional unit;
- Selecting one or more reference products or reference systems to represent the object of the study;
- Designating the environmental assessment parameters which are important for the goal of the LCA;
- Identifying the environmentally significant processes in the product system, connected with goal definition of LCA;
- Determining how the data Should be organized and displayed; and
- Determining the required accuracy of the data.

2.1.3.2. INVENTORY ANALYSIS

A life cycle inventory is a process of quantifying energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes, and other releases for the entire life cycle of a product, process, or activity [11]. Allocating steps for multifunctional processes, and completing the final calculations is also included in this step. Its main result is in an inventory table listing the quantified inputs and outputs to the environment associated with the functional unit, in terms of kilograms of carbon dioxide, mgs of phenol, kilograms of iron ore, cubic meters of natural gas, etc. [12]

Tracking material flows over all of the stages of a life cycle is required for a comprehensive life-cycle inventory as shown in Figure 2.1. This includes the acquisition of raw materials from the earth, the acquisition of energy resources form the earth, processing of raw materials into usable components, manufacturing products and

intermediates, transportation of materials to each process step, manufacture of the product being studied, distribution of the product, use of the product, and final disposal (which may include recycling, reuse, incineration, or landfill). [13]

2.1.3.3. LIFE CYCLE IMPACT ASSESSMENT

Impact assessment is evaluation of potential human health and environmental impacts of environmental resources and releases identified during life cycle inventory (LCI). Impact assessment should address damage to ecosystem, human health, resource depletion.

Life cycle impact assessment (LCIA) as part of an overall LCA can, for example, be used to (ISO 14042):

- Identify product system improvement opportunities and assist the prioritization of them,
- Characterize or benchmark a product system and its unit processes over time,

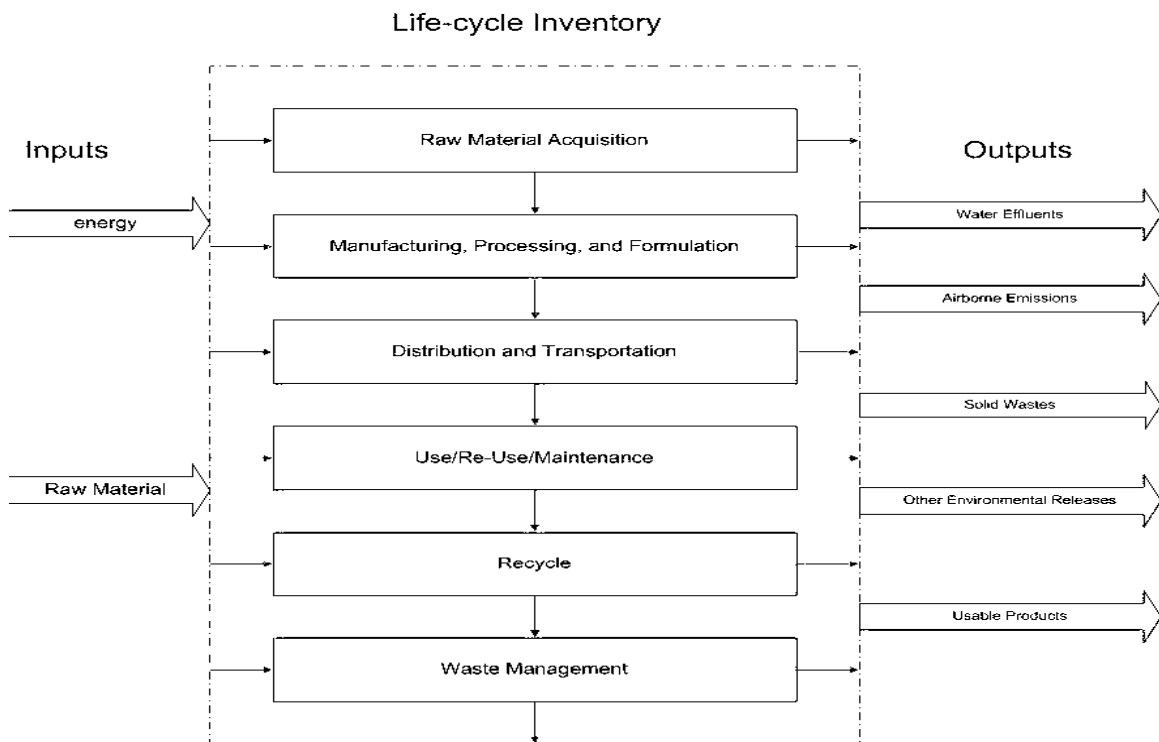


Figure 2.1: Life cycle inventories accounting for material use, energy, waste, emissions and by products over all of the stages of a product's life cycle.

- Make relative comparisons among product systems based on selected category indicators, or
- Indicate environmental issues for which other techniques can provide complementary environmental data and information useful to decision-makers.

Evaluation of Environmental Impact

The environmental impact can be evaluated using the steps followed;

1. Selection of impact category:- identifying relevant impact categories(e.g. acidification, eutrophication, global warming);
2. Classification:-Assigning LCI results in to impact categories (Classifying CO₂ in to GW);
3. Characterization: - modeling LCI impacts within impact categories using science-based conversion factors. (e.g., modeling the potential impact of CO₂ and methane on global warming);
4. Normalization: - expressing potential impacts in ways that can be compared (e.g. comparing the global warming impact of CO₂ and methane for the two options); and
5. Weighting: - emphasizing the most important potential impacts.

Step 1 Selection of Environmental Impacts

The first step in an LCIA is to select the impact categories that will be considered as part of the overall LCA. The items identified in the LCI have potential human health and environmental impacts.

For an LCIA, impacts are defined as the consequences caused by the input and output streams of a system on human health, plants and animals, or the future availability of

natural resources. Typically, LCIA focus on the potential impacts to three main categories: human health, ecological health, and resource depletion. [1]

Step 2 Classification

The purpose of classification is to organize and possibly combine the LCI results into impact categories. For LCI items that contribute to only one impact category, the procedure is a straightforward assignment. For example: carbon dioxide (CO₂) emissions can be classified into the global warming category.

Generally, the following environmental themes are considered in selection and classification of environmental impacts using:

Abiotic depletion potential (ADP) - abiotic depletion concerns the extraction of nonrenewable raw materials such as ores.

Energy depletion potential (EDP) - energy depletion concerns the extraction of nonrenewable energy carriers.

Global warming potential (GWP) - an increasing amount of CO₂ in the earth's atmosphere leads to more absorption of radiative energy, and consequently, to an increase in temperatures on Earth. This is referred to as global warming. CO₂, N₂O, CH₄, and aerosols all contribute to global warming.

Human toxicity (HT) - exposure of humans to toxic substances causes health problems. Exposure can take place through air, water, or soil, especially via the food chain.

Ecotoxicity (ECA/ECT) - exposure of flora and fauna to toxic substances cause health problems in them. Ecotoxicity is defined for water (aquatic ecotoxicity) and soil (terrestrial ecotoxicity)

Acidification potential (AP) - acid deposition onto soil and into water may lead, depending on the local situation, to changes in the degree of acidity. This affects flora and fauna mostly in negative ways.

Nitrification potential (NP) - addition of nutrients to water or soil will increase the production of biomass. This in turn leads to reduction in the oxygen concentration, which affects higher organisms like fish, can lead to undesirable shifts in the number of species in an ecosystem, and thus to a threat to biodiversity. Main elements in this section are nitrogen containing substances, phosphates, and organic materials.

Ozone depletion (ODP) - depletion of the ozone layer leads to an increase in the amount of UV light reaching the earth's surface. This may lead to human diseases and may influence ecosystems in a negative way.

Photochemical oxidant creation potential (POCP) - Reaction of NO_x with volatile organic substances leads, under influence of UV light, to photochemical oxidant creation, which causes smog.

For LCI items that contribute to two or more different impact categories, a rule must be established for classification. There are two ways of assigning LCI results to multiple impact categories [14]

- Allocate a representative portion of the LCI results to the impact categories to which they contribute. This is typically allowed in cases when the effects are dependent on each other.
- Assign all LCI results to all impact categories to which they contribute. This is typically allowed when the effects are independent of each other.

Step 3 Characterization

Impact characterization uses science-based conversion factors, called characterization factors, to convert and combine the LCI results into representative indicators of impacts to human and ecological health. Characterization factors also are commonly referred to as equivalency factors. Characterization provides a way to directly compare the LCI results within each impact category. In other words, characterization factors translate different inventory inputs into directly comparable impact indicators. For example, characterization would provide an estimate of the relative terrestrial toxicity between lead, chromium, and zinc.

Impact indicators are typically characterized using the following equation:

$$\text{Inventory Data} \times \text{Characterization Factor} = \text{Impact Indicators}$$

For example, all greenhouse gases can be expressed in terms of carbon dioxide (CO₂) equivalents by multiplying the relevant LCI results by a CO₂ characterization factor and then combining the resulting impact indicators to provide an overall indicator of global warming potential. Characterization factor for different impact categories is given in table 2.1

Impact category	Global warming	Stratospheric Ozone Depletion	Acidification	Eutrophication	Photochemical Smog
Characterization Factor	CO ₂	CFC-11	H ⁺	PO ₄	C ₂ H ₆

Table 2.1: Characterization factor for different impact categories

Step 4 Normalization

Normalization is an LCIA tool used to express impact indicator data in a way that can be compared among impact categories. This procedure normalizes the indicator results by dividing by a selected reference value.

There are numerous methods of selecting a reference value, including:

- The total emissions or resource use for a given area that may be global, regional or local;
- The total emissions or resource use for a given area on a per capita basis;
- The ratio of one alternative to another (i.e., the baseline); and
- The highest value among all options.

Step 5 Weighting

The weighting step (also referred to as evaluation) of an LCIA assigns weights or relative values to the different impact categories based on their perceived importance or relevance. Weighting is important because the impact categories should also reflect study goals and stakeholder values. As stated earlier, harmful air emissions could be of relatively higher concern in an air non-attainment zone than the same emission level in an area with better air quality. Because weighting is not a scientific process, it is vital that the weighting methodology is clearly explained and documented.

Although weighting is widely used in LCAs, the weighting stage is the least developed of the impact assessment steps and also is the one most likely to be challenged for integrity. In general, weighting includes the following activities: [1]

- Identifying the underlying values of stakeholders.
- Determining weights to place on impacts.
- Applying weights to impact indicators.

Life Cycle Impact Assessment Methods

LCIA methods aim to connect each life cycle inventory (LCI) result (elementary flow or other intervention) to the corresponding environmental impacts. According to ISO 14042, LCI results are classified into impact categories, each with a category indicator. The category indicator can be located at any point between the LCI results and the damage

category (where the environmental effect occurs) in the cause-effect chain. Within this framework, two main schools of methods have evolved:

- a. Classical impact assessment methods e.g. CML (Guinée et al. 2002) and EDIP (Hauschild and Wenzel 1998) restrict quantitative modeling to relatively early stages in the cause-effect chain to limit uncertainties and classify and characterize LCI results in so-called midpoint categories. Themes are common mechanisms (e.g. climate change) or commonly accepted grouping (e.g. aquatic ecotoxicity).
- b. Damage oriented methods such as Eco-indicator 99 Shown in figure 2.2 try to model the cause-effect chain up to the damage.

There is also Combination of the two methods known as IMPACT 2002+ method as shown in the figure 2.3 where it works with damage category and also mid point category in which each midpoint category relating to one or several damage categories. [5]

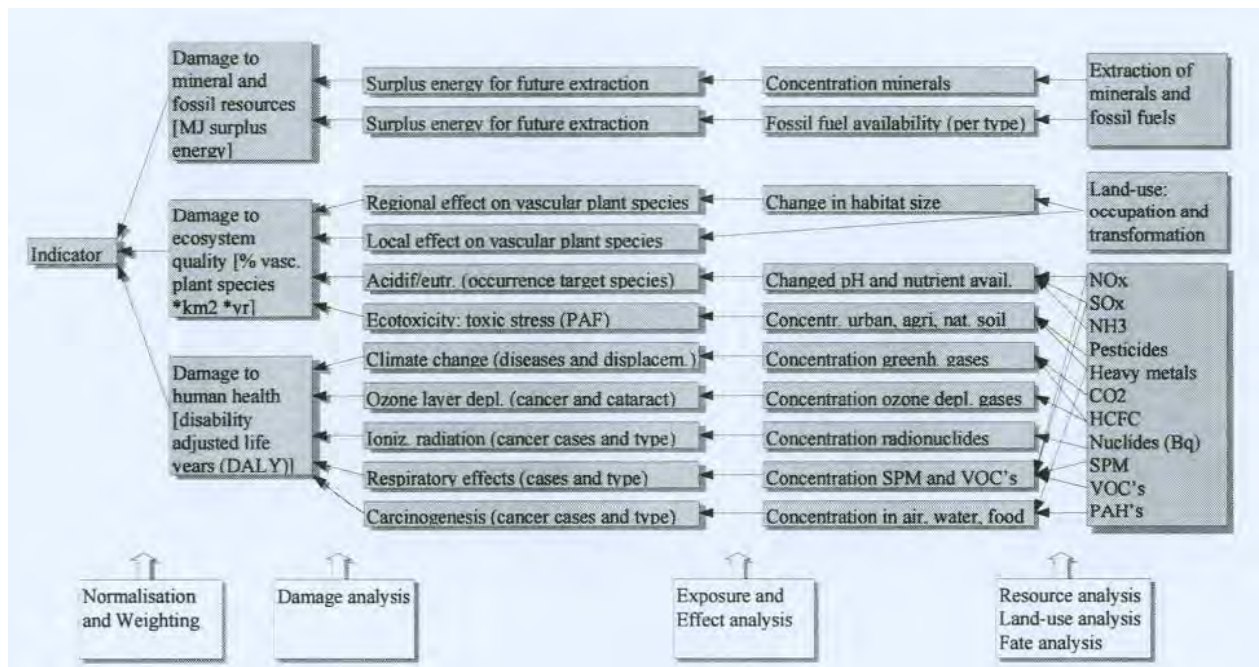


Figure 2.2 General representation of the EI 99 methodology. The white boxes refer to procedures; the other boxes refer to intermediate results. (SOURCE Eco-indicator 99 methodology report, 22 June 2000)

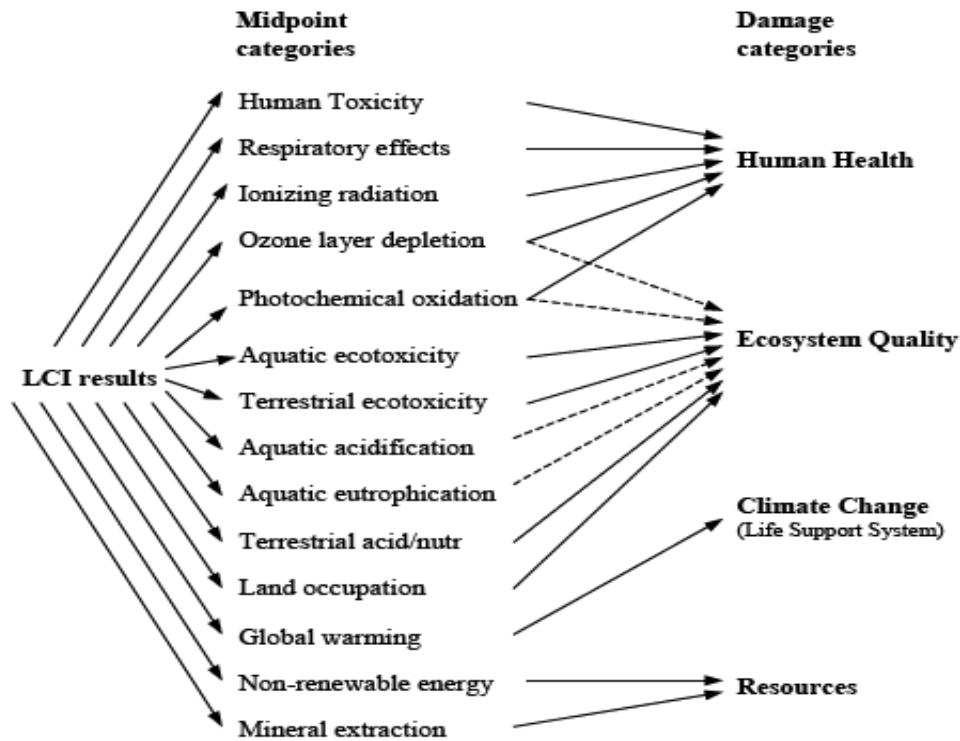


Figure 2.3: Overall scheme of the IMPACT 2002+ framework, linking LCI results via the midpoint categories to damage categories, based on Jolliet et al. (2003a)

For an LCIA, impacts are defined as the consequences caused by the input and output streams of a system on human health, plants and animals, or the future availability of natural resources. Typically LCIA focus on the potential impacts to three main categories: human health, ecological health, and resource depletion. Figure 2.2 and Figure 2.3 show some of the more commonly used impact categories. [16]

2.1.3.4 LIFE CYCLE INTERPRETATION

Life cycle interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the life cycle inventory (LCI) and the life cycle impact assessment (LCIA), and communicate them effectively. Life cycle interpretation is the final phase of the LCA process.

ISO 14043 defines interpretation as “a systematic procedure to identify, qualify, check, and evaluate information from the result of LCI and /or LCIA of product system, and

present them in order to meet the requirements of the application as described in the goal and scope of the study [17].

Furthermore, life cycle interpretation includes communication to give credibility to the results of other LCA phases in a form that is both comprehensible and useful to the decision maker". This is the place to reflect on the results of the previous phases of the LCA and on the choices that have been made during the process of generating these results.

The International Organization for Standardization (ISO) has defined the following two objectives of life cycle interpretation:

- Analyze results, reach conclusions, explain limitations and provide recommendations based on the findings of the preceding phases of the LCA and to report the results of the life cycle interpretation in a transparent manner.
- Provide a readily understandable, complete, and consistent presentation of the results of an LCA study, in accordance with the goal and scope of the study.

Generally the life cycle interpretation step can be related with the other steps using the frame work given in the figure 2.4 below.

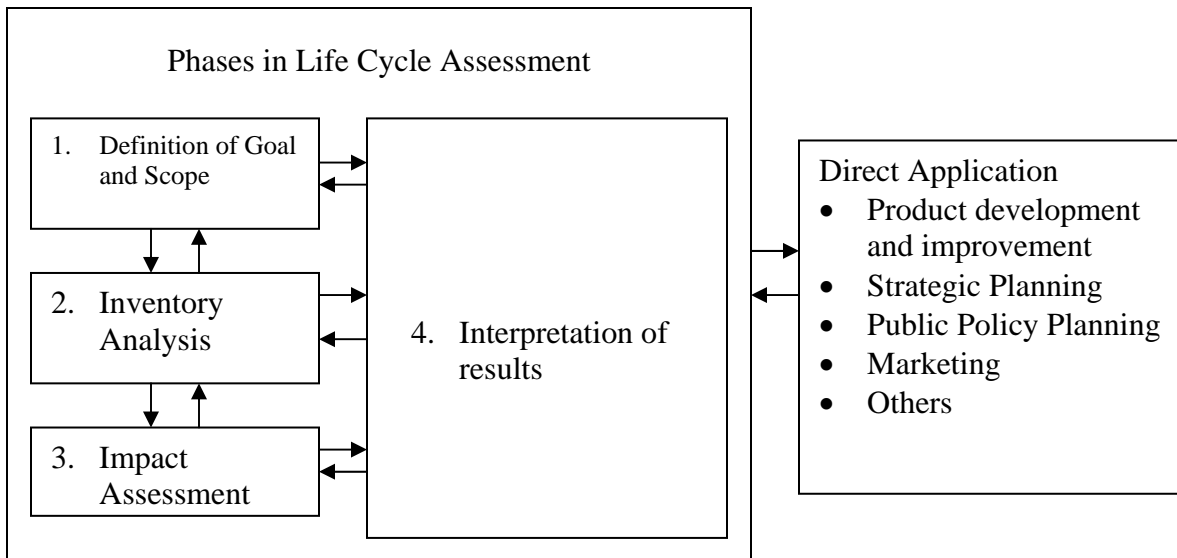


Figure 2.4: Frame work of Life Cycle Assessment

2.1.3.5 KEY STEPS TO INTERPRET THE RESULTS OF THE LCA

Within the ISO standard the following steps to conducting a life cycle interpretation are identified and discussed. [20]

1. Identify Significant Issues
2. Evaluate the Completeness, Sensitivity, and Consistency of the Data
3. Draw Conclusions and Recommendations

Step1. Identify Significant Issues

The first step of the life cycle interpretation phase involves reviewing information from the first three phases of the LCA process in order to identify the data elements that contribute most to the results of both the LCI and LCIA for each product, process or service.

Significant issues can include:

- Inventory parameters like energy use, emissions, waste, etc;
- Impact category indicators like resource use, emissions, waste, etc; and

- Essential contributions for life cycle stages to LCI or LCIA results such as individual unit processes or groups of processes (e.g., transportation, energy production).

Step 2: Evaluate the Completeness, Sensitivity, and Consistency of the Data

The evaluation step of the interpretation phase establishes the confidence and reliability of the results of the LCA. This is accomplished by completing the following tasks to ensure that products/processes are fairly compared:

1. Completeness Check - examining the completeness of the study;
2. Sensitivity Check - assessing the sensitivity of the significant data elements that influence the results most greatly; and
3. Consistency Check - evaluating the consistency used to set system boundaries, collect data, make assumptions, and allocate data to impact categories for each alternative.

Step 3: Draw Conclusions and Recommendations

The objective of this step is to interpret the results of the life cycle impact assessment (not the LCI) to determine which product/process has the overall least impact to human health and the environment, and/or to one or more specific areas of concern as defined by the goal and scope of the study.

Depending upon the scope of the LCA, the results of the impact assessment will return either a list of unnormalized or un-weighted impact indicators for each impact category for the alternatives, or it will return a single grouped, normalized, and weighted score for each alternative.

In the latter case, the recommendation may simply be to accept the product/process with the lowest score.

However, do not forget the underlying assumptions that went into the analysis. If an LCIA stops at the characterization stage, the LCIA interpretation is less clear-cut. The conclusions and recommendations rest on balancing the potential human health and environmental impacts in the light of study goals and stakeholder concerns. [1]

2.1.4 LIMITATION OF LIFE CYCLE ASSESSMENT

There are important *limitations* of LCA that need to be mentioned in advance

- The most important limitation is that any LCA will necessarily involve assumptions and subjective valuation procedures. These assumptions must be fully communicated. As the results might differ substantially according to the assumptions made, great caution should be used in making environmental claims (i.e. in the comparison of products for the public) based on LCA.
- A second big problem is the availability and quality of data. Very clearly, the issue of the quality of data, of how to find missing data and/or correct unreliable data, still requires much methodological and scientific work. One possible path seems to be a collaborative attitude within sectors and countries and the creation of public databases.
- It should be clearly understood that LCA is only one of several environmental management tools and might not always be the most appropriate one in all situations. Decisions for action in a company typically involve other factors such as risks, benefits, costs, which include technical, economic, and social aspects, which are *not* addressed by LCA.

2.2 ENVIRONMENTAL COST ACCOUNTING (ECA)

Environmental cost accounting refers to “the process of identifying, collecting and analyzing information about environmental costs and performance to help an organization’s decision making. [21]

Cost (or management) accounting constitutes the central tool for internal management decisions such as product pricing and is not regulated by law. This internal information system deals with the following questions: What are the production costs for different products and what should be the selling price of these products? The main stakeholders in cost accounting are members of different management positions (e.g. executive, site, and product and production managers). In practice, many companies do not have a separate cost accounting system, but calculate on the basis of the financial accounting data from bookkeeping instead. Financial accounting, in contrast, is mainly designed to satisfy the information needs of external shareholders and financial authorities, both of whom have a strong economic interest in standardized comparable data and in receiving true and fair information about the actual economic performance of the company. Therefore, financial accounting and reporting are being dealt within national laws and international accounting standards.

The core parts of environmental information systems are material flow balances in physical units of material, water and energy flows within a defined system boundary. This can be done at the corporate level, but can also be taken further to directly address cost centers and production processes or even down to specific machinery and products. It would then become the task of process technicians and not necessarily accountants to tackle and trace the necessary data.

Environmental cost accounting, ECA represents a combined approach which provides for the transition of data from financial accounting, cost accounting and material flow balances to increase material efficiency, reduce environmental impact and risk and reduce costs of environmental protection.

ECA is performed by private or public corporations, and has a financial as well as physical component. ECA metrics for internal decision-making include both: physical metrics for material and energy consumption, flows, and final disposal, and monetarised metrics for costs, savings, and revenues related to activities with a potential environmental impact.

2.2.1 PROCEDURES FOR ASSESSMENT OF ENVIRONMENTAL COST ACCOUNTING

i. Identifying Environmental Costs

Environmental costs comprise both internal and external costs and relate to all costs incurred in relation to environmental damage and protection. Environmental protection costs include costs for prevention, disposal, planning, control, shifting actions and damage repair that can occur in companies, governments or people. In this analysis external costs, which result from corporate activities but are not internalized via regulations and prices, are not considered.

Environmental protection expenditure includes all expenditures for measures of environmental protection of a company or on its behalf to prevent, reduce, control and document environmental aspects, impacts and hazards, as well as disposal, treatment, sanitation and clean-up expenditure (see Table 2.2). The amount of corporate environmental protection expenditure is not directly related to the environmental performance of a company.

Environmental protection costs Emission treatment and pollution prevention) Cost of wasted material Cost of wasted capital and labor
Total corporate environmental costs

Table 2.2 Total Corporate Environmental Costs

Social costs will be assessed in the next topic using a completely different approach, as most of the costs besides wages, social security, taxes and voluntary benefits, occur outside the company and external effects and need to be estimated.

ii. Categorizing the Different Environmental Costs

Environmental costs are categorized in to disposal and emission, prevention, purchase of wasted material, production cost of wasted material and environmental revenue. The summary of the environmental cost categories are also given in table 2.3.

- *Waste disposal and emission treatment costs* are the first blocks which include related labor and maintenance materials (materials only, if they are recorded on related cost centers).
- *Prevention and environmental management* adds the labor costs and external services for good housekeeping as well as the “environmental” share of integrated technologies and the “scrap” share of operational plants, if significant. The main focus of the second block is on annual costs for prevention of waste and emissions.
- *Wasted material purchase value* includes all material inputs (including energy and water) for their share of non-product output (scrap percentage, efficiency losses). Wasted materials are evaluated with their material purchase value or materials consumed value in case of stock management.
- *Production costs of non-product output* include labor hours, depreciation of machinery and operating materials. Care has to be taken to avoid double counting with costs already taken care of under other cost categories. This mainly depends on the quality of data availability and information systems.
- *Environmental revenue* is the last block which includes sales of waste or grants of subsidies.

Media Cost Category	Air/ Climate	Waste water	Waste	Soil/ ground water	Biodiversity	Noise/ vibration	Radiation	Other	Total
1. Waste and emission treatment									
2. Prevention and environmental management									
3. material Purchase value of non product output									
4 Processing cost of non product output									
ΣEnvironmental expenditure									
5. environmental revenue									

Table 2.3 Overview on Environmental Cost scheme

iii. Making Material Flow Balance

The basis of environmental performance improvements and for assessing the amounts and costs of non product output (NPO) is the recording of material flows in kilograms by an **Input–Output analysis**. The system boundaries can be on the corporate level, or further split up to sites, cost centers, processes and product levels. The material flow balance is an equation based on the idea that “what comes in must go out—or be stored”. Materials include energy and water. All items are measured in physical units in terms of mass (kg, t) or energy (MJ, kWh). The purchased input is cross-checked with the amounts produced and sold as well as the resulting waste and emissions. The goal is to improve efficiency of material management both economically and environmentally. A material flow balance can be made for a few selected materials or processes, or for all materials and wastes of an organization. The purpose of working to quantify the process balances is to track materials on their way through the company. The starting point is

often at the corporate level, since much information is available on this system boundary. Also, this level is used for disclosure in environmental reports.

The next step after environmental cost assessment and material flow balances have been done on a corporate level is to allocate the data from the system boundary of the company fence to internal processes. Process flow charts, which trace the inputs and outputs of material flows on a technical process level, give insights into company-specific processes and allow the determination of losses, leakages and waste streams at the originating source. This requires a detailed examination of individual steps in production—again in the form of an input–output analysis. The process flow charts combine technical information with cost accounting data. They are not done on a yearly basis but for a specified production unit, machinery or cost center. In total, they should aggregate to the annual amount (fig 2.5).

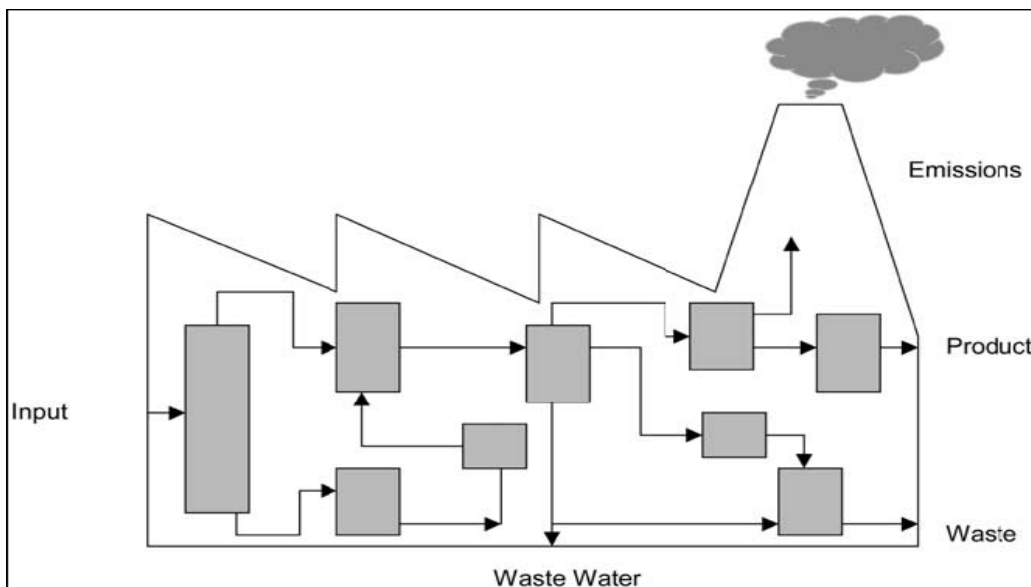


Figure 2.5: Process flow charts :(SOURCE Environmental management acc. Procedure and principles)

This level of material flow analysis will be the responsibility of technicians, but the data splitting up the corporate flows into cost centers, or even down to specific production equipment, allows for more detailed investigation of technical improvement options, but also for tracing the sources of costs. Special attention should be drawn to the quantitative

recording of materials on a consistent kilogram basis. The key questions answered by the approaches of activity based costing and cost flow accounting are:

- What cost center have processed how much of the materials?
- Can material input be further divided into production lines or specific equipment?
- How large were the resulting emissions, scrap and waste, preferably recorded separately for each cost center, production line and machinery?
- What is the correct allocation of costs to products, thus, reducing the amount of costs hidden in overhead cost categories?

2.2.2 LIMITATION OF ENVIRONMENTAL COST ACCOUNTING

ECA has been developed for company internal decision making and therefore focuses on tracing all real environmental and material efficiency loss expenditure for a given year. The focus is on improving a company's information system and decision basis. External costs, costs which are outside the company fence, are not included in the ECA. The focus is not on estimating external effects and "soft" factors, such as image, credibility, ethics, as from an accountant's perspective they will sooner or later be reflected in the annual accounts. [22]

2.2.3 APPLICATIONS OF ENVIRONMENTAL COST ACCOUNTING

ECA metrics for internal decision-making include both: physical metrics for material and energy consumption, flows, and final disposal, and monetarised metrics for costs, savings, and revenues related to activities with a potential environmental impact.

Key application fields for the use of ECA data are:

- Assessment of annual environmental costs/expenditures;
- Product pricing;
- Budgeting;
- Investment appraisal, calculating investment options;
- Calculating costs and savings of environmental projects;

- Design and implementation of environmental management systems;
- Environmental performance evaluation, indicators and benchmarking;
- Setting quantified performance targets;
- Cleaner production and Ecodesign projects;
- External disclosure of environmental expenditures, investments and liabilities;
- External environmental or sustainability reporting;
- Other reporting of environmental data to statistical agencies and local authorities.

2.3 SOCIAL AUDITING

Social assessment, also called social auditing, has been defined as "a process of defining, observing and reporting measure of an organization's ethical behavior and social impact against its objectives, with the participation of its stakeholders and wider community" [26]. For typical industries, social and ethical values would be centered on worker welfare and consumer satisfaction. Moreover, if products are exported, stakeholders would also include the foreign consumer in a developed market whose satisfaction tend to be influenced by internationally accepted social and ethical standards. Given this, relevant indicators for a social assessment of industrial processes would include measures that address consumer and worker welfare. Some of these measures are indicators related to: training and communication, non discrimination, and work security [27]. A more comprehensive set of social practices would include equity indicators as well as measures that reflect the extent of worker involvement in decision making relating to employment and labor practices. A social audit assesses the extent to which industrial processes fulfill social parameters.

Over the past decade, social auditing has taken on an important new role in the monitoring of labor and environmental standards. It has grown rapidly in recent years, involving various companies, consulting firms, labor unions and non-governmental organizations (NGOs) in industries such as forestry, agriculture, clothing and footwear, and textiles. The combined pressure of campaigns by trade unions and NGOs, negative media attention and an increasingly vocal public concern about working conditions have prompted some companies to have their factories audited. Concern about the credibility of such audits has been a major issue in the public debate about corporate social

responsibility. Recent research has begun to consider the methodologies and effectiveness of social auditing initiatives. [28]

2.3.1 METHODOLOGY OF SOCIAL AUDITING

In methodology of social auditing, three notes of caution should be sounded.

- First, the field of social auditing is very dynamic and fast-paced.
- Second, many organizations keep their methodologies confidential,
- Third, freedom of association and the right to collective bargaining are vast subjects and treatment of the entirety of the standards in a short text

Auditing, inspection and monitoring are three terms used interchangeably to refer to the practice of evaluating a company's compliance with a set of standards. However, they represent distinct elements of this evaluation and thus provide a useful framework for the analysis of auditing a standard.

A social audit is undertaken by a company to evaluate the working conditions existing in a facility or supply chain. Unlike monitoring, it lasts anywhere from a few hours to a few days, and involves a number of steps, each one theoretically used in combination with the others. The performance of a social audit tends to involve three related processes: the document review, the site inspection and interviews with workers, management and third-party stakeholders.

An auditor or team of auditors generally conducts the document review, site inspection and interviews. Social auditing does not involve continuous monitoring, although follow-up procedures are not uncommon.

The site inspection entails the direct inspection of production facilities, and sometimes includes informal discussions with workers and management. It tends to last between a few hours and one or two days.

There are announced and unannounced inspections. The ability of the inspector to make skilled observations and judgments concerning a facility's condition is the key issue of the site inspection.

Monitoring is the ongoing and regular surveillance of a facility by one or more people. The most important characteristic of monitoring is the requirement of continuous engagement and presence at the facility. Unlike auditing, it is more capable of offering an in-depth and long-term view of a workplace. Monitoring requires the continuous presence and engagement of monitors.

i Document Review

The document review is an important part of the social audit. It can be used to monitor elements of all labor standards, but it is mostly used in the auditing of wages and working hours

ii Site Inspection

The site inspection is a valuable part of the social audit. It offers auditors an opportunity to view the production facility and gives them a chance to observe its conditions and environment, something particularly worthwhile in the auditing of health and safety standards. Unlike the document review, site inspections are rarely used for the verification of freedom of association. The main aspects of association covered by site inspections are the existence of facilities for union-management meetings and the posting of union announcements and material. There is a number of issues that auditors need to deal with vis-à-vis site inspections. Their duration is of great significance, while the question of whether or not auditors have complete and free access to a facility is also important.

iii Interviews

The interview process is perhaps the most valuable aspect of the social audit. It consists of discussions with various parties and offers the auditor a unique opportunity to speak with workers. Interviews provide the most direct source of information and, when used correctly, can offer detailed and reliable insight into a production facility's working conditions. It is not surprising that they are often a more developed part of the audit process. The interview can be done with different Stakeholders. First interview can be made with representatives of local community groups primarily in order to gather external information. The second is interview with management of the industry which can give an auditor considerable opportunity to explore the issues of freedom of association and collective bargaining with managers. The other one is an interview made with workers which cover various aspects of freedom of association and include anti-union discrimination, disciplinary action and management interface in organized efforts.

2.2.3 SOCIAL ACCOUNTABILITY REQUIREMENTS AND STANDARDS

The social Auditing can be weighted with the international standard called Social Accountability Standard (SA8000). It is directly related with social welfare and health. The social Accountability international (SA8000) specifies requirements for social accountability to enable a company to: [29]

- a. develop, maintain, and enforce policies and procedures in order to manage those issues which it can control or influence;
- b. Demonstrate to interested parties that policies, procedures and practices are in conformity with the requirements of this standard.

The requirements of this standard shall apply universally with regard to geographic location, industry sector and company size. (Definitions and Social Accountability Standards are given in appendix)

CHAPTER 3 INTEGRATING LIFE CYCLE ASSESSMENT WITH ECONOMIC AND SOCIAL MODELS

Integrating the social and economic (environmental economics) terms with life cycle of the product can facilitate the decision making process of a corporate in a production system. The three models, social, environment and economics are related to one another. Usually impact on the environmental system has a direct and/or indirect influence on social and economic system. Considering only the environment or the economic with out incorporating the other terms may come up to a point of poor decision. Therefore, these three terms shall go side by side so as to reach to the point of target.

Integrating of social and economic terms in to LCA (fig 3.1) of a given product, should require first to identify the potential environmental impacts of the given product throughout the product's life cycle and determine its effect on the social and economics.

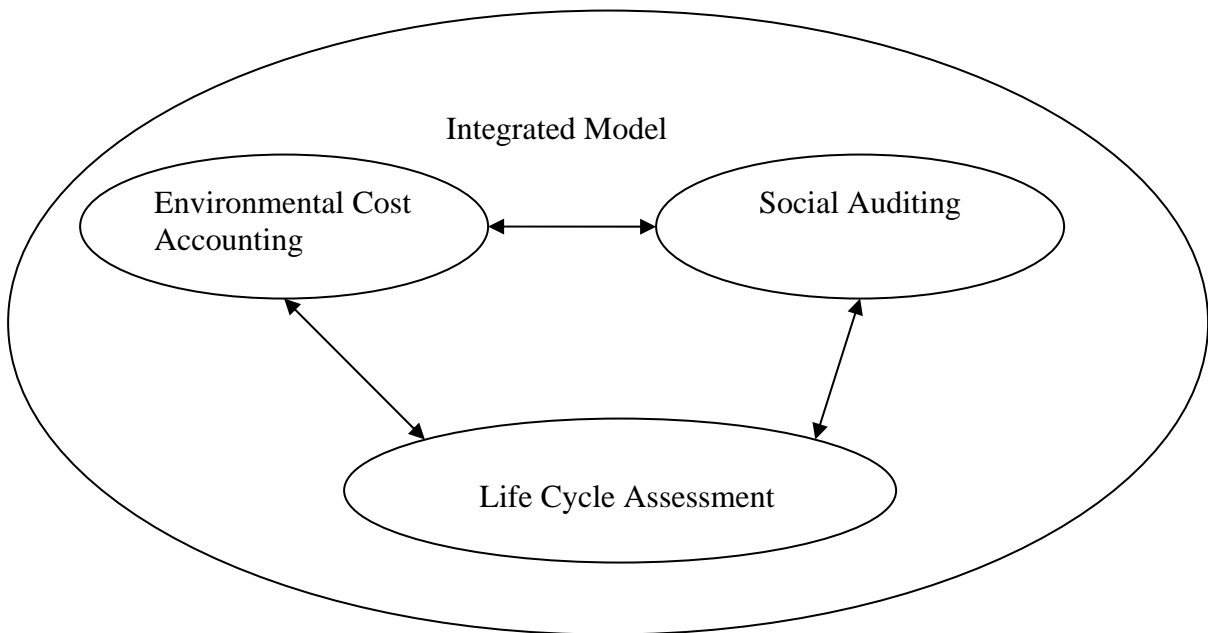


Figure 3.1: representation of an integrated model

The economics can be evaluated using the environmental cost accounting which has a quantified output in terms of money. Social impact of a production system or a product

can be evaluated using the social auditing. Though an output of impact on social has quite difficult to quantify in terms of measuring units, it can be calculate and normalized in terms of monetary value.

An integrated model would combine

- The calculation of the direct and indirect cost linked to environmental impacts/risks and pre-defined social/ethical norms
- Identification of Technical option and managerial actions, which achieve the environmental standards and social goals at lower cost.
- Cost benefit analysis on different remedial actions necessarily to minimize environmental impacts and risks and maintain predetermined social/ethical norms.

CHAPTER 4 CASE STUDY FOR ETHIOPIAN LEATHER INDUSTRIES

4.1 INTRODUCTION

With an abundant of Livestock resources, Ethiopia has the comparative advantage in producing leather products. According to the livestock marketing authority figures, in 2002 Ethiopia had approximately 35 million cattle, 25million sheep and 19million goat. The ministry of Agriculture estimates that the current skin removal rate is 7% for cattle, 33% for sheep and 37% for goats. On average Ethiopia has a capacity to supply 16-18 million pieces of hides and skins to local markets.

In Ethiopia leather industries are counted above seven decades. They are distributed in mainly in four regions: Addis Ababa, Oromiya, Amhara and Tigray. As the data from Ethiopian Investment Agency shows 70 tannery projects were licensed till June 2005, out of which 23 tanneries are on production whereas the rest are under construction.[36]

From those which are actively working leather industries, three companies are selected to collect data for analysis. An average data is taken from those companies so as to represent the leather processing in general. Due to confidentiality the name of the companies is omitted and marked as company A, B and C.

4.2 LEATHER PROCESSING

Leather processing essentially consists of series of physical and chemical operations where by the raw hide or skin of an irregularly shaped, low strength organic material that can petrify is given an almost constant thickness and such characteristics as incorruptibly, good flexibility, high tensile strength, abrasion resistance and finish with good appearance. [30]

Leather manufacturing is the tanning process, which is accomplished through four main operations, namely, beam house, tanning, post tanning and finishing operations, each comprising a number of sub operations as discussed below.

Beam house Operations

Beam hose operation is the first major process where the raw hide or skin is soaked, unhaired, fleshed, delimed and buffed prior to tanning. Main purpose of this operation is removing the unwanted parts of the hide and preparing for the next process.

a. Soaking

It is placing the salted raw hide or skin in water usually, in mixers or drum. It removes blood, dunk and dirt from the skin. It needs water of 5 times the weight of hide/skin. Chemicals used in soaking are 0.2 – 2.0 grams per liter sodium hydroxide, up to 1 gram per liter sodium hypochlorite and/or 0.5 – 2.0 per cent wetting agents, emulsifiers, surfactants etc.

b. Liming /Unhairing

The hide is treated with a solution of lime and sodium sulphide or sodium hydrogen sulphide to remove hair and loosen the hide structure. Unhairing is normally carried out by dissolving in a chemical solution. Chemicals generally used are 2-10 per cent calcium hydroxide (lime), 1-4 per cent sodium sulphide or sodium hydrogen sulphide. Some caustic soda may also be used.

c. Fleshing and Deliming

Fleshing is the mechanical scraping of adhering connective tissue, fat etc. from the flesh. On the other hand, deliming solubilizes the absorbed calcium hydroxide and brings the skin to the desired PH, mainly to avoid interference with the subsequent tanning stage. The process is carried out by washing and by using water combined with neutralizing chemicals. Chemicals used are ammonium chloride or sulphate, 0.5– 2.0 per cent acids (lactic, formic, boric

and mixtures), acidic salts, sodium bisulphite, hydrogen peroxide. The use of gaseous CO₂ instead of ammonium salts has been increasing.

d. Bating

Bating treats the hides with proteolytic enzymes to purify the material prior to tanning. It loosens the hide structure and removes unwanted proteins, and is often carried out in the delimiting liquor. The chemical used is often a 0.5 per cent bating material, which consists of 50 per cent wood flour (or another carrier), 30 per cent delimiting agent (ammonium chloride) and 1-5 per cent pancreatic enzyme.

e. Degreasing

Degreasing is the process of removing fats from the skin. This is especially important in sheepskin tanneries as the fat content of their raw material is large. The process uses solvent degreasing. Solvents, which are increasingly substituted or combined with surfactants and/or enzymes, include perchloroethylene, monochlorobenzene and kerosene.

f. Pickling

It is the final beam hose operation for adjustment of the pH of the pelt, there by sterilizing the skin , ending the bating action and improving penetration of the subsequent tanning material. Chemicals used include sulphuric acid (0.2 – 2.0 per cent) and salt (5-10 per cent).

Tanning Operation

Tanning stabilizes the collagen structure of the hide using natural or synthetic chemicals. The process imparts a particular “feel” to the leather. The most commonly used tanning agent is a basic chromium sulphate. Tanning is completed with a basification to bind the

chromium in the leather. Chemicals used in tanning are: chrome tanning salts with in average of 14 per cent Cr (used in amounts of 8-12per cent for common processes and 5-6 per cent for low chrome processes), 1.0 per cent sodium bicarbonate (basifying agent to adjust pH), 0.5 per cent masking agent (sodium formate), and up to 0.9 per cent fungicide. Summing and Shaving can also include in tanning operation where Summing brings leather to a uniform semi-dewatered state. The leather is passed through a summing machine that squeezes surplus water out of the leather. On the other hand, shaving is a mechanical process that controls the leather thickness.

Post tanning Operation

Post-tanning is s divided into four main stages: neutralization, retanning, dyeing and fat liquoring. Neutralization de -acidifies the leather. Retanning comprises a supplementary tannage and gives the leather its final properties. Dyeing uses aniline dyestuffs, while fat liquoring softens the leather.

Chemicals used include the following (per cent of shaved weight):

- Neutralizing: 1 per cent mild alkali or syntan
- Retan: Tanning agents (often syntans)
- Dye: 1-6 per cent dyestuff/aniline dyestuff
- Fat liquor: 3-10 per cent sulphonated fish, vegetable or animal oils; mineral and synthetic oils

Drying and Finishing

Leather is dried using vacuum drying, suspension drying, toggling, paste drying, microwave drying or a combination of these. [31]

Finishing of the crust leather is done in order to achieve the necessary fastness and properties demanded by the customers. The surface coatings which consist of a polyur ethane polymer are applied by spraying, rolling or padding. A general process flow with major inputs and outputs is shown in figure 4.1 below

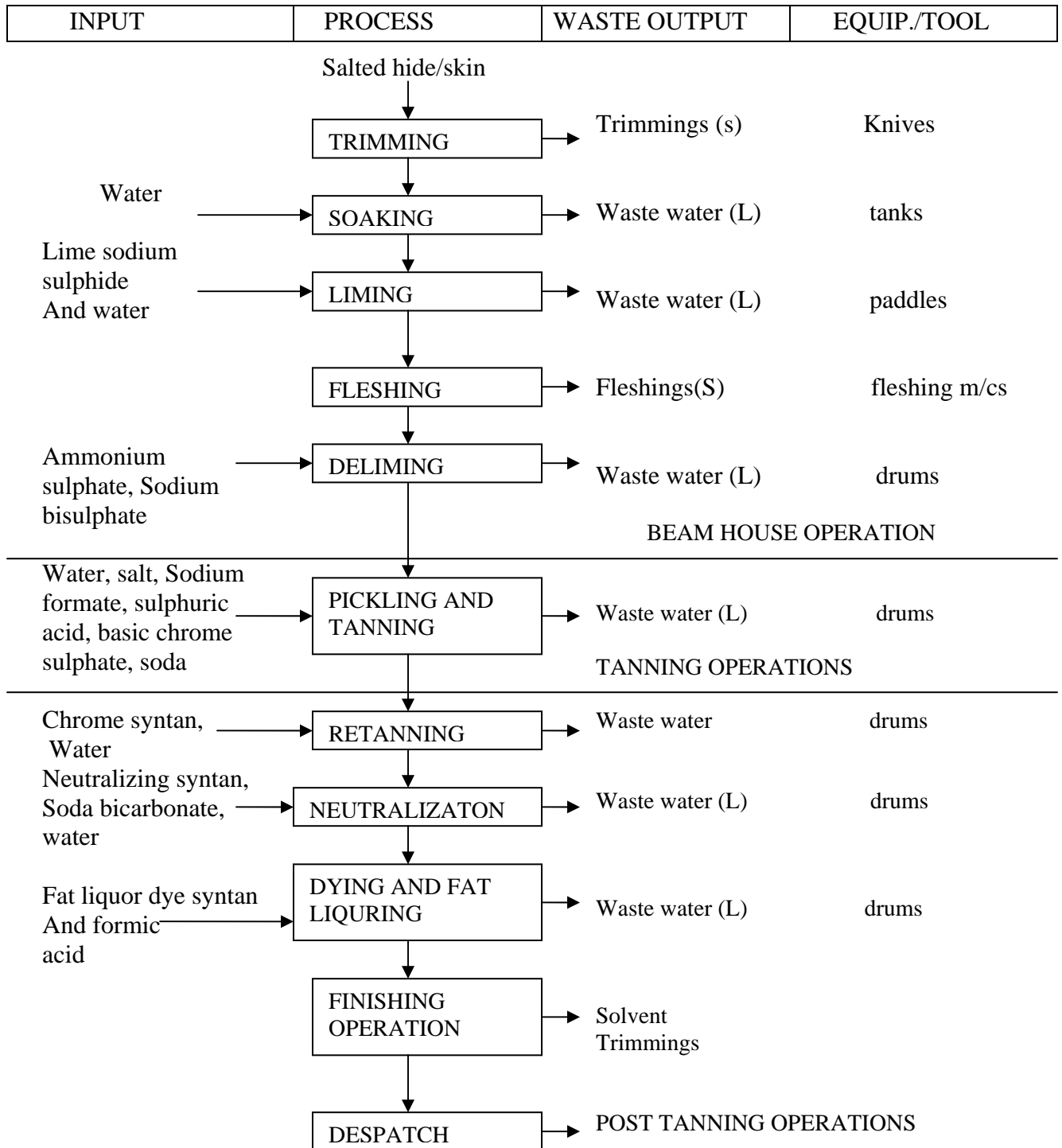


Figure 4.1: Leather process flow chart

4.3 LIFE CYCLE ASSESSMENTS FOR LEATHER PROCESSING

LCA is a technique for

- assessing all the inputs and outputs of a product, process, or service (Life Cycle Inventory);
- assessing the associated wastes, human health and ecological burdens (Impact Assessment); and
- Interpreting and communicating the results of the assessment (Life Cycle Interpretation) throughout the life cycle of the products or processes under review.

4.3.1 METHODOLOGIES

4.3.1.1 GOAL DEFINITION AND SCOPE

The goal of this project is to determine the environmental load of the leather in different processing stages. The LCA is done from the killing of the animal in the slaughter house to the final leather production which is an upstream process called '*cradle to gate*' approach. It is basically focused on the major environmental impacts throughout the process. The lifecycle is done on sheep skin. Even though more than 90% of sheep are killed at home instead of slaughter houses, slaughter house is selected because of the availability of inventory data related to the impact associated with the killing of the animal.

Functional unit

It is quantified performance of a product system for use as a reference unit in a life cycle assessment study [34]. In this case an environmental load was considered for a production of 1 piece of wet salted animal skin (on average 4.2ft²).

System Boundary

The system boundary is an Interface between a product system and the environment or other product systems [34]. In this project the processes investigated are the killing of the animal, preservation of the skin, beam house operation, tanning operation, retaining operation finishing operation and waste treatment. The disposal scenario of the product is not included in this project.

Since Leather industries use chemicals intensively, environmental loads due to production of some chemicals which are toxic and highly consumed are considered. The Impact due to transportation of all imported and local chemicals, electric generation and fuel or oil production is also considered. However the capital goods are excluded in this paper. The boundary stem is shown clearly in the figure 4.2 below.

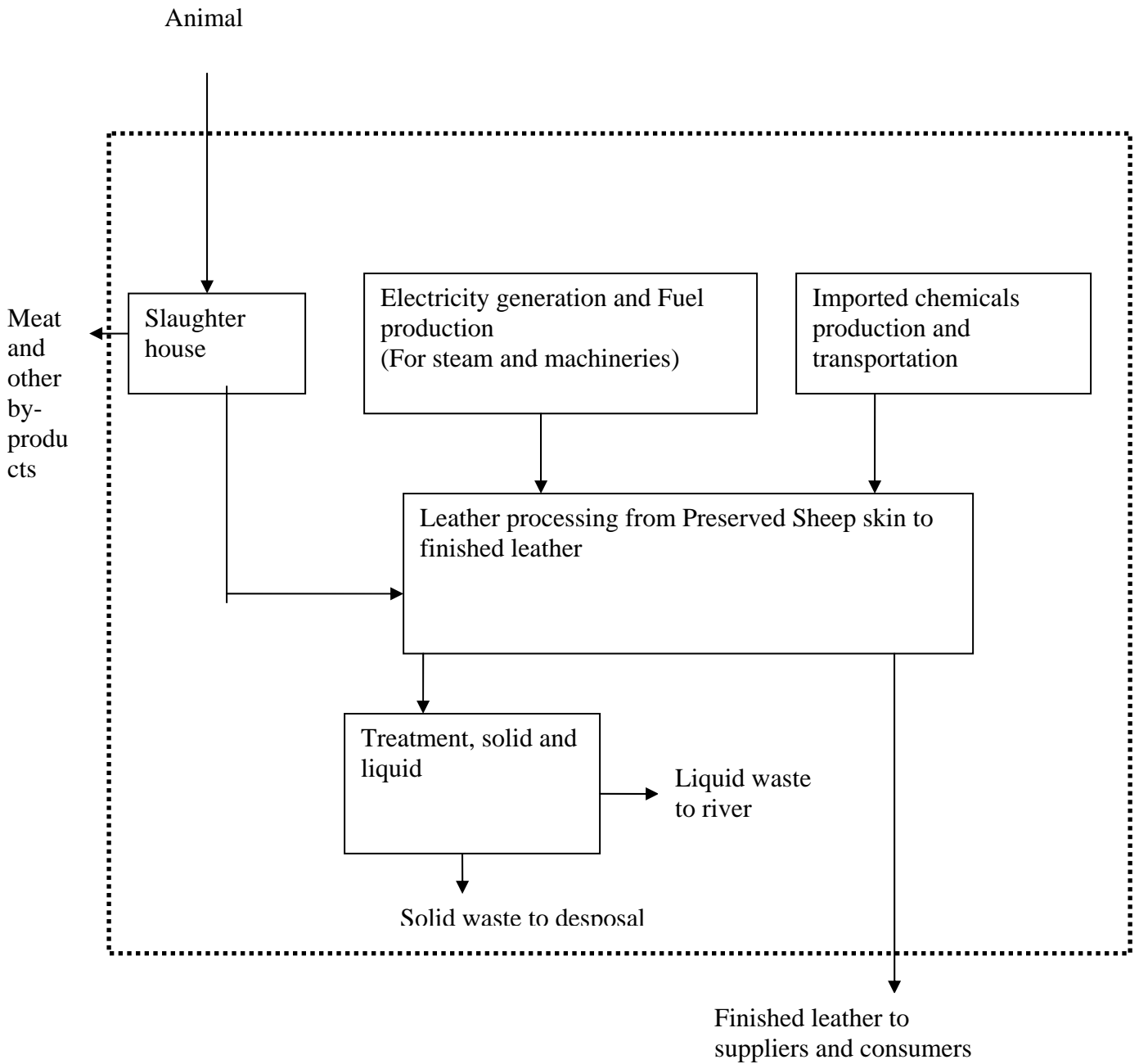


Figure 4.2: System Boundary of the leather processing

Data Quality

The project is focused on the LCA of leather product. Therefore, basic and important data are collected from three representative leather industries, those which have relatively in a good status of processing. An average data is taken for input /out put process. Atmospheric emission data are difficult to measure due to the technologies available in the industries, therefore data is taken from literature for a middling technology leather processing industry.

4.3.1.2 LIFE CYCLE INVENTORIES

In this Project, emission data was collected on major processing stages. Due to lack of measuring devices atmospheric emissions in processing stages was not determined quantitatively. But emissions from the fuel combustion for steam generation and emissions from transporting vehicle is determined using standard data.

To quickly build and analyze the LCA model it is basically required a transparent, high quality and widely accepted inventory data for commonly used materials and processes. ecoinvent data V 1.1 is used in this project. It is a life cycle inventory data including the area of energy, building materials, metals, chemicals, paper and board, forestry, agriculture, detergents, transport services and waste treatment. It is a rich database for impact assessment evaluation.

4.3.1.3 IMPACT ASSESSMENT

The project is mainly evaluated based on method Eco- indicator 99 as it is discussed in chapter 2. The Impact Assessment method of Eco-invent 99 is available in the annex (1).

4.3.2 INVENTORY DATA

An average Inventory data is taken from major processing steps and Auxiliaries. data are evaluated on the basis of a piece of Sheep skin (average area of 4.2ft²). The average input /output data for leather processing of a piece of sheepskin is given in annex (4).The major processing steps considered for emission are :

- i. Slaughter house
- ii. Preservation of skin
- iii. The beam house operation
- iv. Tanning operation
- v. Post tanning operation
- vi. Finishing operation
- vii. Effluent plant treatment plant operation

- i. Slaughter House

The Addis Ababa Abattoir is the largest animal meat processing plant in Ethiopia. The company receives livestock from farmers around Addis Ababa. The life cycle assessment starts from the gate of the Slaughter house.

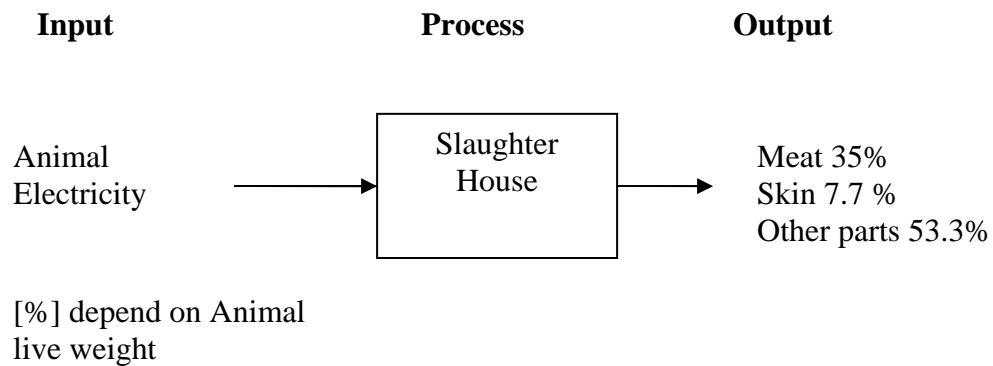


Figure 4.3 input output for slaughter house

The slaughter house works for 14 hours of a day and have a capacity of 300 sheep per day. A 10kw Compressor is used to facilitate the removal of skin. Water consumption for butchery purpose is 30 liters per sheep i.e. 0.03kw/sheep and 21 sheep/hr. The impact associated in the butchery is summarized in table 4.1.

Process	input		output		Major Emissions to Air		Major Emission to water	
	Slaughter House	Electricity	0.03kw h	Skin	1.5kg (7.7%)	*CO ₂	1.2g	*phosphorus
water		30 lt	Meat	17.6kg (90.6%)	Part.<2.5 μm	1.96mg	*Ammonia	0.5mg
Live animal		23kg	Other	0.3311 (1.7%)	* Particulate < 2.5 &<10 μm	0.427mg		
					*SO ₂	0.218mg		

Table 4.1: inventory data for slaughter house (* Source ecoinvent data base)

ii. Preservation of Skin and Transportation

The fresh skin from slaughter house distribute to the different tanneries. Most tanneries are accumulated in radius of hundred kilometers around Addis Ababa. Therefore a distance of 100 km is taken for the transport of skins to the tanneries. Salt is added to the skin in the preservation room.

Emissions associated in preservation are given in the table 4.2 below. Emission associated due to transport of skin is also considered. Therefore, emissions in this case are due to transportation of the skin from abattoir to the tanneries and since salt is considered as preservative, processing of salt from its source is also considered. It includes mining process of sodium chloride, its cleaning form impurities, and the drying step. It is sold as bulk and therefore no packaging materials are included. [35]

iii. Beam House Operation

A total of eight processes are taking place in beam house operation which are Soaking, Unhairing/Liming, Washing, Trimming, Deliming, Bating, washing and pickling. In this study all processes are generalized and taken as one process. Input / output, emissions and environmental impact associated are evaluated as a single process.

The leather industries require about hundred and fifty types of chemicals for processing. Of which, the impact of commonly known chemicals and those which are used in bulk are included in the LCA. Since most chemicals are produced and imported from Europe,

specially Germany and Italy emissions due to production and transportation is determined from Eco-invent database of these chemicals.

These chemicals are transported from Europe to Djibouti port by ship and from the port to the industries by Road. Emissions are evaluated for each processing step which consumes these chemicals.

An Average trans-oceanic distance from Europe to the port is taken as 8000 km and distance from the port to the tanneries is taken as 800 km. Based on these, emissions that arise on the result of transportation are calculated. The processing steps including the production of chemicals which are used in beam house operation and the corresponding energy utilization is discussed in the following paragraphs.

- Caustic soda: Production of chlorine from the electrolysis of salt with simultaneous production of caustic soda. The energy values stem from one early 90's source. Process emissions also stem from an early 90's source and are allocated according to weight. Land use and capital goods are not included. [35]
- Lime: includes crushing, milling, filtering (cyclone), dedusting, transportation, and storing. [35]

Process	Input(material, energy, transportation)		Output [kg]		Major Emissions to Air[g]		Major Emission to water [g]		Major Emissions to Soil [mg]	
			Salted Skin	1.7	-	-	Ammonia	0.034	Aluminum	0.35
Preservation	skin salt Transport lorry	1.5kg 0.2kg 100km			CO ₂ , fossil	113	BOD ₅	0.398	Calcium	12.6
					Methane fossil	0.158	DOC	0.170	Carbon	35.2
					nitrogen oxides	0.408	Nitrogen	2.78	Chloride	75.5
					NM VOC	0.68.6	Sulfate	1.05	Iron	28.8
					part.<2.5µm	0.062	SS	24.9	Magnesium	1.65
					part.>2.5&<10µm	0.177	VOC	0.0055	silicon	5.84
					Sulfur dioxide	0.348	Zinc ion	0.0036	sulfur	3.37

Table 4.2 Inventory data for Skin preservation

Process	Input (material, energy and transportation)		Output[kg]		Major Emissions to Air [g]		Major Emission to water [mg]		Major Emissions to Soil[mg]		Waste to treatment	
											Liquid [lt]	Solid[kg]
Beam House	salted skin	1.7kg	Pickled pelt	1.84	CO ₂ fossil	177.4	Calcium ion	470	calcium	3	41.49	0.147
	water	38.4 lt			Sulfur dioxide	0.428	BOD ₅	315	zinc	0.27		
	NaOH	0.034kg			part.>2.5 & <10µm	1.647	chromium ion	117	iron	2.8		
	sodium sulfate	0.034kg			part.<2.5µm	0.0027	DOC	120	carbon	2.3		
	lime	0.085kg					Cadmium ion	0.22				
	Chemicals transport(trans oceanic)	8000km					Suspended solid	19.8				
	Chemicals Transport road	800km					Arsenic ion	0.15				
	Electricity, Hydropower	10.1kwh										

Table 4.3 Inventory data for beam house operation

- Sodium Sulfate includes energy consumption for production and emission

The beam house operation requires steam (hot water). The demand of steam at this stage is about 0.226 kg/pc of skin which accounts around 22% of the total steam generated during the process. Emissions due to burning and hydropower electricity generation are discussed below.

- Thermal energy generated from burning of 1 kg of Diesel oil, Includes detailed emission data for heat production from diesel, including production and transport of primary energy sources, excluding the infrastructure of the energy systems. [35] In this project, the burning efficiency of 88% is used by taking an average value from the three industries.
- Included processes for hydropower electricity generation are area occupied; a preliminary estimation of greenhouse gas emissions out of the water reservoir; lubricant oil; volume of the reservoir; mass of water passing through the turbines. Net average efficiency, including pipe losses, is 78%. [35]

Inventory data for major Emissions to air, water and soil in beam house operation are given in the table 4.3 above

iv. Tanning Operation

Tanning is a step where a pickled pelt from the beam house is stabilized in order to get resistance of microorganism, acids and so on by using natural and/or synthetic chemicals. The associated emissions due to chemicals consumed and energy utilization in the tanning operations are given in the table 4.4 below.

Process	Input(material, energy, transportation)		Known output[kg]		Major Emissions to Air[g]		Major Emission to water[g]		Major Emissions to Soil[mg]		Waste to treatment	
											Liquid	Solid
Tanning operation	Pickled pelt	1.28kg	Shaved Wet blue	0.78	CO2 fossil	Liquid [lt]	Solid[kg]	4.66	calcium	9.2	3.5lt	-
	water	2.98 lt			SO ₂	0.22	BOD5	0.737	carbon	9.3		
	Sodium formate	0.0128kg			part.<2.5µm	0.065	Chloride	13.9	chloride	58		
	Sulfuric acid	0.051kg			part.>2.5 &<10µm	0.1	DOC	0.94	iron	46.6		
	Chemicals transport(trans oceanic)	8000km			Sulfur oxides	0.34	chromium VI	1.88	zinc	0.345		
	Chemicals transport road	800km					Chromium ion	0.011				
	Electricity, Hydropower	1.0527kwh										

Table 4.4 Inventory data for Tanning Operation

Process	Input (material, energy, Transportation)		Output [kg]		Major Emissions to Air[g]		Major Emission to water[mg]		Major Emissions to Soil[mg]		Waste to treatment	
											Liquid[l]	solid
Post tanning operation	Dried sheep skin	0.41kg	Shaved sheep skin	0.7	CO2 fossil	87	DOC	1975	calcium	2.35	9.72	-
	water	10.6lt			Sulfur dioxide	0.44	BOD5	281	carbon	2.00		
	Sodium formate	0.0357lt			Sulfur oxides	0.44	Chloride	94	chloride	52.5		
	ammonia	0.63kg			part.>2.5 & <10µm	0.3	chromium ion	28	zinc	0.279		
	Sulfuric acid	0.051kg			part.<2.5µm	0.087	aluminum	20				
	Chemicals transport (trans oceanic)	2.4396					chromium VI	0.52				
	Chemicals transport road	8000km										
	Electricity, Hydropower	800km										

Table 4.5 Inventory data for Post tanning Operation

Process	Input (material, energy, Transportation)		output [kg]		Major Emissions to Air[g]		Major Emission to water[g]	
	Finishing operation	Dried sheep skin	0.41kg	Finished leather	0.41	CO2 fossil	8	BOD ₅
Chemicals transport (trans oceanic)		8000km			Toluene	0.9		
Chemicals transport road		800km			NOx	0.12		
Fuel		17.4kJ			Glycol ether	0.13		
					Methyl ethyl ketone	0.75		
					particulates	0.57		

Table 4.6 Inventory data for Finishing Operation

v. Post tanning operation

Retanning, dyeing and fat liquoring are the basic operations in this section where different types of organic chemicals are used in order to give the chrome tanned leather property like fullness and warmth required in the finished leather. The known input output parameters are given in table 4.6 above.

vi. Finishing operation

The leather is summed to remove moistures, and then dried final finishing operation includes application of finishing chemicals. During application of dyes different types of volatile organic chemicals are evolved to the atmosphere. Since it is difficult to measure their emission rate, a standard value is taken from literature for average leather processing technology [1]. The emission associated to the finishing operation is given in table 4.6 above.

vii. Waste Treatment

Solid and effluent waste containing organic substances come up from raw material during processing like blood, manure hair, fat etc, and miscellaneous organic and inorganic chemicals during processing. The main effluent from tannery wastes are BOD, Suspended

Solid inorganic, chromium (Cr³⁺), sulfide, ammonia, and nitrogen, phosphorous and dissolved salts. Their amount of emission is shown in table 4.7 below.

Process	Input (material, energy, Transportation)		Known output[lt]		Major Emission to water[mg/lt]		Solid waste to disposal [kg]	
waster treatment	treatment influent	54.88kg	tannery effluent	30	BOD ₅	11.4	trims and chemical remnants	0.2kg
	Aluminum sulfate	5.3gm			Ammonia	43		
	lime	2.8g			Chromium ion	155		
	Electricity	0.0046kwh			phosphorous	1.86		
					Nitrogen cpds	22		
					Sulfur cpds	200		
					Susp. Solid inorg.	880		

Table 4.7 Inventory Data for Waste water treatment operation

4.3.3 DATA ANALYSIS AND INTERPRETATION

Characterization, normalization and weighting methods for Eco indicator are available in the annex 1. Software has been used to characterize, normalize and weight for the impact of emission at each processing steps.

There are different types of software like GaBi(developed by PE international), SimaPro (by PRe Consultants), Umberto(by Institut für Umweltinformatik Hamburg GmbH) available to evaluate life cycle assessment of a product or service . In this project SimaPro7 software is used to determine the impact assessment as well as the whole life cycle assessment of leather.

SimaPro7, new version of SimaPro, is a professional tool to perform Life Cycle Assessment (LCA) studies following the ISO guidelines. It is designed for easy modeling and analysis of the environmental performance of products from a cradle to grave

perspective. This integrated approach helps companies in prioritizing improvement options.

SimaPro 7 provide with a professional tool to collect analyze and monitor the environmental performance of products and services. It can model and analyze complex life cycles in a systematic and transparent way, following the ISO 14040 series (see annex 2) recommendations. The software contains encoinvent database and different impact assessment methods.

The inventory data is collected and summarized for eight processing steps. The impact on each processing steps is evaluated and integrated in the LCA of leather. The environmental impact in the beam house, tanning, post tanning, finishing and waste treatment operations is evaluated and shown in this paper. Since graphs for characterization normalization and weighing of all the eight processing steps are many, they are not shown in this paper. Only the final single score result for each processing steps are shown form figure 4.3 to 4.8.

i. Beam House operation

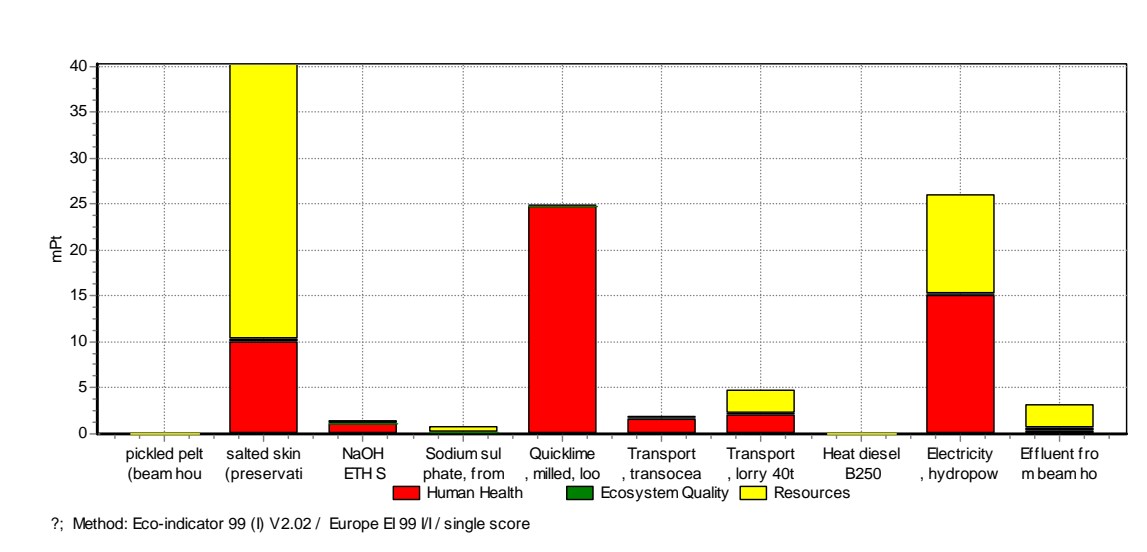


Figure 4.3: Single score weighted value for beam house operation

Figure 4.3 illustrates impact verses input to the beam house operation. The impact value is given in millipoint (mpt), a dimensionless number to compare the different impact categories. From the figure it can be observed that the impact on human health

and resource is more in the beam house operation. This is due to the impact associated in the extraction of salt and chemicals from their source and impact due to electricity and transportation.

ii. Tanning operation

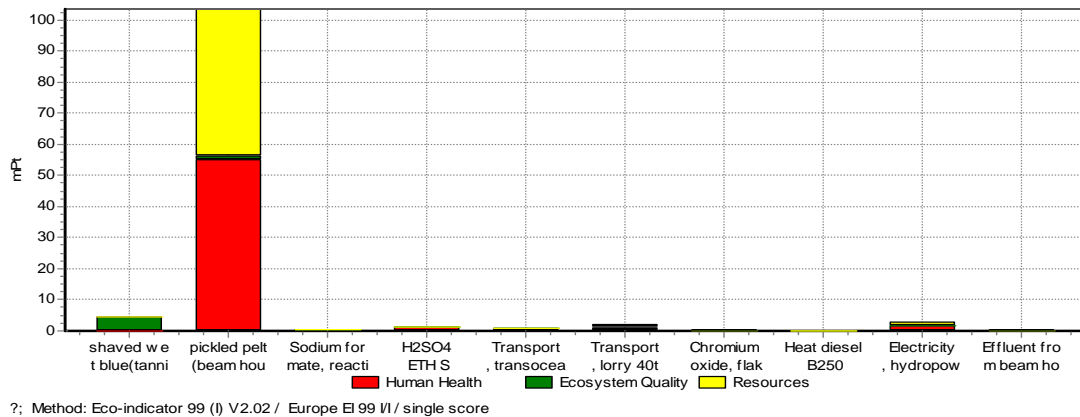


Figure 4.4: Single score weighted value for tanning house operation

As shown in figure 4.4, it can be seen that pickled pelt from the beam house operation is an input to the tanning operation. Impact of the tanned leather is cumulative impact of all processes up to beam house plus impact of tanning process. The tanning process has more impact on ecotoxicity. This is due to the emissions chrome due to processing.

iii. Post tanning

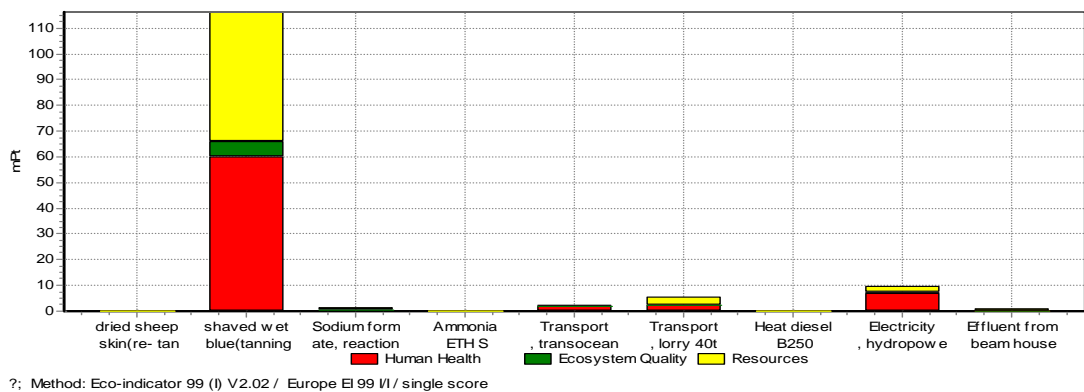


Figure 4.5 Single score weighted value for post tanning house operation

As it can be illustrated from figure 4.5, cumulative impact of a semi finished leather after post tanning operation is more impact on human health and resource depletion.

iv. Finishing operation

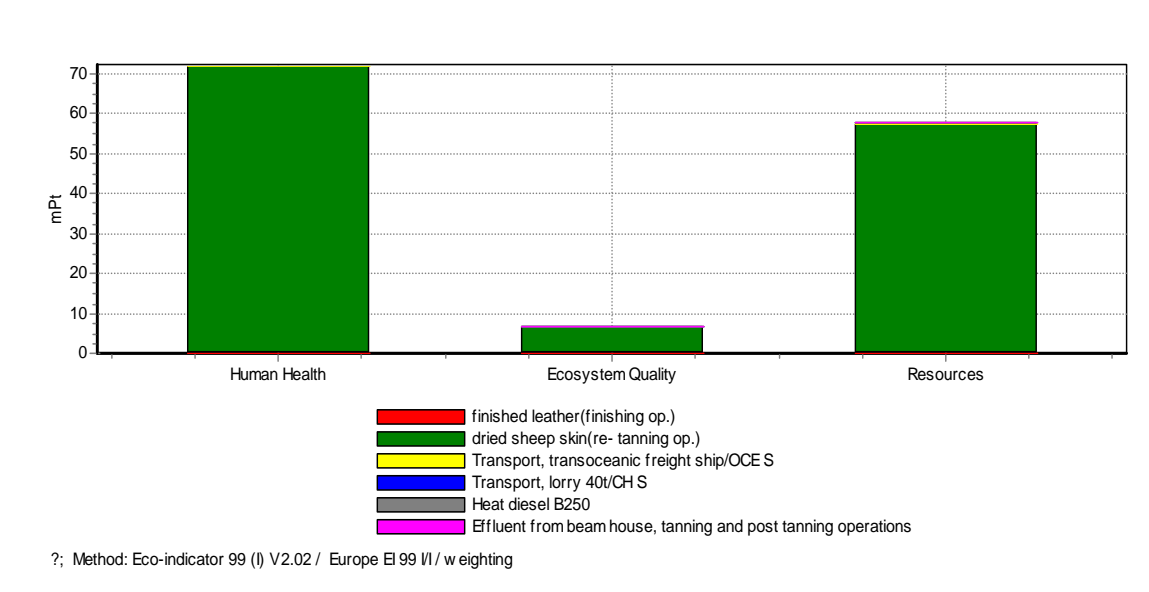


Figure 4.6: Single score weighted value for finishing operation

The cumulative impact of the finished leather is higher on resource and human health where as it is low in ecotoxicity (figure 4.6)..

v. Waste Treatment

In waste water treatment aluminum Sulphate is added for flocculation purpose which has an impact on resource and human health. The effluent from the waste water treatment plant has a typical impact on ecosystem quality. Impact on resource depletion is due to extraction of raw material for aluminum sulfate where as quality of ecosystem is the result of effluent of waste from the treatment plant. The effluent of different types of chemicals like chrome, sulfur, phosphorous, nitrogen suspended solids and organic compounds (see table 4.7) have created an impact on the ecosystem which is shown in the first histogram of figure 4.7 below

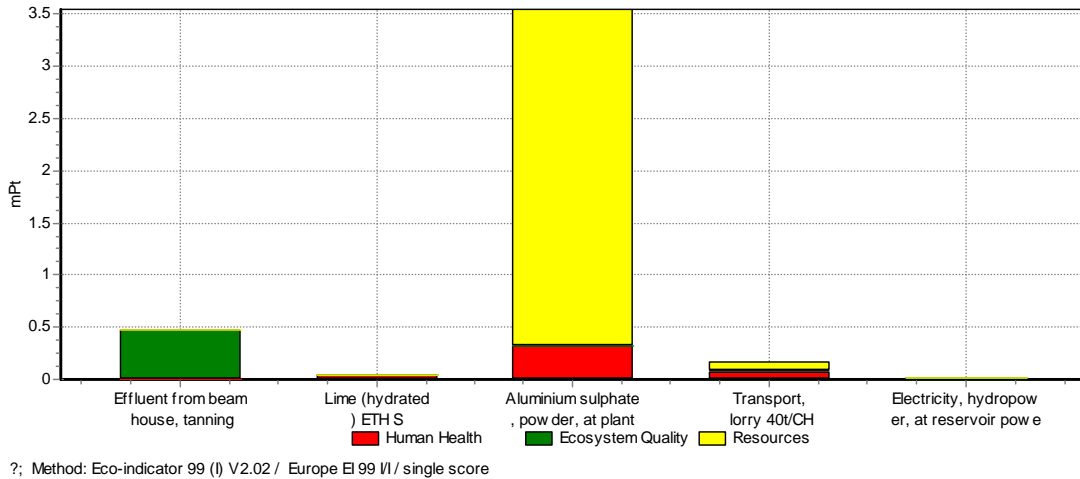


Figure 4.7: Single score weighted value for Waste treatment

LCIA of Finished Leather

The overall weighted value of finished leather is the sum of all weighted values of its processes; the result is indicated in figures 4.8 and 4.9 below. As it can be seen from these figures more impact occurred on human health and resource depletion.

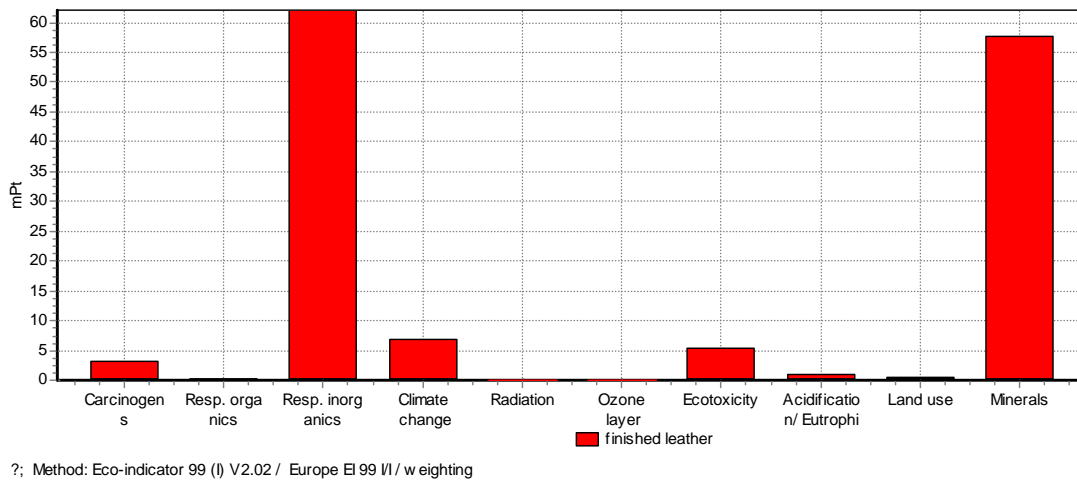


Figure 4.8: Single score weighted value for leather per impact category



Figure 4.9: Single score weighted value for leather

Impact on human health is due to respiratory inorganic chemicals. These are chemicals used in the processing, whereas the impact on resource is due to mineral extraction for the preparation of these chemicals.

The basic findings by applying life cycle network for leather processing are shown in figure 4.10 below. Since environmental impacts of most of the chemicals of leather processing are not known, the network includes only those which are mostly known and highly consumed chemicals.

In the network, those of the processes which have an impact lower than 9% are not shown in figure 4.10, but their impact is considered.

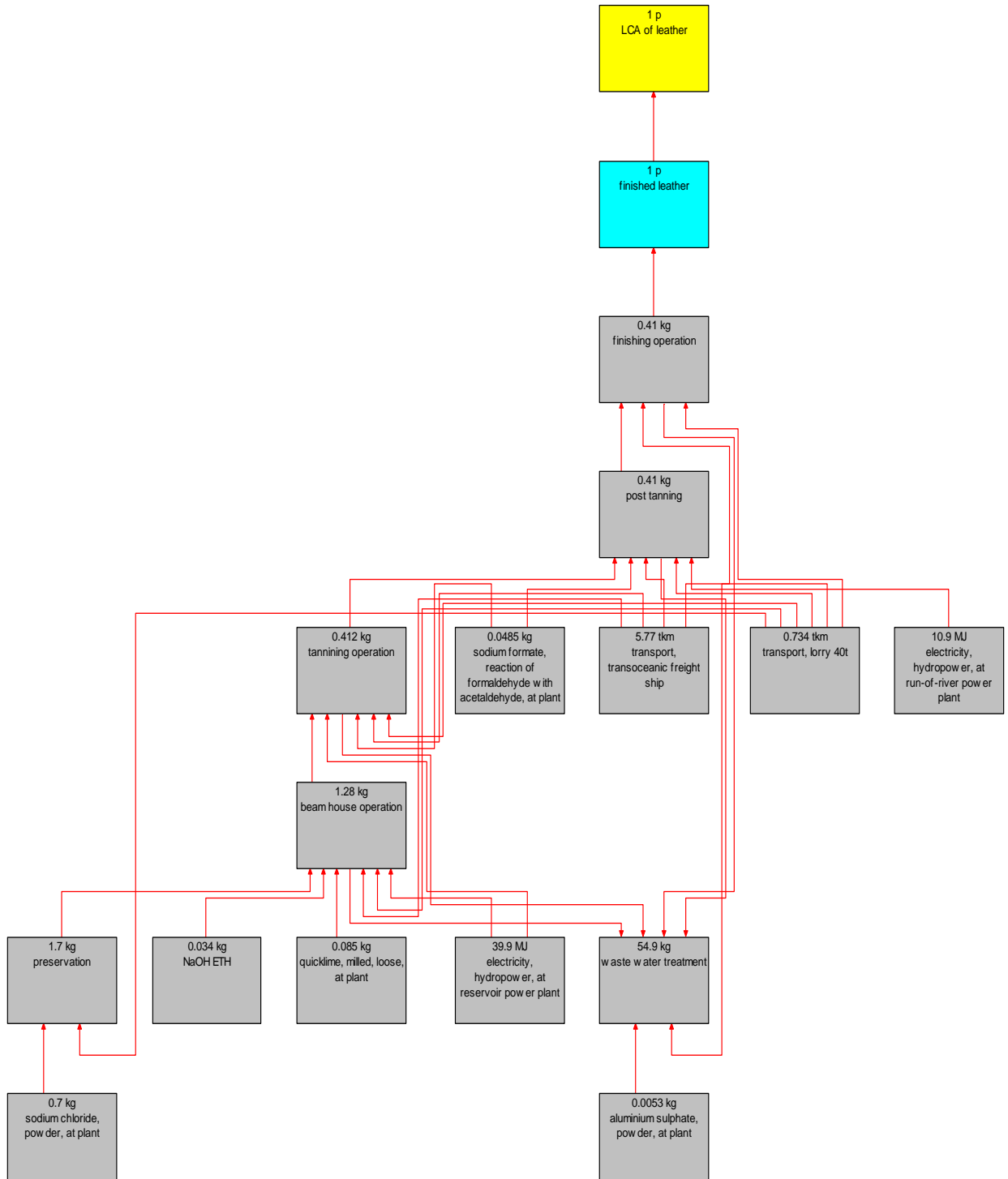


Figure 4.10: Shows the LCA network of leather product from the Slaughter house to the gate of the finished leather output with a cut off 9 percent.

Improvement Methods

Optimizing the consumption of chemicals like, sulphide during liming by adding enzymes and amines and increasing the performance of waste water treatment plant has an important role in minimizing the impact on ecosystem. Optimizing fuel and chemical consumption, preventing leakage in process equipments and substituting toxic chemicals by less toxic ones, proper handling and utilization of chemicals are the basic measures to mitigate impacts on human health.

4.3.4 CONCLUSION

Leather industry is highly chemical intensive and due to this

- First, there is large impact on resource depletion for extraction and processing of this chemical.
- Second, since these chemicals are toxic; their impact on human health specifically on respiratory tract is significant.

Since most of the chemicals are imported from Europe, impact related to extraction of resource is not a local impact so that much cannot be done on it. Whereas health impact and the ecotoxicity are more of an impact from the leather industries, therefore, it is more convenient to take measure by considering the social and economic aspects of the production system.

Most impact assessment methods including ecoindicator 99 are developed based on European standards. However, now a day's ecoindicator 99 has been directly used in more than 50 countries. This method has also been used for our case directly even though there may have a slight cumulative deviation in the output.

4.4 ENVIRONMENTAL COST ACCOUNTING FOR LEATHER PROCESSING

4.4.1 ENVIRONMENTAL COST CATEGORIZING

Environmental costs are evaluated based on the five cost categories shown in the table 4.8 below. Most of the environmental cost values were not directly evaluated. This is because environmental costs are considered as hidden cost in the financial bookkeeping.

Companies	Comp. A	Comp. B	Comp.C	Average
Environmental cost categories				
1. Waste and emission treatment				
1.1. Depreciation for Related Equipment	4.0%	2.145%	3.5%	3.21%
1.2. Maintenance and Operating materials Services	1.013%*	1.224%*	1.41%*	1.216%
1.3. Related Personnel	0.745%	0.228%	0.21%	0.394%
1.4. Fees, Taxes, charges	-	-	-	
1.5. Fines and Penalties	-	-	-	
1.6. Provisions for clean up costs, remediation	-	0.439%*	0.05%	0.245%
2. Prevention and environmental Management activities				
2.1. External service for environmental management costs	0.46%	0.521%	0.41%	0.464%
2.2. Personnel for general environmental management activities	0.44%	0.147%	0.54%	0.376%
2.3.research and Development	0.35%	0.69%*	0.5%	0.51%
2.4. Extra expenditure for cleaner technologies	-	-	-	-
2.5 Other environmental Management costs	0.002%	0.143%	-	0.072%
3. Material Purchase value of non-product output				
3.1. Packing	0.094	0.14%	0.05%	0.0947%
3.2. Operating Materials(Chemicals and salt)	82.9%	83.51%	85.54%	83.9%
3.3. Energy	8.7%	8.4%	10.95%	9.35%
3.4. Water	1.42%	1.283%	-----	1.351%
4. Processing cost of non product output	5.38%*	6.4%*	7.01%*	6.26%
Σ Environmental expenditure	105.504%	103.871%	107.1%	105.32%
5. Environmental Earnings				
5.1. Subsidies, awards	---	-	-	
5.2.other earnings (sales of trim, hair and packing materials ,recovery of Chrome)	- 5.504%	-3.86%	-7.1%	-5.488%
Σ Environmental earnings	-5.504%	-3.86%	-7.1%	-5.488%
Balance cost earnings	100%	100.0%	100%	100%

Table 4.8 Environmental cost categories for different companies

The environmental cost values are estimated of the three companies and an average cost is taken. The cost categories are put in percentage in order to compare and see the difference among various environmental cost categories. Since environmental costs are considered as hidden cost or being as a part of a whole cost, an estimation is done to evaluate some of the cost categories. For example maintenance and operation cost of waste treatment plant is not directly obtain since maintenance and operation cost of treatment plant is not recorded independently rather the whole operation and maintenance is recorded. Maintenance and operational cost is determined by evaluating the percentage cost of overall maintenance and operation.

Material purchase value of operating materials in any processing industries accounts between 40 to 90 percent of the total environmental cost [22]. Since leather industries are chemical intensive industries, the average material purchase value is about 84 % as shown in the table 4.8. A small change in the percentage of the purchased value gives a significant change in the environmental cost values.

In evaluating of environmental cost categories, environmental revenues are taken as a negative value in the cost categories. Most environmental revenues are from selling of trims and chemical packing plastics.

4.4.2 MATERIAL FLOW BALANCE

Since the capacity of the three companies is different, material flow balance is done on a basis of single piece of skin/hide to get an average value from the three companies. The input output flow balance is shown in tables 4.9a and 4.9b.

Input	Comp. A	Comp. B	Comp. C	Average (comp. I)
Raw material(kg/Pc. skin)	1.69	1.68	1.73	1.7
Salt (kg)	0.28	0.141	0.32	0.25
Chemicals(kg)	0.6373	0.709	0.81	0.71
Elec. Energy(kwh)	0.3144	0.44	0.29	0.36
Fuel (lt)	0.2	0.24	-	0.23
Water(lt)	50.8	46.8	53.4	50.3

Table 4.9a: Major input in leather processing

Out put	Comp. A	Comp. B	Comp. C	Average (comp. I)
Product(kg/pc)	0.43	0.38	0.40	0.41
Trims as byproduct(kg)	-	0.176	0.164	0.17
Solid waste(kg)	0.325	0.417	-	0.365
Waste water(lt)	38.5	33.9	42.2	38.2

Table 4.9b: Major output in leather processing

4.4.3 PROCESS FLOW CHARTS

The process flow chart of leather processing is divided in to four main operations, the beam house, tanning, post tanning and finishing operations. It can possible to further categorize and see details of each unit operations and specific equipments.

Material flow and cost associated for each unit operation is shown in the process flow chart. The process flow chart combines the technical information with cost accounting data. Percentage of chemical and water consumption by mass and energy consumption of each unit operation is given in the figure 4.11. The material flow and cost accounting values are evaluated by summing up of all amount and cost of non product outputs.

It can be observed that mainly the beam house operation is chemical and energy consuming process and it accounts an overall material flow cost of around 42 % of all the total cost in overall process (fig 4.11 below). The beam house operation can further classified into sub unit operations and even to individual equipments so as to determine losses, leakages and waste streams at the specific sources. Similarly the same thing is applied for the other three unit operations.

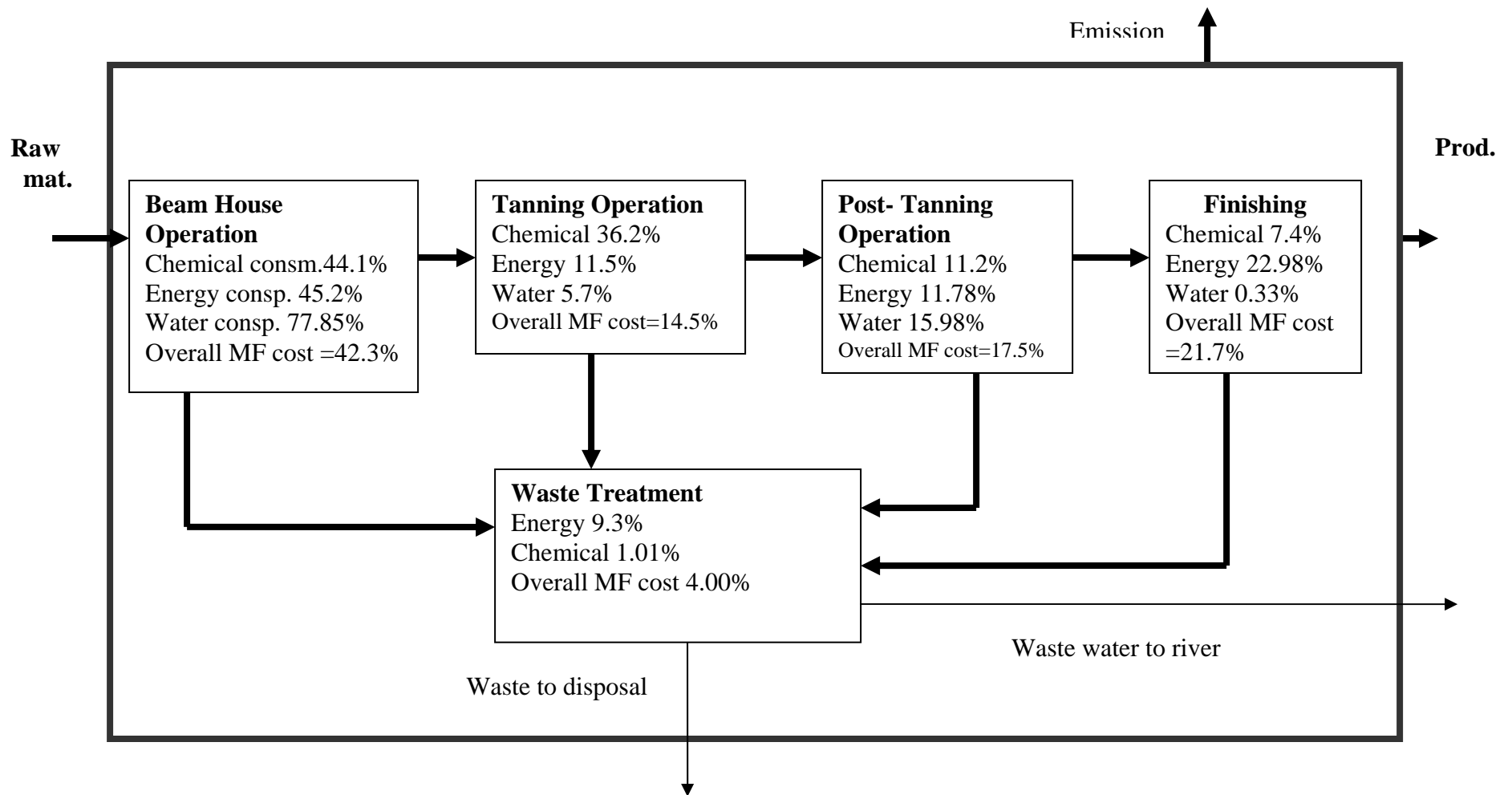


Figure 4.11: material flow and cost accounting chart

4.4.4 CONCLUSION

- Environmental cost accounting on leather processing helps to identify the environmental loads quantitatively.
- The overall environmental cost is determined by calculating of every cost according to its category.
- Material flow cost of the beam house operation accounts 42.3% of the overall flow cost of the leather processing which accounts the larger portion of the flow cost. Likewise, finishing and post tanning operations account 21.7 and 17.5% respectively.
- Material flow cost can be further divided in to sub unit operation and equipments in depth so as to determine the material flow cost of each sub unit operations and equipment.

4.5 SOCIAL AUDITING FOR LEATHER INDUSTRIES

The social auditing is performed for the three companies independently so that the common social norms are evaluated and an average value is taken for the purpose of integrating. In this case the scope of the social auditing covers the company fence and the local community. Other stakeholders such as customers, raw material and chemical suppliers, government etc. are not included.

4.5.1 AUDITING THE THREE LEATHER INDUSTRIES

COMPANY A

i. Document Review

Some of the documents of this company were reviewed and basic information has been collected. According to this, percentage of workers based on their departments is given in table 4.10 below.

Department	Permanent[%]	Non permanent[%]	Total[%]
Production	46.9	11.5	58.4
Quality Control	0.58	-	0.58
Commerce	5.6	3.6	9.2
Maintenance	9	0.8	9.8
Audit and Finance	2.78	-	2.78
Administration	19.14	-	19.14
Total	84.0	15.9	100

Table 4.10 percentage distribution of workers (company A)

It is known that leather industry is a labor intensive. Due to this, there are a large number of workers who are doing in the production and administration department. As shown in table 4.10 around fifty percent of workers in company A are engaged with the production and maintenance activities. Women account 17% of the total workers of the factory.

The company has one shift per day except some areas where a continuous follow up is required. There is a break time of one hour and workers are provide with meal.. In this company all workers are over the age of twenty. Almost all workers have a service car in the morning and after the working time.

The leather industry is not only labor intensive, but also high chemical consuming industry. Organic and inorganic chemical consuming operations are beam house, tanning and finishing operation. Most of these chemicals are volatile and powders which can easily particulate in the air during mixing when mixing with water or other solvents before they get in to the process. These chemicals can easily affect the respiratory tract and skin of workers while processing. The Health impact of workers in company A is given in the table below.

Data had been collected from workers who have taken medical service from August to January 2006. Around 59% of the total workers take medical services every month. Of which 41% of them are from production department and the rest are from administration

and finance. 62% of the total workers in production department are taking medical service every month.

The most common types of disease reported are respiratory, parasitic and skin disease. 30% of the disease registered as respiratory, 28% parasitic and 10% is skin disease. The rest are different types of diseases. Almost all of the respiratory and skin diseases and 72% of the parasitic disease are registered from the production department. From the total of worker in the production department 28.5% of them are suffered from respiratory infection.

Almost all casualties occur in production and technique departments where most of them are due to slippery, chemical exposure and colliding with drums.

ii. Site inspection

Overall view of the factory is relatively attractive and it gives motive and comfort for the workers. When it is seen the inside of the factory from raw material storage to the finished product store, the raw material is well stored in a way that it can be taken easily away for further processing. The beam house and tanning sections are wide enough for work facilitation and ventilation. The drums in these sections are not protected enough in case of emergency. Workers do not use safety glasses when they mix and put chemicals in drums. In post tanning and finishing operation sections, critical observable things are that there are more volatile components are leaking from spraying machines and also particulates of leather crust during shaving. There is an emergency door in every section. There is also gathering and decision making area during emergency. The factory does not have a proper land fill for solid waste disposal instead solid waste is disposed in nearby dumping site. The waste water is treated left in a lagoon where part of it evaporates and the rest segregate in the ground.

iii. Interviews

An interview has been made with workers of different departments and top managements. Interview has also been made with local communities in order to get external information. The issues included in the interviews are working, hygiene, health insurance overtime, meal and break time, off days and forced labor. Efforts have been put in place to find whether these factors are practiced properly or not.

Local communities have a direct or indirect link with the factory. Some of them are workers of this factory and the rest have their own small scale business where they generate income by selling goods for the society in the factory. Due to this they have a good image for the factory. Since there is no people living behind the factory no one claim on the disposal and the waste.

An interview with the top management of the factory was more open so that they were willing to give the necessary information about the social aspects of the factory. There is a freedom of association and an open system between the management and workers.

Although there is a labor union in the factory where workers claim their right, the unity does not accomplish its duty as it is expected due to various reasons. They elect their representative to communicate directly with top management concerning their right. Workers get their salary according to the scale of the factory. They get one to two months bonus every year. Workers who are working in the production section especially those who are working in beam house and tanning sections are taking a periodic medical checkup. Families of the employees are also getting medical services.

COMPANY B

i Document review

Document is reviewed on man power status of the factory (table 4.11). Since there is no well organized medical service in the factory workers get referral outside. Therefore it was difficult to get information related to medical services.

Departments	Male in [%]	Female in [%]	Total in [%]
Administration	14.4	5.2	19.6
Finance and Accounting	0.92	2.76	3.38
Procurement and Sales	5.5	1.84	7.34
production	40.79	15.64	56.34
technique	10.4	0.307	10.47
Quality control	1.84	0.307	2.147
Total	73.85	26.05	100

Table 4.11 percentage distribution of workers (company B) in [%]

The company has one shift per day which has eight working hours. There are a total of 275 working days per annum. Like company A, monthly salary of workers is according to the scale of the company.

ii Site inspection

Similar to Company A, the overall outside view of the factory is attractive. There is a notice board to provide information about the environmental management system policies and qualities of the company. Coming to the production section, the ceiling in raw material storage is short where there is no proper ventilation. Due to this, it generates bad smells. Company B has also a problem in protecting device of workers from the rotating drums. On top of that the working space in beam house section is narrow enough for to facilitate work. The chemical storage room is well safe and organized to give services for

each section. There are emergency doors and fire extinguishers in each section. Waste waters from tanning and beam hose operations are collected separately. Waste water from beam house is undergoing only sedimentation and disposes to the river directly. Solid wastes from tanning and finishing are collected and dispose to the outside. There is no permanent worker in the treatment section.

iii Interview

The local community complains to the company for the inappropriate water treatment and disposal. Interview with top management and workers is similar with that of company A except that there is no worker union and association in which it is undermined. People in the top management said that they have a plan to install a new waste treatment plan so as to minimize the disposal rate.

COMPANY C

Man power status of the company has been reviewed from the documents (table 4. 12). There are more similarities with the company B except few things. First, the production section especially in the beam house section is more compact, but the drums in the beam

Departments	Workers number in [%]
Administration	17.8
Finance and Accounting	3.9
commercial	8.1
production	56.5
technique	11.04
Quality control	2.59
Total	100

Table 4.12 percentage distribution of workers (company C) in [%]

house and tanning sections are well protected from the accident of collusion with operators. Second, the treatment plant is well functioned and the impact of the environment due to effluent of waste water is relatively minimal. Effluents and influents are regularly recorded. Due to this there is not as such significant complain from the local community.

4.5.2 MEASURING USING SOCIAL ACCOUNTABILITY REQUIREMENTS

A detailed social auditing in the three companies is not done. This is because it needs more time and it cannot be accomplished with given specified time. Even though the data are course and need more refinements, it is possible to weigh some of the basic social accountability requirements of the companies. Requirements are discussed below.

Child Labor: ILO defined child labor as; it is any work by a child under the age of 14. Therefore none of the three companies are reported as the exploiting of child labor. This is observed from the document review and site inspection.

Health and Safety: this covers identifying and preventing of potential hazards of the company, providing of healthy and shall take adequate steps in preventing of accidents and injury to health, supplying of regular training related to health and safety, providing of clean bathrooms and access to potable water.

Under these measurements all the three companies are not fully qualified. Especially on the issue of training related to safety prevention of accidents and injury at the working places, there is no record of regular training of health and safety except company B where there were two trainings within one year period. Some of the workers in the beam house and tanning section do not have a suitable glove and protective clothes and the rest have protective clothes which are old enough to protect from chemicals.

Freedom of Association and right to collective bargaining: In this case a company is expected to respect the right of all personnel to form and join trade unions of their choice and to bargain collectively. From interview with workers it is obtained that there is no

freedom of association and worker union except company A which is doing little activities. It is well known that companies should give serious attention in this regard since workers are the source of productivity.

Disciplinary practices, Remuneration, Forced Labor and Management System are also basic requirements for social accountability where it needs regular and continuous assessments. In a short period of time and in a condition where there is no fully written documents and no practice of social auditing, it is difficult to evaluate these companies with these measures [29].

4.5.3 CONCLUSION

Social auditing is a process of defining measuring, reporting of organizations ethical behavior and social impact against its objectives. In these companies there no clearly defined and developed audit framework so that this makes the auditing tough. In general social auditing is not considered as major issues in companies of developing countries like Ethiopia. They mainly focus on their profit. Like the environmental protection agencies the ministry of social affairs is responsible for issues related workers in and community welfare. On top of that companies are also expected to develop a social auditing framework.

4.6 INTEGRATING THE THREE MODELS

An integrated model identifies the life cycle impact of the leather product and extends this impact in relation to social and environmental perspective.

4.6.1 IDENTIFYING AND TAKING A MEASURE TO MINIMIZE THE KEY IMPACTS

The identified impacts from LCA of leather indicate that there is amore impact on human health and resource depletion. Impact on ecosystem has also a significant impact. Resource impact is not a local impact; therefore, measures cannot be taken directly unless

alternative chemicals with less impact on resource depletion have been used. Human and ecosystem impacts can be minimized by taking measures directly.

The impact on human health is due to

- Emission of volatile and non volatile toxic chemicals in the companies,
- Exhaust gas from combustion of boilers in the companies
- Exhaust of raw material and chemical transporting vehicles
- Increasing in the concentration of CO₂ in the reservoir of hydropower plant which is a source of global warming.

Impact on human health is due to hydropower electric generation and exhausts of transporting vehicles are global and regional impacts. These impacts are low compared with exhaust gas from boiler fuel combustion and chemical emissions which occur in the company. Since they are local impacts measures can be taken directly.

Output of medical treatment information from social auditing section has been an input for determination of respiratory impact of human health. Due to unavailability of data on workers health from company B and C, company A is taken as a reference. The social auditing of company A, 28.5% percent of workers in production department are suffered from respiratory problem which accounts 32% of the annual cost budget of medical treatment or 0.57% of the annual revenue of the company. The cost for health care accounts 1.78% of the total annual revenue.

Measures to minimize the impact on human health includes

- Wearing protective devices like goggle and gloves;
- preventing of leakage of finishing equipments;
- substituting normal sprayer with a photo-cell assisted paint spraying technology to avoid over spraying in finishing operation;
- Proper ventilation shaving and finishing rooms: and
- substituting of organic based solvents by water based solvents

These measures reduce the impact on human health. By doing so the *annual provision for clean up cost*, which is 0.245 % (table 4.8) of the overall environmental cost, raise up to 1% depending on the type provision for clean up. By doing so, impact on human health and cost of medical treatment will be minimized.

Impact on Ecosystem quality is mostly due to effluent of waste treatment (Fig 4.6). Effluent contains more of chrome, sulfate and heavy organic compounds.

Measures taken to minimize the impacts are

- Increasing the performance of treatment plant: Cost for waste and emission treatment is 5.07% (table 4.8) of the total environmental cost. This includes depreciation, maintenance and provision of clean up and remediation. Increasing the performance of treatment plant especially on secondary (biological) treatment plant may increase the environmental cost but it can minimize emission of waste and will have a good image of the company by its neighborhoods.
- Substituting of more hazardous chemicals which end up in waste treatment with less hazardous one. For example examine alternatives to chrome in tanning, such as titanium, aluminum, iron, zirconium, and vegetable tanning agents the other is Using non organic solvents for dyeing and finishing rather than organic solvents. [33] Compare the substituted chemical environmental cost with the existed one.
- Optimizing consumption of chemicals, salts and water: optimum consumption of sulfide and lime, recycling of spent chrome liquor chrome which will reduce the environmental cost since around 84% of the environmental cost is purchase value of these chemicals. It also decreases the material flow cost in waste treatment which is 4.00% as shown in fig 4.10.

- Minimize the amount of Solid waste: by proper trimming and recycle wastes to the extent feasible in the manufacture of fertilizer, animal feed, and tallow, provided the quality of these products is not compromised. Use tanned shavings in leather board manufacture in which it requires detail studies.

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5.1. CONCLUSSION

- From an average value taken, it can be said that the three Leather industries have impacts on human health and ecosystem quality. Specifically due to the consumption of chemicals and disposal of waste.
- Human impact in leather processing is due to emission of volatile and non volatile organic and inorganic chemicals which are used for processing. They cause a problem in respiratory tract of workers.
- Environmental cost of the beam house operation accounts 42.3% of the overall cost of the leather processing which accounts the larger portion of the flow cost. Likewise, finishing and post tanning operations account 21.7 and 17.5% respectively.
- Impact on eco system quality (impact in the surrounding vegetation) is due to the result of effluent containing Cr_2O_3 , BOD_5 , sulfates and suspended maters and disposal of solid waste.
- These two impacts have been evaluated using LCA and the consequence is evaluated from the social auditing and environmental cost accounting to arrive on measures.
- Generally using the frame work developed, environmental impacts addressed by life cycle assessment are get approached and reached to decision by considering the economics and social aspects.

5.2 RECOMMENDATIONS FOR FUTURE WORK

- Most leather industries in Ethiopia do not have a custom of data recording and documenting. In a condition like this it is difficult to collect an average data from these industries. Therefore industries should develop such awareness so as to clearly know their input and outputs related to environment.
- A detail and well organized data gives a more accurate result in LCA as well as in environmental cost accounting. For the case of leather industries in Ethiopia data should be collected relatively from those who have a regularly recorded and documented data.
- An integrated approach is not developed in detail where it requires a further analysis that should also incorporate all stakeholders. Further development should be done so as to get a general frame work for any processing and service dealing company.
- A more satisfactory result will be obtained if the boundary of the LCA is further expanded. This is done by including the impact associated in the raising of animal and disposal Scenario of leather product.

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ANNEX 1 DAMAGE FACTOR AND ASSESSMENT FOR
ECO-INDICATOR 99 METHOD

This annex lists the Eco-indicator 99 damage factor in the individualist perspective (I,I) for the substance lists that can be found in most popular LCA database. Next to the damage factors two columns are added with the normalized and weighted damages. Some of the examples of normalization factors and weights are specified below.

	Normalization	Weights
Human Health	121	550
Ecosystem Quality	4.51E+03	250
Resources	1.48E+02	200

1. Damage category to human health (I, I)

The human health damages are specified in DALYs. This is short for Disability Adjusted Life Years. Some of the lists are shown below. DALY calculations are based on age weighting.

All damage factors are expressed per kg emission. The unit of Damage is DALY

Human damage categories	Compartme nt	Substance	Damage factor	Normalized Damage factor	Weighted Damage factor
Carcinogenic Effects	Air	Arsenic	1.00E-03	1.21E-01	6.67E+01
	water	Arsenic	3.42E-02	4.15E+00	2.28E+03
	soil	Arsenic	7.28E-04	8.82E-02	4.85E+01
>>	>>	>>	>>	>>	>>
Respiratory Effect(inorg.)	Air	ammonia	5.1E-05	6.18E-03	3.4E+00
	Air	Dust(PM10)	2.74E-04	3.32E-02	1.83E+01
	Air	SO ₂	3.90E-05	4.73E-03	2.08E+00

	>>	>>	>>	>>	>>	>>
Climatic Change	Air	Methyl chloroform	-4.2E-05	-5.09E-03	-2.80E+00	
	Air	CFC-11	2.20E-04	2.67E-02	1.47E+01	
	Air	CO ₂	2.00E-07	2.42E-05	1.33E-02	
	>>	>>	>>	>>	>>	>>

2. Damage to Ecosystem Quality (I,I)

The ecosystem quality damages are specified as PDF*m²*yr. PDF is Potentially Disappeared Fraction of Species. A damage of one means all species disappear from one m² during one year, or 10% of all species disappear from 10 m² during one year, or 10% of all species disappear from 1m² during 10 years. Within the damage category Ecosystem quality special care is needed to avoid double counting when land use is modeled.

Ecosystem Damage categories	Compartme nt	Substance	Damage factor	Normalized Damage factor	Weighted Damage factor
Ecotoxic emission	Air	1,2,3,-trichlorobenzine	3.51E-02	7.78E-06	1.95E-03
	water	1,2,3,-trichlorobenzine	1.56E-01	3.46E-05	8.65E-03
	Soil	1,2,3,-trichlorobenzine	2.41E+00	5.34E-04	6.60E-02

3. Damage category Resources(I,I)

The damages to resources are specified as MJ surplus energy. A damage of 1 means that due to certain extraction further extraction of resources in the future require one additional MJ of energy, due the lower resource concentration, or other unfavorable characteristics of the remaining reserves.

The damage factors are per Kg of extracted metal or ore:

- “in ore” refers to the metal content in the ore, so 1kg iron(in ore) means one kg of pure iron
- “ore” refers to the ore. An average metal content is assumed to calculate these figures.

The unit of damage is MJ surplus energy per kg of extracted metal

Minerals	Damage Factor	Normalized damage Factor	Weight Damage Factor
Aluminium(in ore)	2.38	1.59E-02	3.17E+00
Chromium(ore)	0.9165	6.11E-03	1.22E+00
Copper(ore)	0.415	2.77E-03	5.53E-01

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ANNEX 2 ISO 14000 STANDARDS ON LCA

In September 1996, ISO, the International Organization for Standardization based in Switzerland, initiated the ISO 14000 series of environmental management system standards. These are a series of environmental management standard guidelines for auditing; Ecolabelling, environmental performance evaluation, and LCA.

ISO 14000 Series of Environmental Standards (as of September 1999)

ISO 14001 Environmental Management Systems—Specifications with Guidance for Use

ISO 14004 Environmental Management Systems—General Guidelines, Principles, Systems, and Supporting Techniques

ISO 14010 Guidelines for Environmental Auditing—General Principles on Environmental Auditing

ISO 14011 Guidelines for Environmental Auditing—Audit Procedures— Auditing of Environmental Management Systems

ISO 14012 Guidelines for Environmental Auditing—Qualification Criteria for Environmental Auditors Life Cycle Assessment—Principles and Guidelines, Standards in draft or committee discussion

ISO 14015 Environmental Aspects of Sites and Entities

ISO 14020 Environmental Labels and Declarations—General Principles

ISO 14021 Environmental Labels and Declarations—Environmental Labeling—Declared Environmental Claims—Terms and Definitions

ISO 14024 Environmental Labels and Declarations—Environmental Labeling Type I—Guiding Principles and Procedures

ISO 14025 Environmental Labels and Declarations—Environmental Labeling Type III—Guiding Principles and Procedures

ISO 14031 Environmental Performance Evaluations

ISO 14032 Environmental Performance Evaluation—Case Studies in the Use of ISO 14031

ISO 14041 Life Cycle Assessment—Goal and Scope Definition and Inventory Analysis

ISO 14042 Life Cycle Assessment-Impact Assessment ISO 14043 Life Cycle Assessment-Interpretation

ANEEX 3 ENERGY CONSUMPTION OF GAREMENT MANUFACTURING
FROM SHEEPSKIN

Operation	Process name	Power consumption, KW	Capacity, pcs/hr	Energy, kJ/pcs	Energy, kJ/sq.ft
Beam house	Preservation	0			
	Soaking	11	500	0.02	0.004
	Liming	16	100	0.16	0.029
	Dewooling	13	120	0.11	0.020
	Fleshing	12	250	0.05	0.009
	deliming	16	6	2.67	0.485
	Bating	16	6	2.67	0.485
	Degreasing	16	6	2.67	0.485
	Pickling	16	6	2.67	0.485
	Tanning	16	6	2.67	0.485
Tanning	Summing	16.5	150	0.11	0.020
	Shaving	45.1	140	0.32	0.059
	Retanning	6.5	25	0.26	0.047
Post tanning	Dying	6.5	25	0.26	0.047
	Fatliqouring	6.5	25	0.26	0.047
	Convotional dring	1.1	250	0.00	0.001
	Summing & setting out	16.5	150	0.11	0.020
	Togglng	11.5	100	0.12	0.021
	Stacking	14.3	130	0.11	0.020
Finishing	Moistening machine	0.8	300	0.00	0.000
	Buffing	14	60	0.23	0.042
	Air blust dedusting m/c	57.5	90	0.64	0.116
	Spraying	22.4	500	0.04	0.008
	Polishing machine	10.5	100	0.11	0.019
	Ironing	39	180	0.22	0.039
	Area measuring	4	300	0.01	0.002
	Steam generator	23.8			
	EMTU	0.018			
	Anti-scaling and deox. agent dosing unit	0.5			
Boiler	Fuel oil feed system from tank	0.6			
	Air compressor	30			
	Submmersible pumps	44			
	Water pumps (supply)	110			
	EMTU	0.04			
	Chlorination station	1.6			
	Total	210.558			

ANNEX 4 OVERALL MASS BALANCE OF SHEEP SKIN FROM PRESERVATION
TO FINISHING OPERATION

Process	Input		Out put	
	Name	Amount kg/Pcs	Name	Amount kg/Pcs
Preservation	Green sheep skin	1.5	Wet salted sheep skin	1.7
	Salts	0.7	Free salt damped	0.221
	Antibacterial	0.03	Water	0.3
			Dung, other dirt	0.00825
Soaking	Wet salted sheep skin	1.7	Soaked sheep skin	1.87
	Water	20.4	Salt	0.19
	Wetting agent	0.0049	Water	19.95
			Wetting agent	0.0049
			Blood, dung	0.024
	Soda ash	0.02	Soda ash	0.02
Unhairing/liming	Soaked skin	1.87	Limed pelt	1.92
	Water	4.74	Water	4.79
	Sodium sulphide	0.0374	Sodium sulphide	0.0384
	Sodium sulphidrate	0.02805	Sodium Sulphidrate	0.0288
	Lime	0.1309	Lime	0.1309
			Fats, soluble protein	0.031
Washing	Limed pelt	1.92	Limed pelt	1.92
	Water	5.76	Water	5.76
			Soluble protein	0.026
Fleshing, trimming	Limed pelt	1.92	Fleshed limed pelt	1.28
			Fleshing	0.47
			Trimming	0.17
Washing	Water	4.00	Water	4.00
Deliming, Bating	Fleshed limed pelt	1.28	Fleshed delimed pelt	1.28
	Water	2.56	Water	2.56
	Ammonium salts	0.0192	Ammonium salts	0.0192
	Enzymes	0.0128	Enzymes	0.0128
Washing	Water	3.5	Water	3.5
	Fleshed delimed pelt	1.28	Fleshed delimed pelt	1.28
Picking	Fleshed delimed pelt	1.28	Picked pelt	1.28
	Water	1.28	Water drain	0.64
			Water in drum	0.64
			Salt(calcium sulphide)	0.013
	Salt	0.128	Salt (Sodium chloride)	
	Sulfuric acid	0.0128	Sulfuric acid	0.0128

Table A3:1 Mass balance of Ethiopia sheep skin beam house operation

Process	Input		Output	
	Name	Amount kg/pcs	Name	Amount kg/pcs
Tanning	Pickled pelt	1.28	Wet blue	1.355
	Water added	0.64	Water	1.28
	Water at pickled bath	0.64	Basic chromium sulphate	0.0256
	Basic chromium sulphate	0.1024	Sodium formate	0.0128
	Sodium formate	0.0128	Sodium bicarbonate	0.0128
	Sodium bicarbonate	0.0064		
Rinsing	Water	1.7	Water	1.20
Summing	Wet blue	1.355	Summed wet blue	0.787
			Water	0.56
Trimming, shaving	Summed wet blue	0.787	Shaved wet blue	0.412
			Trimming	0.15
			Shaving	0.225

Table A3:2 Mass balance of sheepskin tanning operation

Process	Input		Output	
	Name	Amount kg/pcs	Name	Amount, kg/pcs
Washing	Shaved sheep skin	0.412	Shaved sheep skin	0.700
	Water	2.00	Water	1.560
	Wetting agent	0.0452	Wetting agent	0.045
Neutralization	Water	1.4	Water	1.400
	Sodium bicarbonate	0.0105	Sodium bicarbonate	0.011
	Sodium formate	0.021	Sodium formate	0.021
Washing	Shaved sheep skin	0.7	Shaved sheep skin	0.7
	Water	2.8	Water	2.8
Retaining, dying, and fat liquoring	Shaved sheep skin	0.7	Shaved sheep skin	0.88
	Water	0.7	Water	0.7
	Basic chromium sulfate	0.035	Basic chromium sulfate	0.009
	Organic tannin	0.042	Organic tannin	0.006
	Fat liquor	0.105	Fat liquor	0.016
	Dyestuffs	0.021	Dyestuffs	0.003
	Organic acids	0.014	Organic acids	0.002
Rinsing	Water	2	Water	2
Summing	Retanned sheep skin	0.88	Summed sheep skin	0.586
			Water	0.29
Drying	Summed sheep skin	0.586	Dried sheep skin	0.410
			Water	0.176

Table A3:3. Mass Balance of Ethiopia Sheepskin Post-Tanning Operation

Process	Input		Output	
	Name	Amount, kg/pcs	Name	Amount kg/pcs
Base coat	Crust dried	0.41	Base coat crust	0.413
	Pigment	0.001	Pigment	0.00025
	Binders	0.01	Binders	0.0025
	Auxiliary	0.008	Auxiliary	0.002
	Water	0.0394	Water	0.0394
Top spray	Base coated crust	0.413	Finished leather	0.41
	Liquor	0.0204	Liquor	0.0051
	Water	0.135	Water	0.135

Table A3: 4 mass balance of sheepskin finishing operation