ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

CHEMICAL ENGINEERING DEPARTMENT

ENVIRONMENTAL ENGINEERING STREAM

ASSESSMENT OF TANNERY SOLID WASTE MANAGEMENT AND CHARACTERIZATION

A Case of Ethio-Leather Industry Private Limited Company (ELICO)

By

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Advisor

Dr.Ing Belay Woldeyes (Associate Professor)

A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfilment of the Degree of Master of Science in Environmental Engineering

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Table of Contents

Page

List of Tables

List of Figures

List of Annexes

ACRONYMS

AD Anaerobic Digestion

ELICO Ethio-Leather Industry Private Limited Company

ETP Effluent Treatment Plant

FAO Food and Agricultural Organization

IWM Integrated Waste Management

LIDI Leather Industry Development Institute

MIDROC Mohammed International **D**evelopment **R**esearch and **O**rganization **C**ompanies

MSW Municipal Solid Waste

NIMBY Not In My Backyard

NOx Oxides of nitrogen

SLC Standard Methods for Leather Chemical Analysis

SOx Oxides of sulfur

SNCR Selective Non-Catalytic Reduction

VOC Volatile Organic Compound

WTE Waste To Energy

Abstract

Tanning industry generates large quantities of solid wastes during leather manufacturing process and subsequently during effluent treatment. From this point of view, in this study assessment on solid waste management practices and physicochemical characterization of the solid wastes generated from tannery were made at Ethio-Leather Industry Private Limited Company (ELICO) so that to propose appropriate tannery solid waste management options. The assessment made showed that the types of tannery solid wastes are de-dusted salt, raw skin trimmings, hair, fleshings, splitting waste, pickle trimmings, chrome shaving, crust trimmings, finished leather trimmings and sludge. Determination of the solid waste generation rates using material balance analysis techniques shows that in processing 7,251 ton of cattle hide and sheep skins annually, the tannery generates a total of 4048.96 tonne of solid waste from beamhouse, tanning, re-tanning, finishing processes and effluent treatment plant. It was found that 859kg of solid waste is generated during processing one tonne of wet salted hide. Similarly, 262kg of solid waste is generated during processing the same amount of sheep skins. It was observed that beamhouse operations have more than 60% contributions in generating the solid wastes. The solid wastes were characterized for pH, moisture content, volatile organic compound, ash content, calorific value, carbon content, total nitrogen content, carbon to nitrogen ratio, chromium content, sodium content and calcium content using standard solid waste analysis methods and the experimental result reveals that more than 90% of the solid wastes are organic. In order to propose solid waste management options for tannery solid waste, solid waste management strategies (source reduction, recycling and composting, waste transformation/waste to energy and landfilling) were reviewed and two basic thermo-chemical waste to energy technological options (incineration and pyrolysis/gasification), biochemical conversion process (Anaerobic digestion/bio-methanation) and composting were found to be viable to manage tannery solid waste and proposed based on the physico-chemical characteristics of the solid waste.

1. Background

Production of leather from raw hides and skins, by-products of meat industry, has been one of the most important industrial processes since ancient times [1]. The Ethiopian leather industry is a relatively older industry with more than 80 years of involvement in processing leather [2]. Ethiopia is one of the leading countries that have the largest livestock populations in the world providing a strong raw material base for the leather industry. Its livestock population is estimated at 50 million cattle, 25 million sheep and 23 million goats. About 80% of all hides and skins entering the formal market come from rural areas where they are collected by private traders. The remaining 20% are derived from slaughtering facilities found in major town and cities. About 15.5 million pieces of sheep and goat skins and 1.2 million pieces of cattle hides are supplied to the tanneries per annum [3].

There are presently 27 tanneries operating in the country, employing over 5,000 people and having soaking capacity of 1.3 million pieces of hide and 32 million pieces of skins annually. The existing daily soaking capacity of tanning industries is 145, 524 pieces of skins and 7,800 pieces of hides (see Annex 1). About one-third of these tanneries are found in Addis Ababa and its surrounding [4].

Leather industry has been categorized as one of highly polluting industries and it has adverse impact on environment because of the generation of liquid, solid and gaseous wastes. Solid wastes generated from tanning industries contain different chemicals which are used during leather manufacturing process. These tannery solid wastes have different characteristics as different chemicals and mechanical processes are applied to the raw hides/skins. If these solid waste generated during various tanning operations are not properly utilized or disposed they are likely to cause a number of problems on the environment. If salt dust or de-dusted salt that is removed from preserved hide or skin is stored in heaps outside the tanneries or dumped in open dumping area is likely to be washed away during rains and cause groundwater pollution. Discharging hair waste and lime sludge wastes along with the effluents causes choking of drains. Raw and green fleshings, limed fleshings, splits (splitting waste) and trimmings putrefy easily and give rise to noxious smells. In many tanneries, it is the foul odour which emanate from some of these putrescible solid wastes which accounts for much of the smell traditionally associated with tannery wastes. Some of the bio-degradable tannery solid wastes are sources of pathogenic bacteria and volatile organic compounds emission. Vegetable and chrome tanned shavings and splits do not easily decompose. If they are not utilized, problems of disposal are encountered.

Some of tannery solid waste contains chromium metal which is the most widely used in tanning industries as chromium salt and it causes carcinogenic effect when it enters human body through food chain [5].

Assessment of industrial solid waste management greatly varies depending on the nature of the industry, their location and mode of disposal of the waste. Further, for arriving at an appropriate solution for better management of industrial solid waste, assessment of the nature of the waste generated is very essential.

Environmentally sound solid waste management, however, requires the selection and application of suitable techniques, technologies and management programs to achieve specific waste management objectives and goals.

Therefore, it was planned to assess the solid waste management practices, to determine the generation rates of the solid wastes and to characterize the physicochemical properties of tannery solid wastes taking Ethio-Leather Industry private Limited Company (ELICO) as a case study tannery so that to propose appropriate tannery solid waste management options.

1.1. Description of Case Study Tannery (ELICO)

ELICO is a member of MIDROC Ethiopia Technology Group and established in August 1997 after acquisition of three factories from the Ethiopian Privatization Agency. The Industry has three operating units, namely, the Awash Tannery (Gloving and Hides Unit), Abyssinia Tannery (Goat Suede and Shoe Leather Unit) and Leather Garment and Goods Unit. It has actual soaking capacity of 12,170kg of sheep skin, 7,200kg of goat skins and 12,000kg of hides per day. It produces finished garment leathers, sports gloving leather from sheep skin, finished goat suede for shoe upper, finished cow hide for shoe upper, finished crust lining leather and cow hide crust.

1.2. Statement of the Problem

Solid wastes generated from tanning industries, being highly polluting industrial wastes, should be managed in an environmentally safe way. But a report on benchmarking (Technology up-gradation) program in Ethiopian Tanning industry [6] shows that the solid wastes generated from the tanning industries located in Addis Ababa city are collected, transported and disposed along with municipal solid wastes in open dumping area called "Koshe" or "Rapi" (see Annex 2). This dumpsite is being used by the surrounding dwellers as a site for cultivation of habesha-gomen (*Beta vulgaris var. cicla*), *Eragrostis tef* (Teff) and for cattle grazing. As leather industries mostly use chrome sulphate for leather manufacturing process, some of the solid wastes generated from the industry contain chromium (Cr) which is one of the toxic heavy metals and known for contaminating ground water, soil, plants and causing carcinogenic effect on human health. This anthropogenic interference might harm the community as the chromium and other heavy metals are potentially toxic to crops, animals and humans when contaminated soils are used for crop production

In addition to this, since the collection frequency of the municipality service is too low the solid wastes generated from the tanning industries stay in the factory compound for a long period of time that lets the wastes creates unfavourable environmental condition for the community working in the industry.
Therefore, a proper tannery solid waste management system has to be proposed.

1.3. Objective of the Study

1.3.1. General Objective

The general objective of this study is to assess the existing solid waste management practices of Ethio-Leather Industry Private Limited Company and characterizing the solid wastes to propose appropriate solid waste management systems.

1.3.2. Specific Objectives

The specific Objectives of this study are given as below

- To investigate and identify the major types and sources of tannery solid wastes generated during leather manufacturing process in ELICO
- To determine the generation rate of the solid wastes
- To assess the existing tannery solid waste management practices
- To characterize the major types of the solid wastes
- To analyse the data and propose appropriate tannery solid waste management systems

1.4. Framework of the Study

The framework of this study is categorized in to two main groups. The first one is the assessment on the existing solid waste management practices at ELICO Tannery that provides information on the physical composition of solid wastes, their sources and disposal methods and secondly, the characterization of the solid wastes for selected physicochemical parameters that are used to propose tannery solid waste management options. The general conceptual framework of this study is shown the Figure 1.1 as below.

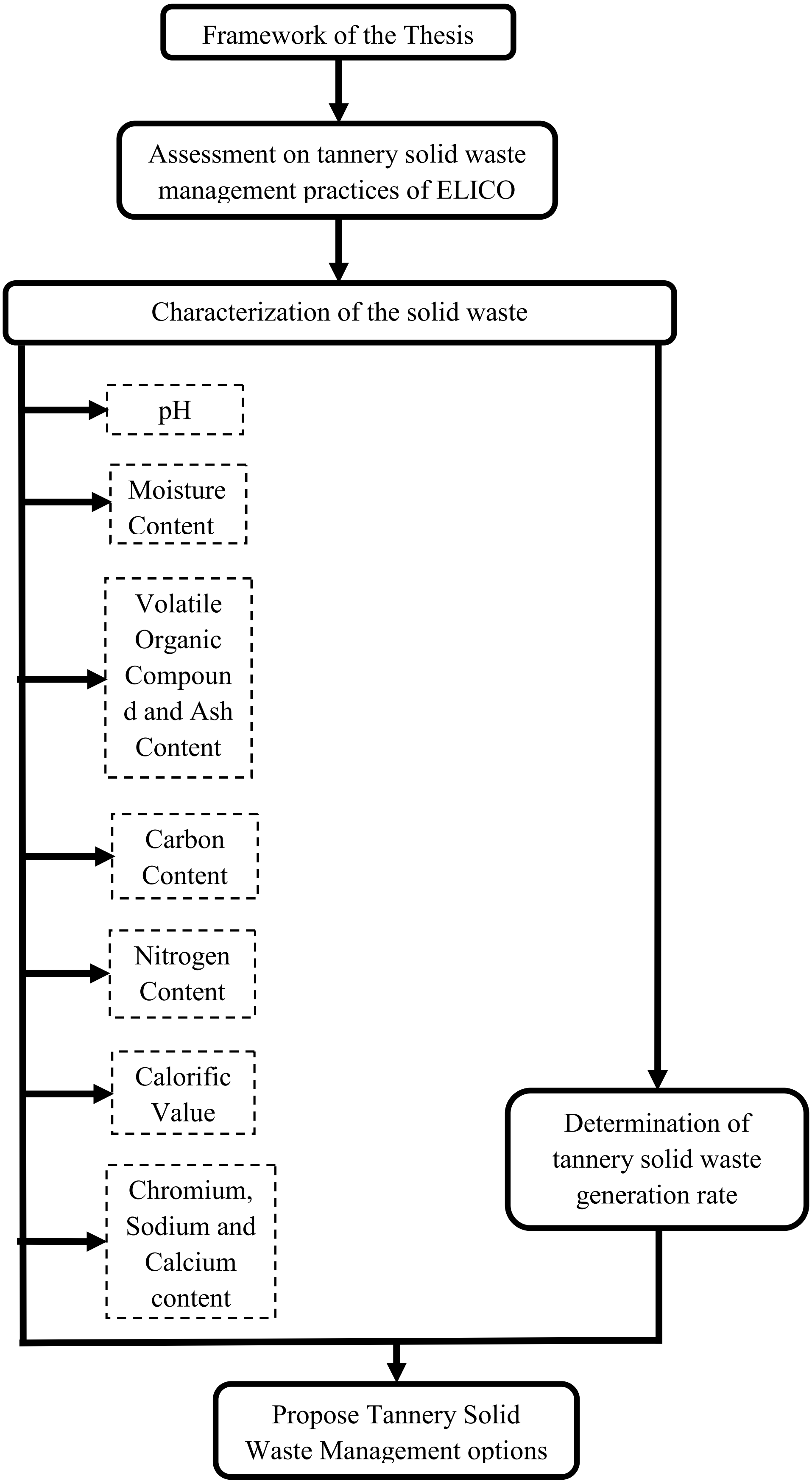


Figure 1.1 Overall Framework of the thesis

1.5. Significance of the Study

In many instances, some components of solid waste stream are managed with one option, while other components are directed to other options. Thus, waste quantity and composition data are necessary to assure that needs are met and that management options available match these needs. From this point of view, this study has of great importance in gathering useful, accurate, and appropriate data on the amount and nature of solid wastes generated during leather manufacturing processes from raw hides and skins input to the final finished leather that assist in the planning of solid waste management programs and facilities.

1.6. Scope of the Study

This study includes the assessment on tannery solid waste management practices at ELICO, determination of the solid waste generation rate, sampling of the solid wastes, physicochemical characterization and proposal of appropriate solid waste management options. Solid wastes generated during leather processing from raw hides and skins input to the final finished leather output was taken in to consideration for characterization of physicochemical parameters.

2. Literature Review

2.1. Introduction

Solid waste means anything that is neither liquid nor gas and is discarded as unwanted [7]. In the modern age of development the increasing quantity of solid waste is one of the growing environmental problem in both developed and developing countries. The solid waste generated from industrial sources contains a large number of chemicals, some of which are toxic. The waste is considered toxic, if the concentration of the ingredients exceeds a specified value [8].

Production of leather from raw hides and skins has been one of the most important industrial processes since ancient times. For centuries, leather was one of few available materials for the production of high durability garments and footwear. The principal aim of the leather industry, which plays a significant role in today's global economy, is to transform animal hides/skins into physically and chemically stable material by subjecting them to chemical and mechanical sequential processes, and therefore to obtain products for meeting various needs of people [9].

Leather industry has been categorized as one of highly polluting industries and it has adverse impact on environment because of the generation of huge amount of liquid, solid and gaseous wastes. The simplified inflow and out flow of tanning industry is shown in Figure 2.1 below.

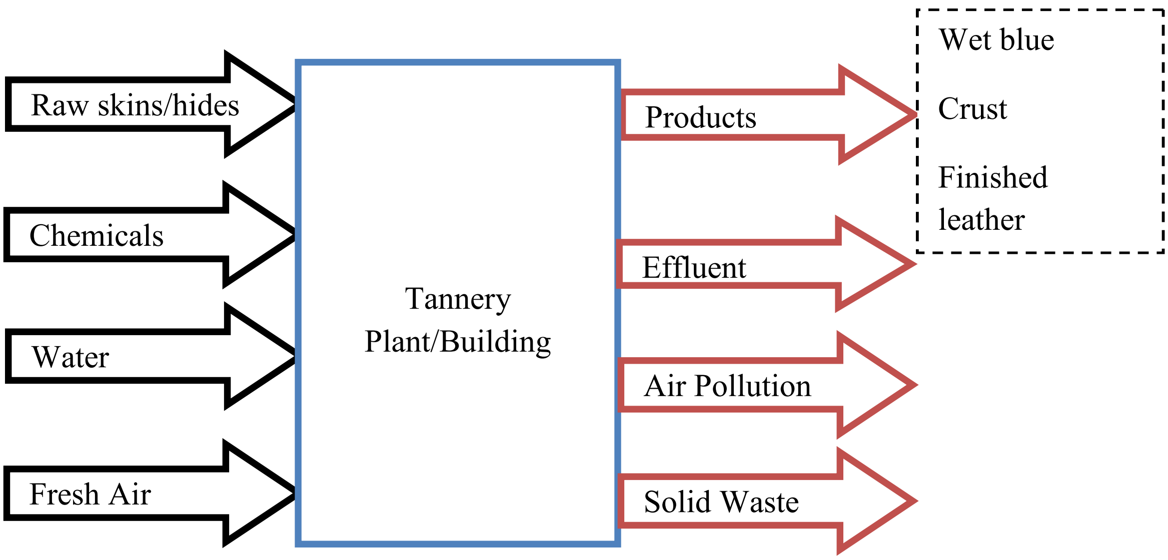


Figure: 2.1 Simplified inflow and out flow of Tanning Industry

2.2. Leather Manufacturing Processes

The leather processing stages can be categorized in to four main stages as follows [9]:

a) Beamhouse processes

Generally, the conventional conversion process of hides/skins to leather involves 'do–undo' operations. The conserved skins/hides are first subjected to a trimming process for removing the unwanted parts called skin/hide trimmings, and then they are soaked to restore the lost water due to the common salt applied during curing process and to remove substances like dirt, blood and conservation salt at alkaline condition (pH ranging from 9.5 to 10.5) using wetting agents, sodium carbonate or sodium hydroxide. This is called **soaking** process. After soaking process the skins/hides are subjected to **liming/un-hairing** process which is treating the materials in alkaline (pH ranging from 12 to 13) solution of lime ($Ca(OH)_2$) and sodium sulphide (Na_2S) to remove hair and swell up the skin/hide. After liming/un-hairing process the flesh and fat adhering to the hide/skin is removed by a mechanical process called **fleshing** process. Another mechanical operation called **splitting** after fleshing process is applied most of the time to cattle hides to split into two or three layers or to remove some unwanted layers of the hide. **De-liming** is chemical process performed to decrease the pH to 8.0 to 9.0 so that to remove the lime added during liming process and to make the hide/skin more receptive to the chemicals that will be used in further stages. After de-liming process, hides/skins are exposed to an enzymatic effect for both opening up the structures of hides/skins, and the removal of unwanted proteins by a process called **bating**. Following the bating process, a **degreasing** process is applied for removing the excess natural fat using aqueous emulsification with detergents, or solvent extraction. After degreasing process the hides/skins are treated in a solution composed of salt and acids in acidic solution at an average pH of 2.5 so as to obtain a homogeneous distribution of tanning material that will be applied in the tanning process. This process is called **pickling** process and the product at this stage is named as pickle.

b) Tanning Processes

After the hides/skins are conditioned as above, the tanning process is applied with various tanning materials (materials able to form stable bonds with collagen) in order to provide the leather with a stable form and high thermal stability. Tanning materials such as vegetable tannins, mineral tanning materials and syntans (synthetic organic tanning materials) are used in tannage. Among mineral tanning materials, **chrome tanning** is the most widely used in leather production due to the unique features chrome that it gives to the leather; thermal stability. Chrome tanning is carried out in acidic solution at a pH ranging from 2.5 to 3.0. Aluminium and vegetable tanning materials are also widely used in leather production. The product of chrome tanning process is called as wet blue because of its colour.

c) Re-Tanning Processes

At re-tanning stage the wet blue hide/skin is changed to crust leather. In this stage, structural differences within wet blue leathers are compensated to obtain uniform structure. It involves the following chemical and mechanical operations.

Shaving – is a mechanical process to even the hide thickness and permit greater precision than is possible by splitting.

Neutralizing – is removal process of the free acid present in the leather, to assure stability in heated conditions and resistant to boiling.

Re-tanning – is a process to give the material the required uniform fullness and ability to retain their consistency after the drying process that tend to flatten the hides and reduce their thickness. This is carried out at a pH ranging from 3.5 to 5.0

Fatliquoring – is done to lubricate the dermic fibres to avoid gluing and to provide the finished article with fullness and softness.

Dyeing – is a process of giving the required colour characteristics. A good dyeing have good colour uniformity, maximum colour depth with the least amount of dye possible, good defect cover and high colour and light fastness.

Setting out – is a process of pressing the leather to reduce the residual moisture in the hide from 100% to 65-70%. It also helps the hide to be widened and the grain to be flattened.

Drying – is an operation to reduce the moisture content from 70% to 20-22%. It is performed in the company through Vacuum drying, toggle frames, or overhead chain. After this stage, it is called as crust leather and prepared for finishing processes.

d) Finishing Processes

Finishing operation is the mechanical modifications on the appearance of the leather such as elasticity, softness and feels by applying an aesthetic covering polymeric film to the derma. Finishing operation involves surface coatings and mechanical operations. Some of the finishing processes are given as follows.

Conditioning – is a process to provide moisture in to the dried hide or skin to eliminate the occurrence of cracking for the next operation.

Staking- is mechanical operation applied to increase smoothness of the leather

Milling – is a mechanical process to improve the softness of the leather and gives the grain a more precise design. A drum similar to the one used in the wet phases is used.

Spreading on toggle frame – is a useful operation of spreading out the hide under tension on the toggle frame and allow drying in a hot air tunnel for a short period of time, but long enough to reduce the humidity from 22-24% to 15-16%. The objective of this operation is to take the advantage of the detachment of the fibres to spread and flatten the hides as much as possible.

Buffing - is a mechanical operation to remove the grain completely and to obtain soft and opaque surface, to make the flesh side of the leather to be refine and smooth, or to remove a more or less significant amount of surface material from low quality hides.

Impregnation – is an operation aims at increasing the ability to adapt to the extension and compression caused by folding, generating a more elegant behaviour.

Coating – is the application of natural or synthetic products, generally water-based, for colouring, covering, sealing effects and for giving body to the leather.

Ironing – is pressing operation to make the leather smooth. It is performed in two different machines, flat presses that work in a discontinuous manner or cylindrical rotary presses that work in a continuous manner.

Polishing – is the last finishing operation to provide a shiny appearance and pleasant feel. Figure 2.2 below shows the leather manufacturing process flow. The dashed ellipse in the Figure 2.2 shows the name of the product output from the corresponding leather processing stages.

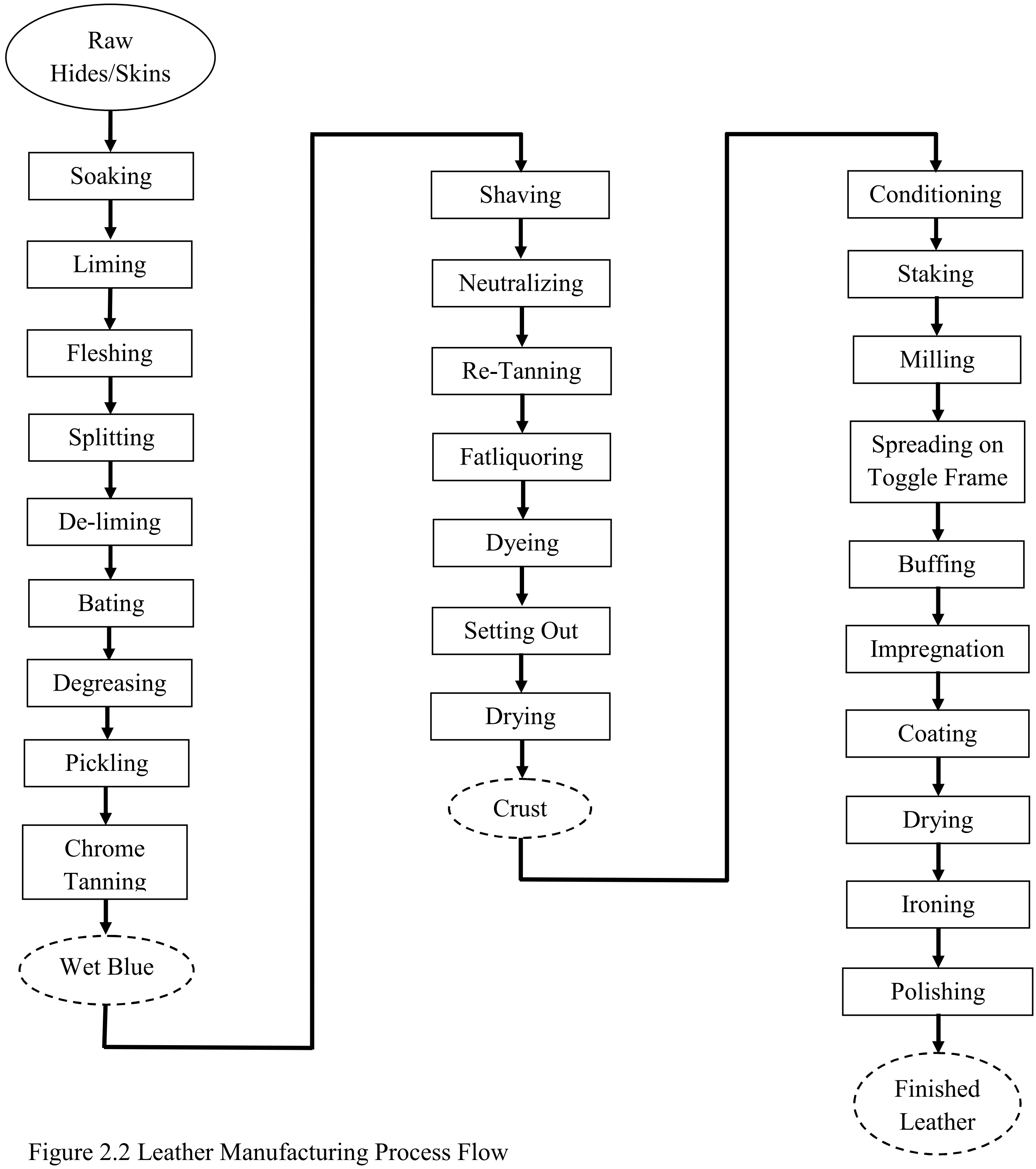


Figure 2.2 Leather Manufacturing Process Flow

2.3. Tannery Waste

Although the leather industry is environmentally important as a user of the by-product of the meat industry, it is perceived as a consumer of resources and a producer of pollutants that are liquid, solid and gaseous in nature [10].

2.3.1. Liquid and Gaseous Waste

Tannery effluents are ranked as the highest pollutants among all industrial wastes [11]. The tanning process involves an important consumption of water and generates a complex pollution consisting of a mixture of organic and inorganic substances that rather difficult to treat. A large amount of Chemicals is used to convert raw cattle hides, goat and sheep skins in to leather. The chemical reagents consumption is very high. For 1000kg of hides about 400kg of chemicals is needed, including sodium chloride, lime, sodium sulphide, sulphuric acid, basic chromium and others. A considerable part of these chemicals are not absorbed in the production process and is discharged in to the environment [12]. The capacity of world leather process is 15 million tons of hides and skins per year. The waste water discharge from world tanneries is about 600 million m^3 per year [13]. On average 45 -50 m^3 of wastewater is discharged from tanning industry per ton of raw hide processed [14].

The main discharge of waste water originates from wet processing stages in the beamhouse, the tanning process, and the post-tanning operations. It has been revealed that beamhouse processes and tanning processes contribute 80–90% of the total pollution load that includes biological oxygen demand (BOD), chemical oxygen demand (COD), total solids (TS), total dissolved solids (TDS), chromium (Cr), sulphides (S^{2-}), sludge, etc.) [15].

Compared to emissions to water, air emissions occur generally in relatively small quantities. Traditionally tanneries have been associated with odour rather than any other air emissions, although the emissions of organic solvents are a major problem. Whether a tannery has the following air emissions depends on the type of processes employed. Air emissions from tannery are particulate, organic solvents, hydrogen sulphide, ammonia and odour [16].

Emissions to air have effect beyond the tannery site, but also affect the workplace and possibly the health of the tannery workforce. Apart from odours, particular mention should be made here of organic solvent emissions, aerosols and dust (buffing dust and powdery chemicals) [16].

Particulates

The majority of particulate emissions arise from dry processes, such as milling, buffing and spray finishing operations. These emissions can be abated by using filters, down flow booths, chemical dosing equipment and/or dust free chemicals (dust free bates, liquid dyes and liquid re-tanning agents) [16].

Organic solvents

The principal source of organic solvent emissions in tanneries is from finishing operations. Abatement techniques, such as scrubber units, are used and are effective in capturing a large part of the organic solvent emissions. Tanneries employing solvent based degreasing processes (mainly sheepskins) have also organic solvent emissions requiring special abatement [16].

Hydrogen sulphide

The generation of hydrogen sulphide is pH dependent. Hydrogen sulphide can be formed during de-liming and pickling processes and when alkaline effluent streams containing sulphide are mixed with acidic effluent streams. To prevent the generation of hydrogen sulphide, the liquors from the de-liming and pickling processes are treated by means of oxidising the sulphide with sodium metabisulphite or hydrogen peroxide. This treatment is not applicable for waste lime liquors or mixed effluent due to the presence of too much organic substances. Extraction fans above processing vessels or improved process control can also minimise odours. Optimisation of washing processes in order to sufficiently remove sulphide before de-liming and pickling will further reduce the odour emissions. Hydrogen sulphide is also formed in waste water treatment by anaerobic bacteria from sulphates and therefore presents problems in waste water treatment, sludge storage, and dewatering operations. Hydrogen sulphide can also be formed in the sewerage system when sulphide containing effluent is not treated carefully [16].

Ammonia

Ammonia can be formed in de-liming processes and the dyeing process. Good housekeeping practices, such as effective washing and process control, can minimise these emissions. Extraction fans above processing vessels or improved process control can also minimise odours. These ammonia and hydrogen sulphide emissions can be abated as VOCs, usually by wet scrubbing or bio-filters [16].

Odour

Odour emissions from raw hides can be controlled by ensuring correct curing procedures, improving storage conditions and ensuring adequate stock rotation. Cool and dry conditions should be maintained in storage facilities and doors should remain closed. Odours may arise from degradation of organic matter or from chemical substances that are also toxic. Odours can arise from storing hides and skins, from beamhouse operations (sulphides, ammonium), from ammonia releases in dyeing, from VOC released in finishing processes and from the waste water treatment. Odour is one of the main reasons for complaints from neighbours. Sulphur dioxide emissions might occur during bleaching [16].

2.3.2. Solid Waste

Apart from liquid and gaseous wastes, large quantities of solid wastes are also generated during leather processing and subsequently during effluent treatment. Although some of the wastes find limited applications, the safe disposal of the bulk of the solid wastes has posed serious problems [17]. Out of which some portion of chromium containing hazardous wastes are also generated. These chrome containing wastes are categorised as hazardous wastes. The main sources of solid wastes are from trimming, fleshing, splitting and shaving processes. A further potential source of solid waste is the sludge from the effluent treatment plant [15]. Tannery effluent treatment plants produce large amounts of sludge: generally, 10% of the total weight of goat and sheep skins and 14% of cow/buffalo hides [18].

The solid waste generation from tannery process in the world is estimated at 6 million tons per year [13]. At an average 80% of solid waste is generated from tanning industry per ton of raw hide processed [14]. The types of solid wastes generated in a tannery processing one ton of raw skins/hides have been quantified in Table 2.1 as below

Table 2.1: Nature and Quantity of Solid Wastes Produced from Processing 1 Ton of Raw Skins/Hides [17]

S.Nº	Nature of solid waste	Quantity (kg)
1	Salt from handshaking	80
2	Salt from solar pans (not realized)	220
3	Hair (pasting ovine)	100
4	Raw trimmings	40
5	Lime sludge (mostly bovine)	60
6	Fleshing	120
7	Wet blue trimmings (grain splits)	30
8	Chrome splitting (bovine)	65
9	Chrome shaving (mostly bovine)	95
10	Buffing dust (including shaving bovine after crust)	65
11	Dyed trimmings	35
12	Dry sludge from ETP	125

2.3.2.1. Characteristics of Tannery Solid Waste

The chemical composition of solid wastes generated from beamhouse operations (fleshings, trimmings, splits) depends mainly on a kind and quality of the raw material, treatment type and process conditions. The main components are proteins and fat, up to 10.5% (w/w) for both groups. Water content is high, moisture amounts up to 60%. These wastes contain small amounts of mineral substances, 2-6% (w/w). Chromium compounds are not present in the material [14].

The tanned leather wastes are mainly useless splits, shavings and trimmings. These waste groups differ mostly in size and shape, the chemical composition is comparable for each. They contain 3-6% (w/w) of fat and about 15% (w/w) of mineral components, including 3.5-4.5% (w/w) of chromium as Cr_2O_3. Sludge from wastewater treatment plants contains mostly water (up to 65% (w/w)), organic substances (30% (w/w)) and chromium (III) compounds (about 2.5% (w/w)) [14].

Some research work on tannery sludge shows that the level of chromium content is 500 mg kg^{-1} and this is five folds higher than that should be present in the soil (100 mg kg^{-1}). It has a moisture content (60.6%), pH (7.4), Organic Carbon (20%), Total kjeldhal nitrogen (1.0) and carbon to nitrogen ratio (20). Due to the low solubility of chromium, only a little (Cr) is bio-available, which means that even when crops are grown in soils treated with sludge relatively high in Cr, phytotoxicity is rarely observed [19].

2.3.2.2. Environmental Impacts of Tannery Solid Waste

Solid wastes generated from tanning industries contain different chemicals which are used during leather manufacturing process. These tannery solid wastes have different characteristics as different chemical and mechanical processes are applied to the raw hides/skins. If these solid waste generated during various tanning operations are not properly utilized or disposed they are likely to cause a number of problems on the environment. Salt dust or de-dusted salt if stored in heaps outside the tanneries or dumped in open dumping area is likely to be washed away during rains and cause groundwater pollution. Hair waste and lime sludge if discharged along with the effluents are likely to choke the drains. Raw and green fleshings, limed fleshings, splits (splitting waste) and trimmings putrefy easily and give rise to noxious smells. In many tanneries, it is the foul odour which emanate from some of these putrescible solid wastes which accounts for much of the smell traditionally associated with tannery wastes. Some of the bio-degradable tannery solid wastes are sources of pathogenic bacteria and volatile organic compounds emission. Vegetable and chrome tanned shavings and splits do not easily decompose. If they are not utilized, problems of disposal are encountered. Primary and secondary sludge obtained during the treatment of tannery wastes are also putrescible [5].

Excess heavy metal accumulation in soil is toxic to humans and other animals. Exposure to heavy metals is normally chronic (exposure over a longer period of time), due to food chain transfer. Acute (immediate) poisoning from heavy metals is rare through ingestion or dermal contact, but is possible. Some of tannery solid waste contains chromium metal which is the most widely used in tanning industries as chromium salt and it causes carcinogenic effect when it enters human body through food chain. The standard safe limit for chromium metal in the soil is 150ppm [5].

In general where tanning industries have long been established there has been usually a simultaneous growth in industries which can use tannery solid wastes to produce some valuable products. This pattern is especially helpful to the tanning industry in the case of obnoxious rag and limed fleshings, trimmings and splits which are lifted by glue and gelatin units [5].

When solid waste is disposed off on land in open dumps or in improperly designed landfills (e.g. in low lying areas), it causes the following impact on the environment [20].

- Ground Water Contamination by the Leachate Generated by the Waste Dump
- Surface Water Contamination by the Run-off from the Waste Dump
- Bad Odour, Pests, Rodents and Wind-Blown Litter in and Around the Waste Dump
- Generation of Inflammable Gas (e.g. Methane) Within the Waste Dump
- Bird Menace above the Waste Dump Which Affects Flight of Aircraft
- Fires Within the Waste Dump
- Erosion and Stability Problems Relating to Slopes of the Waste Dump
- Epidemics Through Stray Animals
- Acidity to Surrounding Soil And
- Release of Green House Gas

2.4. Solid Waste Management

Solid waste management is the collection, transportation, storage, recycling or disposal of solid waste, or the subsequent use of a disposal site that is no longer operational [7]. It is a complex process because it involves many technologies and disciplines. These include technologies associated with the generation (including source reduction), on-site handling and storage, collection, transfer and transportation, processing, and disposal of solid wastes. All of these processes have to be carried out within existing legal, social, and environmental guidelines that protect the public health and the environment and are aesthetically and economically acceptable.

The objective of solid waste management is to reduce the quantity of solid waste disposed off on land by recovery of materials and energy from solid waste [20].

2.5. Integrated Waste Management

Integrated waste management (IWM) can be defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals [20].

To be responsive to public attitudes, the disciplines that must be considered in integrated solid waste management include administrative, financial, legal, architectural, planning, environmental, and engineering functions. For a successful integrated solid waste management plan, it is necessary that all these disciplines communicate and interact with each other in a positive interdisciplinary relationship. The four basic waste management options (strategies) for IWM are: (1) source reduction, (2) recycling and composting, (3) combustion (waste-to-energy facilities), and (4) landfills. Figure 2.3 below shows waste management hierarchy [20].

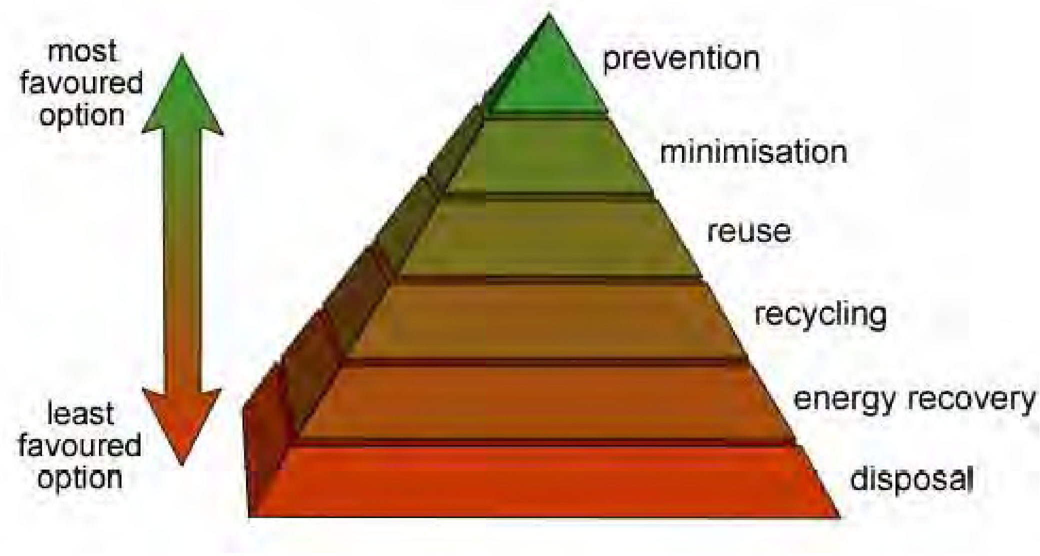


Figure 2.3**:** Waste Management Hierarchy

In this literature survey the energy recovery and reuse methods of waste management strategies are reviewed as below so that they can be applied to manage tannery solid wastes.

2.6. Waste-To-Energy (WTE) Technological Aspects

Waste to energy technology offers a way to manage solid municipal waste while at the same time generating the energy needed to stop the dependence on foreign oil and other fossil fuels. There are several different processes and technologies that can be used to change waste into energy. Energy can be recovered from the organic fraction of waste (biodegradable as well as non-biodegradable) basically through two methods (Thermo-chemical Conversion and Bio-chemical conversion) [21].

2.6.1. Thermo-Chemical Conversion

Thermo-chemical conversion process entails thermal de-composition of organic matter to produce either heat energy or fuel oil or gas. The Thermo-chemical conversion processes are useful for wastes containing high percentage of organic non-biodegradable matter and low moisture content. The main technological options under this category include Incineration and Pyrolysis/Gasification [22].

2.6.1.1. Incineration

Incineration is the process of direct burning of wastes in the presence of excess air (oxygen) at temperatures of about 800^0C and above, liberating heat energy, inert gases and ash. It is a waste treatment process that involves the combustion of organic substances contained in waste materials. The ash is mostly formed by the inorganic constituents of the waste, and may take the form of solid lumps or particulates carried by the flue gas. The flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the atmosphere. Net energy yield depends upon the density and composition of the waste; relative percentage of moisture and inert materials, which add to the heat loss, ignition temperature, size and shape of the constituents, design of the combustion system (fixed bed/ fluidised bed), etc. In practice, about 65 to 80 % of the energy content of the organic matter can be recovered as heat energy, which can be utilised either for direct thermal applications or for producing power via steam turbine generators (with typical conversion efficiency of about 30%) [22].

The combustion temperatures of conventional incinerators fuelled only by wastes are about 760^0C in the furnace and in excess of 870^0C in the secondary combustion chamber. These temperatures are needed to avoid odour from incomplete combustion but are insufficient to burn or even melt glass. To avoid the deficiencies of conventional incinerators, some modern incinerators utilise higher temperatures of up to 1650^0C using supplementary fuel. These reduce waste volume by 97% and convert metal and glass to ash [22].

Ash is the weight of residue after combustion in an open crucible. By resource recovery facilities, several solid residuals are produced including bottom ash and fly ash. Bottom ash is the unburned and non burnable portion. It can contain considerable amounts of metals and glass as well as unburned organics. Fly ash is composed of the micron and submicron particulates that have been collected by the air pollution control system, it must be handled very carefully to avoid fugitive dust emissions, which may be harmful to workers and the surrounding environment [22].

Wastes burned solely for volume reduction may not need any auxiliary fuel except for start-up. When the objective is steam production, supplementary fuel may have to be used with the pulverized refuse, because of the variable energy content of the waste or in the event that the quantity of waste available is insufficient. While incineration is extensively used as an important method of waste disposal, it is associated with some polluting discharges which are of environmental concern, although in varying degrees of severity. These can fortunately be effectively controlled by installing suitable pollution control devices and by suitable furnace construction and control of the combustion process [22].

One of the most attractive features of the incineration process is that it can be used to reduce the original volume of combustibles by 80 to 95 %. Air pollution control remains a major problem in the implementation of incineration of solid waste disposal. In the United States, the cost of best available technology for the incineration facility may be as high as 35 % of the project cost. The cost of control equipment will, however, depend upon the air pollution regulations existing in a given lesser developing country. Waste incineration may be advantageous when a landfill cannot be sited because of a lack of suitable sites or long haulage distances, which result in high costs [22].

Incineration plants can be located close to the centre of gravity of waste generation, thus reducing the cost of waste transportation.

Incineration provides the best way to eliminate methane gas emissions from waste management processes. Furthermore, energy from waste projects provides a substitute for fossil fuel combustion.

The following are the types of plants for burning waste: [22].

Moving Grate:

The incineration plant used for treating municipal solid waste (MSW) is moving grate. This grate is capable for hauling waste from combustion chamber to give way for complete and effective combustion. Moving grates are more precisely known as incinerators of municipal solid waste.

Fixed Grate:

This was the fixed and much older version for grate. This kind generally is lined with the brick while lower or ash pit is made up of metal.

Rotary-kiln:

Industries and municipalities generally use this sort of incinerator. This incinerator consists of two chambers i.e. primary and secondary chamber.

Fluidized Bed:

In this sort of incineration, air is blown at high speed over a sand bed. The air gets going through the bed when a point comes where sand granules separates and let air pass through them and here comes the part of mixing and churning. Therefore, a fluidized bed comes in to being and fuel and waste are then can be introduced.

Applicability of Incineration

Incineration projects are immediately applicable only if the following overall criteria are fulfilled [23].

- A mature and well-functioning waste management system has been in place for a number of years
- Solid waste is disposed of at controlled and well operated landfills.
- The supply of combustible waste will be stable and amount to at least 50,000 metric tons/year.

- The lower calorific value must on average be at least 7000KJ/kg, and must never fall below 6000KJ/kg in any season. Higher calorific value indicates the combustion of waste with a lesser amount of auxiliary fuel support. The amount of energy generated at a waste to energy facility depends primarily on the calorific value of the waste. To facilitate self combustion of waste, the calorific value of the waste should be at least 5000kJ/kg and approximately 6000KJ/kg for power generation
- The community is willing to absorb the increased treatment cost through management charges, tipping fees, and tax-based subsidies.
- Skilled staff can be recruited and maintained

2.6.1.2. Pyrolysis/ Gasification

Gasification and pyrolysis are similar processes; both decompose organic waste by exposing it to high temperatures. Both processes limit the amount of oxygen present during decomposition; gasification allows a small amount of oxygen, pyrolysis allows none. In other words, gasification and pyrolysis limit or prevent oxidation [24].

The gasification process means treating a carbon-based material with a limited oxygen or steam to produce a gaseous fuel. The gas can either be cleaned and burned in a gas engine, or transformed chemically into methanol that can be used as a synthesis compound. Nowadays, this technology is not used for mass waste but for somewhat homogeneous waste [24].

Pyrolysis is the application of heat in an atmosphere of zero or limited oxygen to a substance in order to induce chemical decomposition and avoid combustion. Organic material is processed within an enclosed chamber where heating releases valuable gas, leaving residual solids and coke, and in some cases, oil. The gas is afterwards combusted to obtain energy. The residual solids can be land filled or vitrified. Like gasification, pyrolysis is a technology sufficiently developed only for homogeneous waste [21].

2.6.2. Bio-Chemical Conversion

Bio-chemical conversion process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol. The bio-chemical conversion processes, on the other hand, are preferred for wastes having high percentage of organic bio-degradable matter and high level of moisture/water content, which aids microbial activity. The main technological options under this category are Anaerobic Digestion (Bio-methanation) and fermentation process which can take biomass and create ethanol, using cellulosic waste or organic material. In the fermentation process, the sugar in the waste is changed to carbon dioxide and alcohol. Normally fermentation occurs with no air present. In addition to the above two methods to convert solid waste to energy, a chemical processes called esterification can also be used to produce biodiesel from the solid wastes [23].

2.6.2.1. Anaerobic Digestion (Bio-Methanation)

In anaerobic digestion (AD) process the organic fraction of waste is segregated and fed to a closed container (biogas digester) where, under anaerobic conditions, the organic wastes undergo bio-degradation producing methane-rich biogas and effluent/sludge. The biogas production ranges from 50- 150m^3/tonne of wastes, depending upon the composition of waste. The biogas can be utilised either for cooking/heating applications, or through dual fuel or gas engines or gas/steam turbines for generating motive power or electricity. The sludge from anaerobic digestion, after stabilisation, can be used as a soil conditioner, or even sold as manure depending upon its composition, which is determined mainly by the composition of the input waste [23].

Fundamentally, the anaerobic digestion process can be divided into three stages with three distinct physiological groups of micro-organisms:

Stage I: It involves the fermentative bacteria, which include anaerobic and facultative micro-organisms. Complex organic materials, carbohydrates, proteins and lipids are hydrolyzed and fermented into fatty acids, alcohol, carbon dioxide, hydrogen, ammonia and sulphides.

Stage II: In this stage the acetogenic bacteria consume these primary products and produce hydrogen, carbon dioxide and acetic acid.

Stage III: It utilizes two distinct types of methanogenic bacteria. The first reduces carbon dioxide to methane and the second decarboxylates acetic acid to methane and carbon dioxide.

Factors, which influence the anaerobic digestion process, are temperature, pH (Hydrogen Ion Concentration), nutrient concentration, loading rate, toxic compounds and mixing. For start-up a good inoculums such as digested sludge is required. A temperature of about 35-38^{0}C is generally considered optimal in mesophilic zone (20-45^{0}C) and higher gas production can be obtained under thermophillic temperature in the range of 45-60^{0}C. Provision of appropriate heating arrangements and insulation may become necessary in some parts of the country [23].

The important chemical parameters to be considered for determining the energy recovery potential and the suitability of waste treatment through bio-chemical or thermo-chemical conversion technologies include volatile solids, fixed carbon content, inerts, calorific value, C/N ratio (Carbon/Nitrogen ratio) and toxicity. The desirable range of important waste parameters for technical viability of energy recovery through different treatment routes is given in the Table 2.2 below. The parameter values indicated therein only denote the desirable requirements for adoption of particular waste treatment method and do not necessarily pertain to wastes generated/collected and delivered at the waste treatment facility. In most cases the waste may need to be suitably segregated/processed/ mixed with suitable additives at site before actual treatment to make it more compatible with the specific treatment method. This has to be assessed and ensured beforehand. For example, in case of anaerobic digestion, if the C/N ratio is less, high carbon content wastes (straw, paper etc.) may be added; if it is high, high nitrogen content wastes (sewage sludge, slaughter house waste etc.) may be added, to bring the C/N ratio within the desirable range [22].

Table 2.2: Desirable Range of Important Waste Parameters for Technical Viability of Energy Recovery [22]

Waste Treatment Method	Basic Principle	Important Waste parameters	Desirable Range
Thermo-chemical conversion	Decomposition of organic matter by action of heat	Moisture content	<45%
Incineration Pyrolysis Gasification		Organic/volatile matter	>40%
		Fixed carbon	<15%
		Total inerts	<35%
		Calorific value	>5040KJ/Kg
Bio-chemical Conversion	Decomposition of organic matter by microbial action	Moisture Content	>50%
Anaerobic Digestion/ Bio-Methanation		Organic/volatile matter	>40
		C/N ratio	25-30

Anaerobic digestion has applicability in tanning industry. One of the feasible options is to digest the fleshing generated from tannery under anaerobic condition and use the digested sludge as manure. The pilot study was carried out to assess the feasibility of anaerobic digestion of fleshing and subsequent biogas generation. Anaerobic digestion of liquefied fleshing along with tannery wastewater for biogas generation is considered economically feasible. 20 30% of the energy required for operation of the effluent treatment plant can be recovered by treating wastewater along with biologically liquefied fleshing in the reactor in addition to solving the disposal problem of waste fleshing [13].

2.6.2.2. Composting

Composting is a controlled biological process that uses natural aerobic processes to increase the rate of biological decomposition of organic materials. It is carried out by successive microbial populations that break down organic materials into carbon dioxide, water, minerals and stabilized organic matter. Carbon dioxide and water are released into the atmosphere, while minerals and organic matter are converted into a potentially reusable soil-like material called compost. The loss of water and carbon dioxide typically reduces the volume of remaining material by 25–60%. Compost can be used as a soil amendment in a variety of agricultural, horticultural or landscaping applications, as long as appropriate measures are taken to eliminate contaminants and impurities from the finished product. The release of organic acids may decrease the pH and production of ammonia from nitrogenous compounds may raise the pH. At higher pH levels, more ammonia gas is generated and may be lost to the atmosphere. A pH value between 6.5 and 8.5 is optimal for compost microorganisms. As bacteria and fungi digest organic matter, they release organic acids [25]. The standard physicochemical parameters required for composting is give in Table 2.3 as below.

Table 2.3: Standard Values of Physicochemical Parameters for Composting [26]

S.Nº	Physicochemical parameters	Standard values suitable for composting
1	pH	5.5-8.0
2	Moisture (%dry basis)	<50
3	Organic matter (%dry basis)	>20
4	Nitrogen (%dry basis)	>0.6
5	Carbon (%dry basis)	30-40
6	C:N ratio (total dry basis)	25-50:1

The important physical parameters requiring consideration include size of constituents, density and moisture content. Smaller size of the constituents aids in faster decomposition of the waste. Wastes of high density reflect a high proportion of biodegradable organic matter and moisture. Low density wastes, on the other hand, indicate a high proportion of paper, plastics and other combustibles. Moisture content indicates water contents of the waste, which is the percentage of the wet weight material to dry material. Microorganisms can only use organic molecules if they are dissolved in water, so the compost pile should have a moisture content of 60-80% of water holding capacity. If the moisture content falls below 40% of water holding capacity the microbial activity will slow down or become dormant. If the moisture content exceeds 80% of water holding capacity, aeration is hindered, nutrients are leached out, decomposition slows, and the odor from anaerobic decomposition is emitted [26].

High moisture content causes biodegradable waste fractions to decompose more rapidly than in dry conditions [22].

2.6.3. Advantages and Disadvantages of Different Waste to Energy Technological Options

The possible waste to energy solid waste management options discussed above are compared and presented in Table 2.4 as below. The Table 2.4 provides the main advantages and disadvantages of anaerobic digestion, incineration and pyrolysis/gasification processes during their usage to convert the solid wastes to energy.

Table 2.4: Advantages and Disadvantages of Waste to Energy Technological Options **[**11**]:**

Advantages	Disadvantages
Anaerobic Digestion	
Energy recovery with production of high grade soil conditioner.	Heat released is less- resulting in lower and less effective destruction of pathogenic organisms (disease causing organisms) than in aerobic composting. However, now thermophilic temperature systems are also available to take care of this
No power requirement unlike aerobic composting, where sieving and turning of waste pile for supply of oxygen is necessary.	Unsuitable for wastes containing less organic matter
Enclosed system enables all the gas produced to be collected for use.	Requires waste segregation for improving digestion efficiency
Controls Green House Gases emissions	
Free from bad odour, rodent and fly menace, visible pollution and social resistance.	
Modular construction of plant and closed treatment needs less land area	
Net positive environmental gains.	
Can be done at small-scale	
Incineration	
Most suitable for high Calorific Value waste, pathological wastes, etc.	Least suitable for aqueous/ high moisture content/ low Calorific Value
Units with continuous feed and high through-put can be set up.	Excessive moisture and inert content affects net energy recovery
Thermal Energy recovery for direct heating or power generation.	Auxiliary fuel support may be required to sustain combustion
Relatively noiseless and odourless.	Concern for toxic metals that may concentrate in ash, emission of particulates, SOx, NOx, chlorinated compounds, ranging from HCl to Dioxins
Low land area requirement.	High capital, operation and maintenance costs. Skilled personnel required for operation and maintenance
Can be located within city limits, reducing the cost of waste transportation.	Overall efficiency low for small power stations
Hygienic.	
Pyrolysis/ Gasification	
Production of fuel gas/oil, which can be used for a variety of applications	Net energy recovery may suffer in case of wastes with excessive moisture.
Compared to incineration, control of atmospheric pollution can be dealt with in a superior way, in techno-economic sense.	High viscosity of pyrolysis oil may be problematic for its transportation and burning.

2.6.4. Environmental, Social and Political Aspects of Waste to Energy Technologies

Waste-to-energy is renewable because its fuel source, garbage, is sustainable and non-depletable. Waste-to-energy facilities produce electricity with “less environmental impact than almost any other source of electricity,” according to the U.S. Environmental Protection Agency. Waste-to-energy facilities today meet some of the most stringent environmental standards (see Annex 3) and employ the most advanced emissions control equipment. In addition to combustion controls, waste-to-energy facilities employ sophisticated air quality control equipment as stated below [21].

- A “Selective Non-Catalytic Reduction” or “SNCR” converts nitrogen oxides – a cause of urban smog – to harmless nitrogen by spraying ammonia or urea into the hot furnace
- A “scrubber” sprays a mixture of lime and water into the hot exhaust gases. The lime neutralizes acid gases, just as a gardener uses lime to neutralize acidic soil. Scrubbing also can improve the capture of heavy metals such as mercury in the exhaust gases.
- A “carbon Injection” system blows powdered carbon into the exhaust gas to absorb mercury. Carbon injection also reduces emissions of trace organics such as dioxins.
- A “bag house” works like a giant vacuum cleaner with hundreds of fabric filter bags that clean the air of soot, smoke and metals.

As a result of the controls employed at these plants, dramatic reductions in emissions have been achieved. When a ton of trash is delivered to a waste-to-energy plant, several things happen: the energy content of the waste is retrieved, metals are recovered and recycled, and electricity is generated [21].

A modern waste-to-energy plant provides for the avoidance of greenhouse gases through three different operations: [21].

- For every megawatt of electricity generated through the combustion of solid waste, a megawatt of electricity from conventional, e.g., coal or oil-fired, power plants is avoided, creating a net savings of emissions of greenhouse gases, i.e. carbon dioxide.
- A modern municipal waste-to-energy facility separates ferrous and/or nonferrous metals for recycling. This is more energy efficient than mining virgin materials for the

production of new metals such as steel. As a result, there is a significant energy savings and additional avoidance of greenhouse gas emissions

- When a ton of solid waste is delivered to a waste-to-energy facility, the methane that would have been generated if it were sent to a landfill is avoided. While some of this methane could be collected and used to generate electricity, some would not be captured and would be emitted to the atmosphere. Methane is a potent greenhouse gas twenty-three times more potent than carbon dioxide.

Waste-to-energy reduces the volume of trash by about 90%, resulting in a 90% decrease in the amount of land required for garbage disposal. Ash from waste to energy facility also exhibits concrete-like properties causing it to harden once it is placed and compacted in a landfill, reducing the potential for rainwater to leach contaminants from ash landfills into the ground [21].

Modern waste-to-energy facilities are subject to comprehensive health risk assessments that repeatedly show that waste-to-energy is safe and effective. Waste-to-energy facilities destroy pathogens, organics, and other disease-bearing material in trash. Trash coming into a waste-to-energy facility is handled in enclosed tipping halls that are maintained under negative pressure to pull air directly into the boilers and destroy any odours [21].

Potential facility sites should be determined focusing principally on territorial factors (neighbourhood impact, urban planning requirements, traffic access, landscape integration, atmospheric dispersion capacity of the zone, etc), economic factors (cost of transporting waste to and from the incinerator, refrigeration water availability, land prices, etc.) and socio-political factors (citizens' acceptance, consensus among the relevant national and local authorities, etc.). The site selection process is very sensitive to citizens' acceptance. A reaction of non-acceptance of the facility is usual due to the well known "not in my backyard effect" (NIMBY effect). It is recommended carrying out a participatory site selection process with a transparent awareness campaign aimed at citizens and stakeholders. The responsible authority should communicate clear information about the reasons for building the facility, the pros and cons of site alternatives and the planned measures for reducing and controlling the possible negative effects [21].

2.6.5. Cost Effectiveness of Waste-To-Energy Technologies

There are many waste-to-energy technologies, but how many of these are cost effective? As stated above, the waste to energy technology includes incineration, gasification/pyrolysis, anaerobic digestion, fermentation, and esterification. Some of these technologies are very cost effective, while others may not be as much so. Some use thermal processing, others use chemical processing, and still others use biochemical processing [21].

Gasification and pyrolysis are some of the most effective waste to energy technologies available currently. These two technologies can be performed together to maximize the cost effectiveness. Pyrolysis needs an outside heat source, and this is supplied by the gasification process, making both processes together self-sustaining. This reduces the cost of the process, making them both more cost effective [21].

The cost effectiveness of esterification will depend on the feedstock being used, and all the other relevant factors such as transportation distance, amount of oil present in the feedstock, and others [21].

All waste to energy technology can be developed to be cost effective. This is crucial because most of the people will not pay a lot more just to use a green energy source. This means that any methods used must be cost effective or it will not succeed. All of the factors involved need to be examined and it is important to set up any waste to energy plant in a location that meets all the needs. The waste must be available, although this would not be a problem in any area usually, plus the labour, resources, and infrastructure must be present as well. Otherwise the cost of creating the energy from waste is too high, and will not be used. Using cost cutting measures, and placing the waste to energy plant in the right location, can bring down the energy cost significantly. Waste to energy technology can be extremely cost effective and efficient when implemented correctly [21].

2.6.6. Challenges of Waste-To-Energy Technologies

Lack of versatility: - Many waste-to-energy technologies are designed to handle only one or a few types of waste (whether plastic, biomass, or others). However, it is often impossible to fully separate different types of waste or to determine the exact composition of a waste source. For many waste-to-energy technologies to be successful, they will also have to become more versatile or be supplemented by material handling and sorting systems.

Waste-gas cleanup: - The gas generated by processes like pyrolysis and thermal gasification must be cleaned of tars and particulates in order to produce clean, efficient fuel gas.

Regulatory hurdles. The regulatory climate for waste-to energy technologies can be extremely complex. Regulations may prohibit a particular method, typically incineration, due to air-quality concerns, or classify ash by-products of waste-to-energy technologies as hazardous materials.

Opposition from environmental and citizen groups Because traditional incineration-based waste-to-energy technologies can produce significant pollution from the burning of waste, environmental and citizen groups have often opposed such systems [21].

In general, the main purpose of this literature review is to identify the available solid waste management strategies (source reduction, recycling and composting, combustion (waste-to-energy facilities), and landfilling) so that they can be used for tannery solid waste management based on the physicochemical characteristics of the solid waste.

3. Materials and Methods

The following materials and methods were used to carry out this study.

3.1. Materials

Hides and skins were used to produce finished leather for garment, glove and shoe upper. Leather processing chemicals, tannery machineries for processing the raw hides/skins and laboratory equipments (Atomic absorption Spectrophotometer, Oven, digital balance, solid waste sample collection containers (plastic), pH meter, pipette, shaker, wide-necked polyethylene flask, calorimeter, Distillation unit, volumetric flasks) for the characterization of the sample solid wastes were also used.

3.2. Methods

The methods used to reach at each specific objectives of this study are described as in the following sub-titles

3.2.1. Investigation and Identification of Types and Sources of Tannery Solid Wastes

The sources and types of tannery solid waste generated during manufacturing of different types of finished leather were identified by physical observations and interviewing the foreman working on each stages of leather processing at ELICO. The observations were made at two units of the tannery (hides and skins unit). The first observation was made at the hides unit in which finished leather for shoe upper is produced and then at skins unit where finished leather for glove and garment are manufactured.

3.2.2. Determination of Tannery Solid Waste Generation Rate

Waste generation is the first element of waste management. It is a prerequisite to any waste management plan to have adequate knowledge of the generators of waste, its generation rates, physical and chemical characteristics. Waste generation embodies activities in which materials are identified as no longer of value and either thrown away or gathered together for disposal of which reliable estimate of solid waste generation is very important for proper waste management planning.

To determine the generation rate of each types of solid waste generated from the tannery, the following methods were used.

- Based on random sampling techniques, samples of ten pieces of wet salted cattle hides being processed to produce finished leather for shoe upper were taken piece by piece at each unit operations of leather manufacturing processes which are expected to generate the solid wastes (i.e. fleshing, splitting, chrome shaving, crust trimming and finished leather trimming) and material balance analysis techniques were applied (i.e. weighing the samples before and after the operations) to determine the generation rate of the solid waste
- In a similar manner, samples of ten pieces of wet salted sheep skins being processed to produce finished leather for glove and garment were randomly taken piece by piece at each unit operations of leather manufacturing processes which are expected to generate solid wastes (i.e. desalting, raw skin trimming, un-hairing, Fleshing, shaving, crust trimming and finished leather trimming) and material balance analysis techniques were applied to determine the generation rate of the solid wastes

3.2.3. Assessment on Tannery Solid Waste Management Practices at ELICO

In a similar manner, prior to sample collection for the analysis, a visit was made within the compound of ELICO to observe and assess the existing solid waste management practices of the tannery. In addition to physical observation, interviews were made with the concerned personnel of the tannery to gather information on how the solid wastes generated from the tannery are being managed.

3.2.4. Characterization of the Major Types of Tannery Solid Wastes

In order to determine selected physicochemical parameters (pH, moisture content, volatile organic compound, ash content, carbon content, nitrogen content, calorific value, chromium content, sodium content and calcium content) of the solid wastes generated during leather manufacturing processes at ELICO , the following methods were used.

3.2.4.1. Determination of pH

The pH of the sample solid wastes were determined by shaking five gram of sample of solid wastes in 100ml of distilled water for 16 – 24 hours followed by direct measurement of the pH according to the standard methods of SLC 13 [27]. The level of pH in the waste depends upon the decomposition rate and characteristics of feed material [28].

3.2.4.2. Determination of Moisture Content

Moisture content of solid waste is usually expressed as the mass of moisture per unit mass of wet or dry materials. In order to determine the moisture content of the solid wastes, samples of the solid waste was first weighed and put in an oven at 105^0C for 24 hours. It was kept in desiccators for about 30 minutes and then weighed and recorded. The wet-mass moisture content is expressed as follows [29]:

Moisture content (%) = ((w-d) /w) x 100 ……………………………………………3.1

Where w = initial mass of sample as delivered and

d = mass of sample after drying.

3.2.4.3. Determination of Volatile Organic Compound and Ash Content

The volatile organic compound and ash content were determined after burning the dry solids in a furnace at 600 to 650^0C for 2 hours [28]. The samples were again sent to a desiccator for about 30 minutes and weighed.

$$\text{Ash Content (\%)} = \left(\frac{W_1}{W_2}\right) * 100 \quad \ldots\ldots 3.2$$

$$\text{Volatile organic compound (\%)} = \frac{(W_2 - W_1) * 100}{W_2} \quad \ldots\ldots 3.3$$

Where: W_1 is the weight of the sample solid waste left after burning

W_2 is the weight of the sample solid waste before burning

3.2.4.4. Determination of Carbon Content

The determination of the C/N ratio, which is so important in regard to nitrogen conservation and for estimating the quantity of the finished compost, is more of a problem, because the quantitative analysis of carbon is difficult, time consuming, and expensive. For composting work, the percentage of carbon can be estimated satisfactorily from the percentage of ash a much simpler test by the equation

$$C = \frac{(100 - \%Ash)}{(1.8)} \quad \ldots\ldots 3.4$$

The University of California group on checking this simpler method, found the results to be within 2%-10% of the more accurate carbon determination [28].

3.2.4.5. Determination of Total Nitrogen

To determine the total nitrogen content of the sample solid waste a standard method of SLC 7 [27] which is kjeldhal method was used. It involves two steps, digestion, distillation and titration.

Digestion

Ten grams of milled organic was weighed into a 500ml kjeldhal flask moistened with distil water. Selenium powder and sodium sulphate was added as a catalyst and 30ml of concentrated sulphuric acid was also added and then digested for 2 hours using the Bunsen burner flame. The solution was then cooled and decanted into a 100ml volumetric flask and made up to the mark.

Distillation and Titration

An aliquot of 10ml of the digested sample was taken into a distillation unit and 20ml of 40% NaOH was taken and 10ml of 4% boric acid was added to it resulting in a pink colour. The distillate was then collected over NaOH solution and boric acid for about 5 minutes. The presence of nitrogen gave a blue colour. The solution was titrated with 0.1MHCL until the blue colour changed to pink signifying the end point. Using the recorded titre value and the relation below the % of nitrogen was then calculated.

$$\%\text{Total Nitrogen} = 14 * (A - B) * N * \frac{100}{1000 * 1} \quad \ldots\ldots 3.5$$

Where: A is the volume of standard HCL used in the sample titration.

B is the volume of the standard solution used in the blank titration.

N is the normality of standard HCL

3.2.4.6. Determination of Calorific Value

The calorific value of the sample solid waste was determined using Bertholet Calorimeter under 23-30 atmospheric pressure by burning with electric current in an aerobic environment and monitoring the temperature increase of a certain amount of water by the generated heat [9].The feasibility of combustion depends on moisture content, volatile combustible matter, fixed carbon and ash content. The combustion is expressed by the term calorific value of waste, which is a quantitative estimation of heat energy released by burning.

3.2.4.7. Determination of Carbon to Nitrogen (C: N) Ratio

The carbon to nitrogen ration of the sample solid wastes was determined by dividing the percentage of carbon content to the percentage of nitrogen content of the samples. Carbon and nitrogen are essential to microorganisms that break down organic material. In the process of breaking down the organic material, microorganisms utilize the carbon as a source of energy and the nitrogen as the building block for protein synthesis. Carbon can be considered as "food" and nitrogen as the digestive enzymes. A nutritional requirement for microorganisms is that the C: N ratio of organic matter must be at a level for optimum decomposition efficiency. The limiting C: N ratio for most microbial organisms ranges from 25:1 to 30:1 (i.e., 25–30 parts carbon to 1 part nitrogen). When the C: N ratio of the compost exceeds 30:1, the organisms become deficient in nitrogen and the process of decomposition is slowed [29].

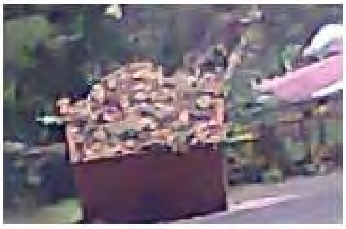
3.2.4.8. Determination of Chromium, Sodium and Calcium Content

Atomic absorption spectrophotometer at laboratory of Addis Ababa Environmental Agency was used to determine chromium (Cr), sodium (Na) and calcium (Ca) contents of the sample tannery solid wastes. The samples were first treated with an acid digestion process and sample solutions were filled up to 100 ml with pure water after they reached room temperature (it may be filtered through filter paper if necessary). Desired measurements were later done in these obtained solutions by using atomic absorption. The amount of Cr, Na and Ca in the sample solid wastes were detected with Perkin-Elmer 2380 Atomic Absorption Spectrophotometer. Cr was measured at 357.9nm with 0.7 slit intervals by using air plus acetylene (C_2H_2) mixture, Na was measured at 589.6nm with 1.4 slit intervals by using air plus propane (C_3H_8) mixture and Ca was measured at 422.7nm with 1.4 slit intervals by using air plus C_2H_2 mixture [9].

4. Results and Discussion

4.1. Types and Sources of Tannery Solid Waste

According to the study made at Ethio-Leather Industry Private Limited Company (ELICO), the physical composition of tannery solid waste generated during leather manufacturing processes was found to be de-dusted salt, hair waste, fleshings, raw skin trimmings, splitting waste, Pickle trimmings, shavings, Crust Trimmings and leather trimmings and it has been observed from literature review [17] that similar types of solid is generated during manufacturing of finished leather from hides and skins. In addition to these, sludge and other solid wastes are also generated during tannery wastewater treatment (see Figure 4.1 below) and the main sources of these solid wastes were found to be un-hairing, trimming, fleshing, splitting, which are all carried out in beamhouse, chrome shaving after chrome tanning operation, crust trimming after re-tanning, finished leather trimming after finishing processes and wastewater treatment plant.



a) Raw Sheep Skin Trimmings

b) Hair waste

C) Fleshings and Trimmings

d) Splitting (with Shavings)

e) Chrome Shaving Waste

f) Pickle Trimmings waste

g) Solid Waste generated from General Liquor Screening

Figure 4.1 Types of Solid Waste Generated from Tannery

4.2. Generation Rate of Tannery Solid Waste

In order to determine the generation rate of tannery solid waste per kilogram of raw hide or skin processed at each unit operations of leather manufacturing process which are expected to generate solid waste, salt preserved cattle hides and sheep skins were prepared to produce finished leather for shoe upper, glove and garment and the generation rate of each types of the solid wastes were determined using material balance analysis technique.

I. Solid Waste Generated during Cattle hide Processing

Salt preserved cattle hides were used to produce shoe upper leather and the solid wastes generated from each unit operations were determined. In order to determine the weight of a single piece of wet salted hide ten batches of wet salted hides were taken randomly from different batches prepared for soaking operation and then each sample batch containing different number of pieces of hides ranging from 350 to 447 pieces were weighed. The weight of each sample batch was divided to its number of pieces of hides to determine the weight of a piece of wet salted hide. Based on this calculation the average weight of a single piece of wet salted hide was found to be 10.42kg (see Annex 4). On average the area of a single piece of wet salted hide 2.23 square meters and its weight is taken as 17.00kg. But it is observed that 80% of the raw hides and skins used as input to the tanning industries in the country are collected from rural areas [3] and take a few weeks to reach the tannery that lets the hides and skins to loss their moisture content resulting in weight loss.

a) Fleshings and Trimming Waste

Fleshings are a solid waste generated during a mechanical process called fleshing that aims to remove the flesh or fats from the inner part of the hide or skin. Trimmings are unwanted parts removed by cutting the edge of hides just after fleshing operation is completed. To determine the fleshings and trimmings waste generated per kilogram of raw hide processed ten pieces of hides that have already passed through soaking and liming processes were randomly taken from ten different batches and weighed before and after fleshing and trimming operations. The data obtained from the experiment are presented in the Table 4.1 as follows.

From the experiment performed it was observed that 0.26kg of fleshing and trimming waste is generated per kilogram of wet salted hide processed to produce shoe upper leather. This indicates that a tannery having a daily soaking capacity of one tonne (1000kg) of wet salted hides will generate 260kg of fleshing and trimming waste daily. This value is found to be more than double with the amount observed from literature review [17] due to the fact that the trimmings waste generated during trimming operation which was applied following fleshing operation was incorporated in this study.

Table 4.1. Fleshing and Trimming Waste Generated per kilogram of wet salted hide

S.N^{o}	Weight of a single piece of wet slated hide (kg)	Weight of a single piece of hide Before Fleshing and Trimming (kg)	Weight of a single piece of hide After Fleshing and Trimming (kg)	Weight of Fleshing and Trimming waste generated (kg/kg of raw hide)
1	9.30	13.30	11.35	0.21
2	10.00	14.00	11.20	0.28
3	10.10	14.10	11.68	0.24
4	11.80	15.80	12.61	0.27
5	9.30	13.30	10.51	0.30
6	10.90	14.90	12.50	0.22
7	11.30	15.30	12.48	0.25
8	11.20	15.20	12.62	0.23
9	8.90	12.90	10.59	0.26
10	11.40	15.40	12.09	0.29
Average weight (kg)	10.42	14.42	11.76	0.26

b) Splitting Waste

Hides which have already fleshed and trimmed are usually subjected to mechanical operation called splitting to remove some unwanted layers of the hides. Splitting operation can also be applied when it is required to divide the hide in to two layers so that both splits can be utilized and this is the condition at which the splits are not considered as a waste. Sometimes the splitting operation comes after tanning operation, which means at wet blue stage called wet blue splitting. In this study splitting just after fleshing and trimming operation also called pelt splitting was considered as it is mostly practiced in hide processing. To determine the splitting waste generated per kilogram of wet salted hide, a sample of ten pieces of hides which have already gone through fleshing and trimming processes were randomly taken from ten different batches and weighed before and after splitting operation and the data obtained during the experiment are presented in the Table 4.2 as below.

Table 4.2. Splitting Waste Generated per Kilogram of wet salted hide processed

S.N^{o}	Weight of a single piece of wet slated hide (kg)	Weight of a single piece of hide Before Splitting (kg)	Weight of a single piece of hide After Splitting (kg)	Weight of Splitting waste generated (kg/kg of raw hide)
1	9.30	11.35	8.84	0.27
2	10.00	11.20	8.10	0.31
3	10.10	11.68	9.26	0.24
4	11.80	12.61	9.19	0.29
5	9.30	10.51	8.19	0.25
6	10.90	12.50	10.32	0.2
7	11.30	12.48	8.64	0.34
8	11.20	12.62	9.48	0.28
9	8.90	10.59	8.28	0.26
10	11.40	12.09	8.78	0.29
Average weight (kg)	10.42	11.76	8.91	0.27

From Table 4.2 above it can be observed that 0.27kg of splitting waste is generated per kilogram of wet salted hide processed to produce finished leather for shoe upper. This indicates that a tannery having a daily soaking capacity of 1000kg of wet salted hide is expected to generate 270kg of splitting waste if the splitting operation is done at pelt stage.

c) Chrome Shaving Waste

In hide processing it is usual that after tanning process the wet blue will be divided into two parts which is called siding process. These two parts of the wet blue is called sides. To determine wet shaving waste generated per kilogram of raw wet salted hide processed, a sample of ten pieces of wet blue hides were randomly taken from ten different batches and shaved to a thickness of 1.70mm which is the average thickness of finished leather for shoe upper made from cattle hide. The samples were weighed before and after shaving and the data obtained from the experiment are presented in Table 4.3 as below.

Table 4.3 Wet shaving waste generated per kilogram of wet salted hide processed

S.Nº	Weight of a single piece of wet slated hide (kg)	Weight of a single piece of wet blue hide before shaving (kg)	Weight of a single piece of wet blue hide After shaving (kg)	Weight of Shaving waste generated (kg/kg of raw hide)
1	9.30	10.80	5.80	0.54
2	10.00	6.00	4.20	0.18
3	10.10	8.20	5.60	0.26
4	11.80	8.60	5.40	0.27
5	9.30	10.00	5.80	0.45
6	10.90	8.60	5.00	0.33
7	11.30	8.60	6.20	0.21
8	11.20	7.60	4.60	0.27
9	8.90	8.60	6.20	0.27
10	11.40	7.60	4.60	0.26
Average weight (kg)	10.42	8.46	5.34	0.30

As can be seen from Table 4.3 above 0.30kg of shaving waste is generated per kilogram of wet salted hide processed to produce finished leather for shoe upper. This result shows that a tannery having a daily soaking capacity of 1000kg of wet salted hide is expected to generate 300kg of shaving waste per day.

d) Crust Trimmings Waste

In hide processing, wet vacuum drying is applied at crust stage just after setting out operation to reduce the moisture content of the crust leather. Before this drying process the crust leather has to be trimmed to avoid some unwanted parts which are considered as crust trimmings waste. In order to determine this crust trimmings waste generated at wet vacuum drying stage per kilogram of wet salted hide processed to produce finished leather for shoe upper, a sample of ten pieces of crust leather made from hide were randomly taken from ten different batches and weighed before and after trimming operation and the data obtained from the experiments are presented in the Table 4.4 below.

Table 4.4.Crust trimming waste generated per kilogram of wet salted hide processed at wet vacuum drying

S.Nº	Process Stage	Weight of a single piece of wet slated hide (kg)	Weight of a single piece of Crust Leather before Trimming (kg)	Weight of a single piece of Crust Leather After Trimming (kg)	Weight of Crust Trimming waste generated (kg/kg of raw hide)
1	Wet Vacuum Drying	9.30	4.35	4.13	0.024
2		10.00	4.11	3.92	0.019
3		10.10	4.21	4.00	0.021
4		11.80	4.25	4.01	0.020
5		9.30	4.20	4.04	0.017
6		10.90	4.44	4.24	0.018
7		11.30	4.23	4.05	0.016
8		11.20	4.41	4.18	0.021
9		8.90	4.39	4.24	0.017
10		11.40	4.15	3.95	0.018
Average weight (kg)		10.42	4.27	4.08	0.019

From Table 4.4 above it can be observed that 0.019kg of crust trimming waste is generated per kilogram of wet salted hide processed to produce finished leather for shoe upper. This indicates that a tannery having a daily soaking capacity of 1000.00kg of wet salted hide is expected to generate 19.00kg of crust trimmings waste during crust leather trimming process at wet vacuum drying operation. In a similar manner after staking process which makes the crust leather softer and smoother it is subjected to dry vacuum drying to flatten and remove moisture. Here also there is some crust trimmings that is removed. Therefore, the same sample size was taken and weighed before and after trimming at dry vacuum operation stage to determine the generation rate of crust trimmings waste per kilogram of wet salted hide and the data obtained are presented in Table 4.5 below.

Table 4.5 Crust trimming waste generated per kilogram of wet salted hide processed at dry vacuum drying

S.Nº	Process Stage	Weight of a single piece of wet slated hide (kg)	Weight of a single piece of Crust Leather before Trimming (kg)	Weight of a single piece of Crust Leather After Trimming (kg)	Weight of Crust Trimming waste generated (kg/kg of raw hide)
1	Dry Vacuum Drying	9.30	1.88	1.80	0.009
2		10.00	1.40	1.29	0.011
3		10.10	1.59	1.47	0.012
4		11.80	1.78	1.66	0.010
5		9.30	1.62	1.56	0.006
6		10.90	1.90	1.83	0.006
7		11.30	1.55	1.46	0.008
8		11.20	1.49	1.44	0.004
9		8.90	1.61	1.57	0.004
10		11.40	1.81	1.74	0.006
Average weight (kg)		10.42	1.66	1.58	0.008

From the above Table 4.5 it can be observed that a 0.008kg of crust trimming waste is generated per kilogram of wet salted hide processed to manufacture finished leather for shoe upper during trimming process performed at dry vacuum drying operation. This indicates that 8.00kg of crust trimmings waste is generated from a tannery having a daily soaking capacity of 1000.00kg of wet salted hide. Therefore, the total crust trimmings waste generated per kilogram of wet salted hide during crust leather trimming processes at the two stages of drying operation was found to be 0.027kg. This shows that 27.00kg of crust trimmings waste is generated per day as a solid waste from a tannery producing finished leather for shoe upper and having a daily soaking capacity of 1000.00kg wet salted hide.

e) Finished Leather Trimmings

Finished leather trimmings are solid waste generated during trimming of finished leather to remove some unwanted parts of the leather. To determine the amount of the finished leather trimmings waste generated per kilogram of wet salted hide processed a sample of ten pieces of finished leather were randomly taken from ten different batches of finished leather prepared for trimming operation and weighed before and after trimming operation and the data obtained during the experiment are presented in Table 4.6 as below.

Table 4.6. Finished leather trimmings waste generated per kilogram of wet salted hide processed

S.N^{o}	Weight of a single piece of wet slated hide (kg)	Weight of a single piece of finished leather Before Trimming (kg)	Weight of a single piece of finished leather After Trimming (kg)	Weight of finished leather Trimming waste generated (kg/kg of raw hide)
1	9.30	1.92	1.88	0.004
2	10.00	2.01	2.00	0.001
3	10.10	1.99	1.96	0.003
4	11.80	1.86	1.85	0.001
5	9.30	1.93	1.89	0.004
6	10.90	2.02	2.01	0.001
7	11.30	1.86	1.84	0.002
8	11.20	2.03	2.01	0.002
9	8.90	1.87	1.85	0.002
10	11.40	1.98	1.95	0.003
Average weight (kg)	10.42	1.947	1.924	0.002

From the Table 4.6 above it can be observed that 0.002kg of finished leather trimmings is generated while processing one kilogram of wet salted hide. This experimental result indicates that 2.00kg of solid waste as finished leather trimmings can be generated per day from a tannery having a daily soaking capacity of 1000.00kg of wet salted hide.

The generation rate of the main types of tannery solid wastes during wet salted hide processing to produce finished leather for shoe upper are summarised in the Table 4.7 as below.

Table 4.7 Tannery Solid Waste Generation Rate (during wet salted hide processing)

S.Nº	Types of tannery solid wastes	Generation Rate (kg/kg of wet salted hide)	Generation Rate (kg/tonne of wet salted hide)	Total Solid waste generated (kg/tonne of wet salted hide)
1	Fleshing and Trimmings waste	0.26	260	859
2	Splitting waste	0.27	270	
3	Chrome Shavings	0.30	300	
4	Crust Trimmings waste	0.027	27	
5	Finished leather trimmings waste	0.002	2	

It can be seen from Table 4.7 above that processing one tonne of wet salted hide can generate 859kg of solid wastes which accounts 86% of the raw hide processed which is found to be comparatively similar with the value obtained from literature review [14]. On the other hand it was found that the daily hide soaking capacity of the ELICO tannery is 12,000kg. Taking 300 working days per annum, the annual soaking capacity of the tannery is 3,600 tonne of hide. This indicates that 3,092.4 tonne of solid waste is generated annually during leather manufacturing processes (beam house to finishing processes) and disposed to the open dumping area used for municipal solid waste disposal. In addition to this, sludge generated from effluent treatment plant is 14% of hide processed [18] which indicates that 504 tonne of sludge is generated annually from the tannery and being disposed in the same manner with the other types of solid wastes.

In general, including the sludge, a total of 3,596.4 ton of solid waste is generated annually only from hide processing unit of the tannery.

The percentage share of solid wastes generated during processing of one tonne of raw hide is given in the Figure 4.2 as below.

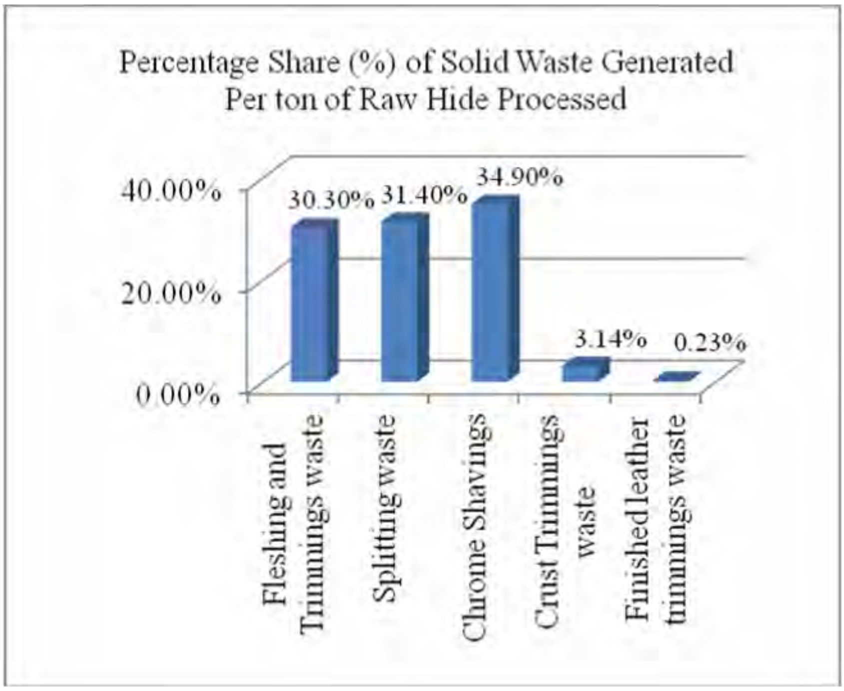


Figure 4.2. Percentage share of tannery solid wastes generated per ton of raw hide processed

The contribution of leather manufacturing process stages in generating solid wastes during production of finished leather from hides is shown the Figure 4.3 below.

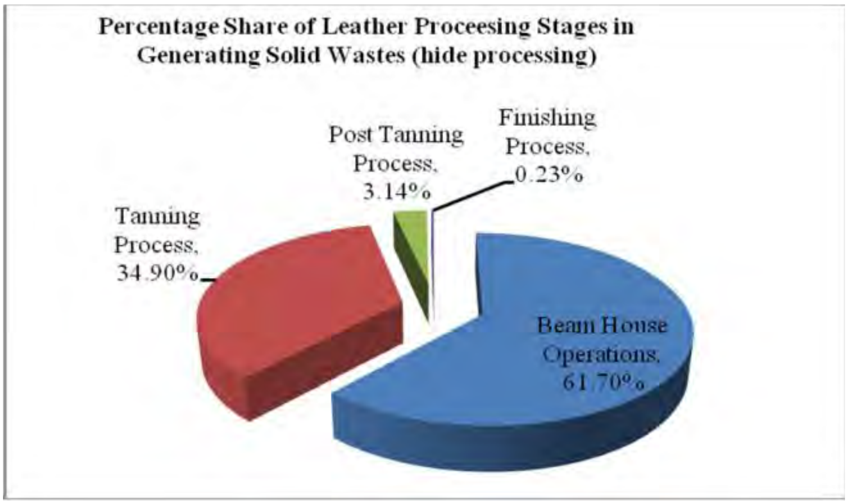


Figure 4.3. percentage share of leather processing stages in generating solid wastes (hide processing)

II. Solid Waste Generated during Sheep skin Processing

Wet salted sheep skins were used to produce glove and garment leathers and the solid wastes generated from each unit operations were determined. To determine the amount of solid waste generated, a sample size of ten pieces of sheep skins were taken from ten batches randomly at each unit operations of leather manufacturing process which are considered to generate solid waste.

a) De-dusted Salt

De-dusted salt is a salt removed by shaking the wet salted sheep skins before soaking operation. Usually this shaking operation is not performed for the purpose of removing the preservative salt. Rather, during unloading of the wet salted sheep skins to the warehouse the salt is get removed from the skin and this de-dusted salt is being disposed along with other types of tannery solid wastes. In order to determine the amount of salt removed from sheep skin, samples of ten pieces of wet salted sheep skins were randomly taken from ten batches of skins prepared for soaking process and each pieces of the sample skin was weighed before and after hand shaking operation to determine the de-dusted salt generated per kilogram of wet salted sheep skins and the results of this experiment are presented in Table 4.8 as below.

Table 4.8 De-dusted salt generated per kilogram of wet salted sheep skin processed

S.Nº	Weight of a single piece of wet salted sheep skin before hand shaking (kg)	Weight of a single piece of wet salted sheep skin after hand shaking (kg)	Weight of de-dusted salt (kg/sheep skin)	Weight of de-dusted salt generated (kg/kg of raw sheep skins)
1	1.220	1.198	0.022	0.018
2	1.230	1.204	0.026	0.021
3	1.210	1.181	0.029	0.024
4	1.200	1.176	0.024	0.020
5	1.240	1.213	0.027	0.022
6	1.210	1.182	0.028	0.023
7	1.230	1.210	0.020	0.016
8	1.220	1.195	0.025	0.020
9	1.200	1.175	0.026	0.022
10	1.210	1.187	0.023	0.019
Average weight (kg)	1.217	1.192	0.025	0.021

From the Table 4.8 above it can be observed that on average 0.021kg of de-dusted salt is generated during hand shaking of a kilogram of wet salted sheep skin. This shows that a tannery having a daily soaking capacity of 1000.00kg of wet salted sheep is expected to generate 21.00kg of salt per day.

b) Raw Sheep Skin Trimmings

Usually raw wet salted sheep skins are trimmed to remove some unwanted parts of the skin before soaking operation. Therefore, to determine the solid waste generated as a raw sheep skin trimmings per kilogram of sheep skins processed, a sample of ten pieces of wet salted sheep skins were randomly taken from ten different batches of skins prepared for soaking operation and weighed before and after trimming operation and the results obtained are given in the Table 4.9 as below.

Table 4.9. Raw skin trimmings generated per kilogram of wet salted sheep skin processed

S.N^{o}	Weight of a single piece of wet slated sheep skin before trimming (kg)	Weight of a single piece of wet salted sheep skin after trimming (kg)	Weight of raw skin trimmings generated (kg/kg of raw sheep skins)
1	1.220	1.197	0.019
2	1.230	1.206	0.020
3	1.210	1.184	0.021
4	1.200	1.179	0.018
5	1.240	1.216	0.019
6	1.210	1.185	0.021
7	1.230	1.203	0.022
8	1.220	1.192	0.023
9	1.200	1.179	0.018
10	1.210	1.190	0.017
Average weight (kg)	1.217	1.193	0.020

As can be seen from the Table 4.9 above 0.020kg of raw skin trimmings is generated per kilogram of wet salted sheep skin during sheep skin trimming process. This shows that 20.00kg of raw skin trimmings is generated per day from a tannery having a daily soaking capacity 1000.00kg of wet salted sheep skin.

c) Hair Waste

Unlike cattle hide processing, sheep skins are subjected to a chemical process called un-hairing process to remove the hair. The skins are subjected to the un-hairing process just after soaking operation is completed and before going for fleshing process. In order to determine the hair waste generated per kilogram of raw wet salted sheep skin, a sample of ten pieces of soaked sheep skins were randomly taken from ten different batches of soaked sheep skins prepared for un-hairing process and weighed before and after un-hairing process and the results obtained are presented in Table 4.10 as below.

Table 4.10. Hair waste generated per kilogram of wet salted sheep skin processed

S.N^{o}	Weight of a single piece of wet slated sheep skin (kg)	Weight of a single piece of Soaked sheep skin Before Un-hairing (kg)	Weight of a single piece of Soaked sheep skin After Un-hairing (kg)	Weight of hair waste generated (kg/kg of raw sheep skins)
1	1.220	1.952	1.786	0.136
2	1.230	1.968	1.803	0.134
3	1.210	1.936	1.777	0.131
4	1.200	1.920	1.757	0.136
5	1.240	1.984	1.820	0.132
6	1.210	1.936	1.773	0.135
7	1.230	1.968	1.801	0.136
8	1.220	1.952	1.790	0.133
9	1.200	1.920	1.754	0.138
10	1.210	1.936	1.772	0.136
Average weight (kg)	1.217	1.947	1.783	0.135

It can be seen from Table 4.10 above that 0.135kg of hair waste is generated from a kilogram of wet salted sheep skin processed. This shows that 135.00kg of hair waste is generated per day from tanning industry having a daily soaking capacity 1000.00kg of wet salted sheep skin.

d) Fleshing Waste

In order to determine the fleshing waste generated per kilogram of wet slated sheep skin processed, a sample of ten pieces of un-haired sheep skins were taken randomly from ten different batches of un-haired sheep skins prepared for fleshing process and weighed before and after fleshing process and the results are presented in Table 4.11 as below.

Table 4.11. Fleshing Waste Generated per kilogram of wet salted sheep skin processed

S.N^{o}	Weight of a single piece of wet slated sheep skin (kg)	Weight of a single piece of sheep skin Before Fleshing (kg)	Weight of a single piece of sheep skin After Fleshing (kg)	Weight of Fleshing waste generated (kg/kg of raw sheep skins)
1	1.220	1.786	1.773	0.011
2	1.230	1.803	1.760	0.035
3	1.210	1.777	1.760	0.014
4	1.200	1.757	1.730	0.022
5	1.240	1.820	1.800	0.016
6	1.210	1.773	1.724	0.040
7	1.230	1.801	1.790	0.009
8	1.220	1.790	1.770	0.016
9	1.200	1.754	1.740	0.012
10	1.210	1.772	1.760	0.010
Average weight (kg)	1.217	1.783	1.761	0.019

From the above Table 4.11 it can be seen that 0.019kg of fleshing waste generated from a kilogram of wet salted sheep skin processed to manufacture glove and garment leather. This indicates that 19.00kg of fleshing waste is generated from a tannery having a daily soaking capacity of 1000.00kg of wet salted sheep skin.

e) Pickle Trimmings

Pickle trimmings are solid wastes generated by trimming the pickle during leather processing just after pickling process. In order to determine the pickle trimmings waste generated per kilogram of wet salted sheep skin, a sample of ten pieces of pickled sheep skins were taken randomly from ten different batches of pickle products prepared for chrome tanning process and weighed before and after trimming process and the results obtained are presented in Table 4.12 as below.

Table 4.12. Pickle trimmings waste generated per kilogram of wet salted sheep skin processed

S.N^{o}	Weight of a single piece of wet slated sheep skin (kg)	Weight of a single piece of pickled sheep skin Before Trimming (kg)	Weight of a single piece of pickled sheep skin After Trimming (kg)	Weight of Pickle Trimming waste generated (kg/kg of raw sheep skin)
1	1.22	0.43	0.406	0.020
2	1.23	0.42	0.398	0.018
3	1.21	0.47	0.447	0.019
4	1.20	0.44	0.414	0.022
5	1.24	0.46	0.441	0.015
6	1.21	0.50	0.475	0.021
7	1.23	0.45	0.429	0.017
8	1.22	0.49	0.466	0.020
9	1.20	0.54	0.513	0.023
10	1.21	0.41	0.385	0.021
Average weight (kg)	1.217	0.461	0.437	0.019

Table 4.12 above shows that 0.019kg of pickle trimmings waste is generated per kilogram of wet salted sheep skin processed. This result indicates a tannery having a daily soaking capacity of 1000.00kg of wet salted sheep skin generates 19.00kg of pickle trimmings waste.

f) Shaving Waste

Unlike hide processing, sheep skins are shaved after re-tanning processes are completed (i.e. it is shaved at crust stage). The thickness at which shaving machine is set depends on the type of the end use of the finished leather to be produced. Usually glove leather and garment leather are shaved to a thickness ranging from 0.40 to 0.55mm and 0.60mm to 0.80mm respectively depending on the customer requirement. In order to determine shaving waste (dry shaving waste) generated per kilogram of wet salted sheep skin processed, a sample of ten pieces of crust leather were randomly taken from different batches of crust leather prepared for shaving process and weighed before and after shaving operation. The samples were shaved at a thickness of 0.45mm and 0.55mm (for glove leather). The data generated is presented in the Table 4.13 below.

Table 4.13. Dry shaving waste generated per kilogram of wet salted sheep skin processed (for glove leather)

S.N^{o}	Weight of a single piece of wet slated sheep skin (kg)	Weight of a single piece of Crust sheep skin Before Shaving (kg)	Weight of a single piece of Crust sheep skin After Shaving (kg)	Weight of Shaving waste generated (kg/kg of raw sheep skin)
1	1.22	0.161	0.114	0.039
2	1.23	0.159	0.110	0.040
3	1.21	0.158	0.116	0.035
4	1.2	0.162	0.114	0.040
5	1.24	0.160	0.112	0.039
6	1.21	0.114	0.088	0.021
7	1.23	0.110	0.081	0.024
8	1.22	0.116	0.079	0.030
9	1.2	0.117	0.091	0.022
10	1.21	0.112	0.086	0.021
Average weight (kg)	1.217	0.137	0.099	0.031

Table 4.13 above shows that 0.031kg of dry shaving waste is generated per kilogram of wet salted sheep skin processed to produce finished leather for glove. This result indicates that a tannery having a daily soaking capacity of 1000.00kg of wet salted sheep skin generates 31.00kg of dry shaving waste. In a similar manner the same sample size was taken and shaved at a thickness of 0.70mm for garment leather and the data generated is presented in the Table 4.14 as below.

Table 4.14. Dry shaving waste generated per kilogram of wet salted sheep skin processed (for garment leather)

S.N^{o}	Weight of a single piece of wet slated sheep skin (kg)	Weight of a single piece of Crust sheep skin Before Shaving (kg)	Weight of a single piece of Crust sheep skin After Shaving (kg)	Weight of Shaving waste generated (kg/kg of raw sheep skin)
1	1.22	0.161	0.115	0.038
2	1.23	0.159	0.128	0.025
3	1.21	0.158	0.116	0.035
4	1.2	0.162	0.119	0.036
5	1.24	0.160	0.124	0.029
6	1.21	0.114	0.098	0.013
7	1.23	0.110	0.089	0.017
8	1.22	0.116	0.089	0.022
9	1.2	0.117	0.098	0.016
10	1.21	0.112	0.096	0.013
Average weight (kg)	1.217	0.137	0.107	0.024

It can be seen from Table 4.14 above that 0.024kg of dry shaving waste is generated per kilogram of wet salted sheep skin processed to produce finished leather for garment. This result indicates that a tannery having a daily soaking capacity of 1000.00kg of wet salted sheep skin generates 24.00kg of dry shaving waste. Therefore, the average weight of chrome shaving waste generated from one ton of wet salted sheep skin was found to be 28.00kg

g) Crust Trimmings

Crust trimmings are solid wastes generated during trimming operation to remove some unwanted parts of the crust leather. To determine the crust trimmings waste generated per kilogram of wet salted sheep skin processed a sample of ten pieces of crust leather made from sheep skins were randomly taken from ten different batches of crust leathers and weighed before and after trimming operation. The data obtained from the experiment are presented in Table 4.15 as below.

Table 4.15. Crust trimmings waste generated per kilogram of wet salted sheep skin processed

S.N°	Weight of a single piece of wet slated sheep skin (kg)	Weight of a single piece of Crust sheep skin Before Trimming (kg)	Weight of a single piece of Crust sheep skin After Trimming (kg)	Weight of Crust Trimming waste generated (kg/kg of raw sheep skin)
1	1.22	0.207	0.189	0.014
2	1.23	0.206	0.192	0.011
3	1.21	0.201	0.189	0.010
4	1.20	0.199	0.179	0.017
5	1.24	0.209	0.189	0.016
6	1.21	0.199	0.181	0.015
7	1.23	0.210	0.194	0.013
8	1.22	0.200	0.185	0.012
9	1.20	0.211	0.198	0.011
10	1.21	0.205	0.186	0.016
Average weight (kg)	1.217	0.205	0.188	0.014

The Table 4.15 above shows that a 0.014kg of crust trimmings waste is generated per kilogram of raw sheep skin processed. From this experimental result it can be seen that 14.00kg of crust trimmings waste is generated from a tannery having a daily soaking capacity of 1000.00kg of wet salted sheep skin.

h) Finished Leather Trimmings Waste

To determine the amount of the finished leather trimmings waste generated per kilogram of wet salted sheep skin processed a sample of ten pieces of finished sheep skin leather were randomly taken from ten different batches of finished leather prepared for trimming operation and weighed before and after trimming operation and the data obtained during the experiment is presented in Table 4.16 as below.

Table 4.16. Finished leather trimmings waste generated per kilogram of wet salted sheep skin processed

S.N°	Weight of a single piece of wet slated sheep skin (kg)	Weight of a single piece of finished leather Before Trimming (kg)	Weight of a single piece of finished leather After Trimming (kg)	Weight of finished leather Trimming waste generated (kg/kg of raw sheep skin)
1	1.22	0.169	0.163	0.005
2	1.23	0.163	0.160	0.002
3	1.21	0.166	0.164	0.002
4	1.2	0.170	0.158	0.010
5	1.24	0.161	0.155	0.005
6	1.21	0.172	0.169	0.002
7	1.23	0.165	0.164	0.001
8	1.22	0.167	0.163	0.003
9	1.2	0.168	0.156	0.010
10	1.21	0.170	0.169	0.001
Average weight (kg)	1.217	0.167	0.162	0.004

From the data obtained it can be seen that a 0.004kg of finished leather trimmings were generated while processing one kilogram of wet salted sheep skin (see Table 4.16 above). This experimental result indicates that 4.00kg of solid waste as finished leather trimmings can be generated from a tannery having a daily soaking capacity of 1000.00kg of wet salted sheep skin.

The generation rate of the main types of tannery solid wastes generated during wet salted sheep skin processing are summarised in the Table 4.17 as below.

Table 4.17. Tannery Solid Waste Generation Rate (During wet salted sheep skin processing)

Types of tannery solid wastes	Generation Rate (kg/kg of wet salted sheep skin)	Generation Rate (kg/ton of wet salted sheep skin)	Total Solid waste generated (kg/ton of wet salted sheep skin)
De-Dusted Salt	0.021	21	262
Raw skin trimmings	0.02	20	
Hair Waste	0.135	135	
Fleshings	0.019	19	
Pickle Trimmings	0.021	21	
Shaving Waste	0.028	28	
Crust Trimmings	0.014	14	
Finished Leather Trimmings	0.004	4	

From the Table 4.17 above it can be seen that processing one ton of wet salted sheep skin generates 262.00kg of solid waste which is 26.2% of the total weight of sheep skin processed. The daily sheep skin soaking capacity of ELICO tannery is 12,170kg. Taking 300 working days per annum, the annual soaking capacity of the tannery is found to be 3,651 ton of wet salted sheep skin. This shows that 956.56 ton of solid waste is generated annually during leather manufacturing processes (beam house to finishing processes) and disposed to the open dumping area used for municipal solid waste disposal. In addition to this, sludge generated from effluent treatment plant is 10% of skin processed [18] indicating that 365.10 ton of sludge is generated annually from the tannery and being disposed in the same manner with the other types of solid wastes.

In general, including the sludge, a total of 1,321.66 ton of solid waste is generated annually only from the sheep skin unit of the tannery.

The percentage share of each types of the solid waste generated is given the Figure 4.4 as below.

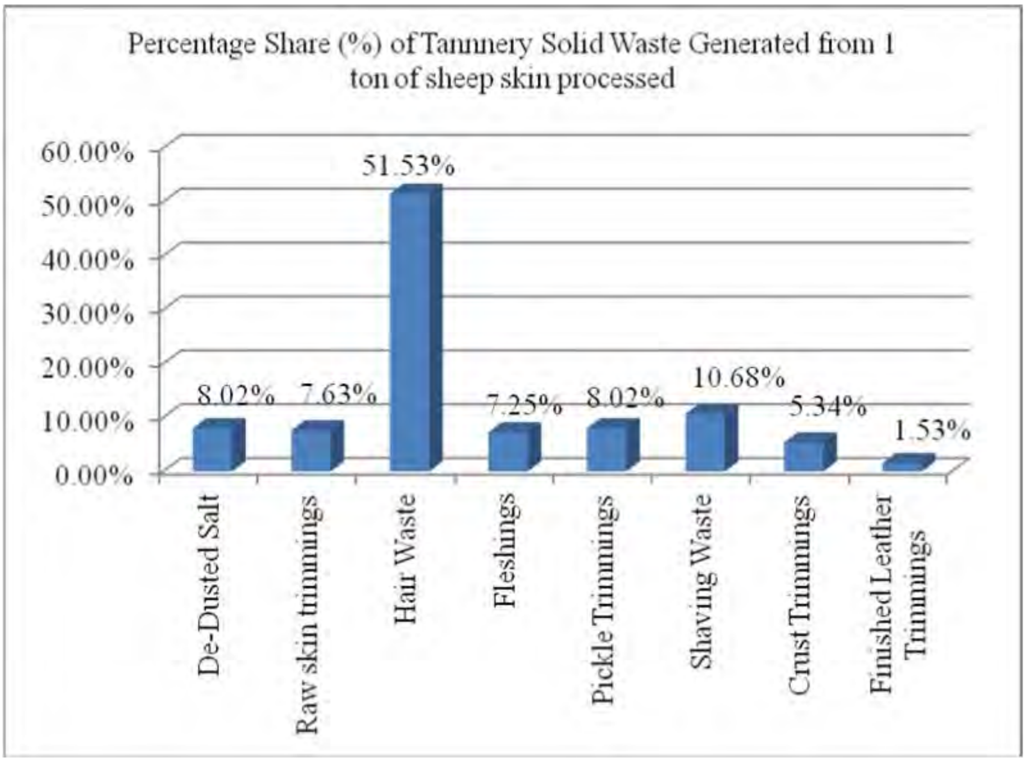


Figure 4.4. Pernegage share of Tannery solid wastes geneated during wet slated sheep skin Processing

The percentage share (%) of leather manufacturing stages in generating solid wastes during sheep skin processing is shown in the Figure 4.5 as below

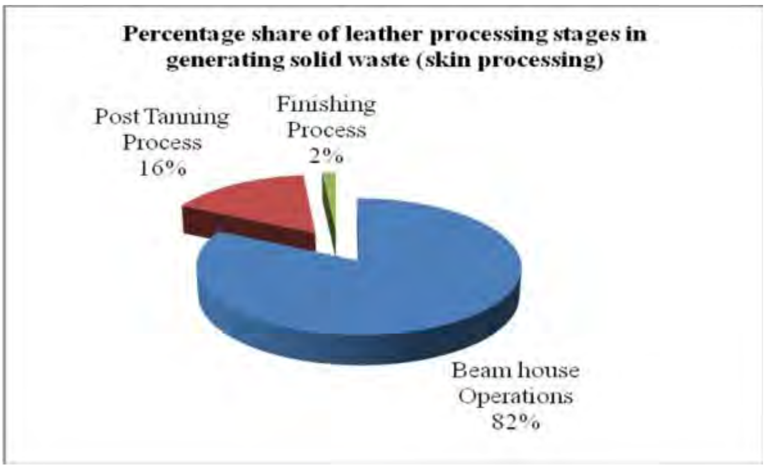


Figure 4.5 percentage share of leather processing stages in generating solid wastes (sheep skin processing)

4.3. Tannery Solid Waste Management Practices at ELICO

Though industrial solid waste has to be managed separately due to the fact that they contain hazardous components that affect both human health and the environment, the assessment made on the existing solid waste management practices of ELICO indicates that all the solid wastes generated during leather manufacturing processes and from the primary effluent treatment plant of the tannery are being collected and disposed along with municipal solid waste to an open dumping area called “koshe” which is serving since 1964 for dumping municipal solid waste generated from Addis Ababa city.

It was observed that there are different types of tannery solid wastes generated during hide and skin processing having different properties. In addition to this, some of the solid wastes contain chromium metal which is toxic to human and the environment. Therefore, tannery solid wastes has to be segregated from being disposed along with municipal solid waste and appropriate solid waste management has to implemented based the physical and chemical nature of the solid wastes.

4.4. Physico-chemical Characteristics of Tannery Solid Waste

a) pH

From the laboratory result it was observed that the pH value of solid wastes fall in the range from 3.00 to 11.4 (see Table 4.18 below). This indicates that the pH values of the solid wastes have similarities with the pH values at which hides and skins are processed (i.e. un-hairing and liming processes are carried out at alkaline pH value. On the other hand, pickling, chrome tanning and finishing processes are carried out at acidic condition. It was found that fleshing waste has the highest pH value as the liming process which is carried out prior to fleshing process is done at a pH value ranging from 12-13 [9]. Figure 4.6 below shows the pH pattern of the sample tannery solid waste.

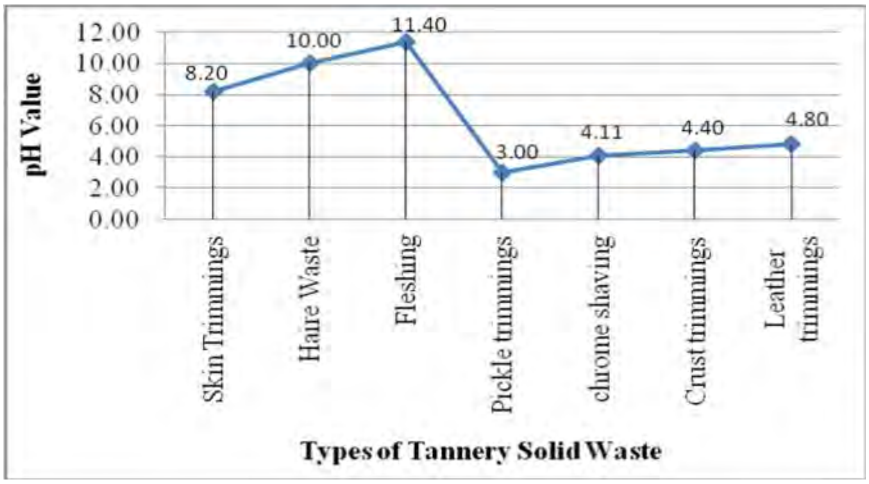


Figure 4.6. pH values of tannery solid waste

From the determination of the solid waste generation rate it was found that 82% of the solid waste is generated from beamhouse operations during sheep skin processing. Except pickle trimmings waste the other types of solid wastes (i.e. raw skin trimmings, hair waste and fleshings) which are 66.41% of the total solid wastes are alkaline in nature. Similarly, in hide processing it was found that 61.70% of the solid waste generated from beamhouse operations is alkaline and the rest 38.30% of the solid waste is acidic in nature. Since the acid-base reactions are among the most important reactions regarding the environment and most of the living organisms are very sensitive to environmental pH, the solid wastes has to be subjected to neutralization process before disposing to the environment.

b) Moisture Content

As can be seen from Table 4.18 below, the moisture content of the sample solid wastes ranges from 6.65% for crust trimmings waste and 80% for fleshings. From the obtained data it was found that fleshing and pickle trimmings wastes show higher amounts of moisture content in comparison to other waste types. This is happened due to the fact that fleshing and pickle trimmings waste are generated from wet processing stages. On the other hand, the moisture content of crust trimmings and finished leather trimmings waste was found to be lower (see Table 4.18 below) since they are generated from dry processing stages. Therefore, thermo-chemical conversion technologies like incineration, pyrolysis/gasification technology can be used to generate energy from crust trimmings and leather trimmings waste. The moisture content of the skin trimmings, hair waste, fleshings and pickle trimmings was found to be greater than 50% which is the minimum value required to apply bio-chemical conversion [22]. Therefore, methane gas which is used as energy source can be generated from these solid wastes using anaerobic digestion. In addition to generating energy from the solid waste, the sludge remains after the process can also be used as soil conditioner or fertilizer.

Due to the high moisture content of tannery solid wastes, infusion of the chemicals, especially chrome in chrome shaving wastes, into soil, surface and ground water causes the deterioration of the natural structures of these receiver environments. Therefore, chrome shaving wastes has to be used for production of valuable products or disposed in a secured landfill.

c) Volatile Organic Compound and Ash Content

The volatile organic compound (VOC) of the samples, which was measured in wet-weight method, was found to vary from 87.13% for pickle trimmings waste and 97.3% for leather trimmings waste (see Table 4.18 below). In general the average VOC of the sample tannery solid wastes was found to be 92.22%. On the other hand, the ash content of the samples tested ranges from 2.70% for leather trimmings waste and 12.87% for pickle trimmings waste (see Table 4.18 below) and the average ash content of the samples was found to be 7.79%. This shows that more than 90% of the tannery solid wastes are organic wastes.

d) Calorific Value

As can be seen from the Table 4.18 below, the calorific values of the sample tannery solid wastes ranges from 7694 KJ/Kg for pickle trimmings waste which is the minimum value and 18,772 KJ/Kg for finished leather trimmings waste and this is found to be the maximum value and the average value was found to be 13,208KJ/Kg. All the solid wastes generated during leather manufacturing process contain a calorific value of more than the minimum required value which is 5040KJ/Kg [22], for the implementation of thermo-chemical conversion technologies. Though tannery solid wastes contain high calorific values, high moisture contents of some of the solid wastes especially those generated from beamhouse processes need very high temperature for the implementation of combustion or incineration technology to generate energy from the solid wastes. Crust trimmings and finished leather trimmings waste generated from dry processing stages of the tannery has calorific value of 71,556KJ/Kg and 18,772KJ/Kg (see Table 4.18 below) and their daily generation rate is 494.38kg and 72.68kg respectively. Therefore, the solid wastes that are generated from dry processing stages have to be segregated and collected in a different container so that to implement the aforementioned technologies.

e) Carbon Content

It can also be observed from the table 4.18 below that the carbon content of the sample tannery solid wastes ranges from 48.41% for pickle trimmings waste and 54.06% for leather trimmings and the average carbon content of the sample was found to be 51.24%.

f) Nitrogen Content

The obtained laboratory result (see Table 4.18 below) shows that the nitrogen content of the sample tannery solid waste tested ranges from 13.10% for fleshing waste and 63.10% for chrome shavings waste and the average value was found to be 38.17%. Fleshing waste was found to contain the minimum nitrogen content due to the fact that fleshing wastes are the ones generated by the removal of a hypodermis layer, which is rich in fat and poor in protein [9].

g) Carbon to Nitrogen Ratio (C:N ratio)

The carbon to nitrogen ratio is a very important factor for the microorganisms to decompose the solid waste. The result obtained (see Table 4.18 below) shows that C:N ratio of the solid waste samples ranges from 0.82:1 for chrome shavings waste and 4.11:1 for fleshings waste. The C:N ratio of fleshing waste was found to be almost one sixth of the minimum standard value suitable for composting (see Table 2.2). The solid wastes have to be suitably segregated/ processed/ mixed with suitable additives at site before actual treatment to make it more compatible with the specific treatment method. This has to be assessed and ensured beforehand. For example, in case of compositing, if the C/N ratio is less, high carbon content wastes (straw, paper etc.) may be added; if it is high, high nitrogen content wastes (sewage sludge, slaughter house waste etc.) may be added, to bring the C/N ratio within the desirable range [22]. Therefore, it is possible to prepare compost from fleshing waste by mixing with some other organic wastes.

Table 4.18: The average value of physicochemical parameters of tannery solid waste

Types of tannery solid wastes	pH	Moisture Content (%)	VOC (%)	Ash Content (%)	CV (KJ/Kg)	C (%)	N (%)	C:N Ratio
Skins Trimmings	9.85	59.00	95.60	4.40	7853	53.11	34.71	1.53:1
Hair Waste	9.90	57.00	93.11	6.89	7888	51.73	44.63	1.16:1
Fleshings	11.4	80.00	96.40	3.06	8998	53.86	13.10	4.11:1
Pickle Trimmings	3.00	65.00	87.13	12.87	7694	48.41	15.24	3.18:1
Chrome shaving	4.21	47.80	93.20	6.80	7663	51.78	63.10	0.82:1
Crust Trimmings	4.40	6. 65	91.40	8.60	17, 556	50.78	39.61	1.28:1
Leather Trimmings	4.80	9.83	97.30	2.70	18,772	54.06	48.7	1.11:1

h) Chromium, Sodium and Calcium Content

As can be seen from the Table 4.19 below, chromium was not detected in skin trimmings, hair waste, fleshings and pickle trimmings waste due to the fact that these solid wastes are generated before chrome tanning process. The highest value of chromium was recorded in chrome shavings waste which is 16,943ppm as this is the solid waste generated just after chrome tanning operation and this value indicates that it is much higher than the standard safe limits of the amount of chromium metal in soil [19, 5]. Therefore, it should not be disposed to the open dumping area being used for dumping municipal solid waste generated from Addis Ababa city and it should be disposed in secure landfill.

The sodium content of the solid wastes was found to be higher in skin trimmings waste (see Table 4.19 below) due to the fact that salts of sodium is used during preservation of raw hides and skins. In addition to this, there are some salt removed from raw hide and skins in the warehouse which is considered as solid waste and being disposed to the open dumping area (koshe) together with the other solid wastes. But the presence of common salt in irrigation water can be a disaster. The structure of some soils can be changed, and a combination of toxicity and osmotic effects dramatically reduces crop yields. Moreover, in hot climates even moderate salinity in the soil will increase dramatically due to surface evaporation, percolation, and transpiration from growing plants [30]. Therefore, the desalted salt has to be reused for preservation and or for other wet processing that require salt like pickling process.

From the Table 4.19 below it can also be observed that the calcium content of fleshing waste is higher as compared to the other types of solid waste and this is due to the fact that lime is used during liming process.

Table 4.19. Average Value of Chromium, Sodium and Calcium content of tannery solid waste

Types of tannery solid wastes	Cr (ppm)	Na (ppm)	Ca (ppm)
Skins Trimmings	Non	45,435	Non
Hair Waste	Non	11,325	Non
Fleshings	Non	44,384	12,799
Pickle Trimmings	Non	39,320	831
Chrome shaving	16,943	13,234	711
Crust Trimmings	14,821	879	787
Leather Trimmings	12,530	797	797

4.5. Analysis of Data Generated and Solid Waste Management Options for Tannery Solid Waste

The generation rate of tannery solid waste during hide processing reveals that 530kg of solid waste is generated from beamhouse operations per ton of raw hide processed as fleshing, trimmings and splitting wastes. In a similar manner, 195kg of solid waste is generated per ton of skin processed only from beamhouse operations as raw skin trimmings, hair waste, fleshing waste and pickle trimmings waste. It was found that the average moisture content of these solid wastes is 65% due to the fact that they are generated from wet leather processing stages. The solid wastes are bio-degradable and therefore anaerobic digestion can be used to generate energy from these types of solid wastes. Literature survey indicates that one of the feasible options is to digest the fleshing generated from tannery under anaerobic condition and use the digested sludge as manure. Anaerobic digestion of liquefied fleshing along with tannery wastewater for biogas generation is considered economically feasible. 20 - 30% of the energy required for operation of the effluent treatment plant can be recovered by treating wastewater along with biologically liquefied fleshing in the reactor in addition to solving the disposal problem of waste fleshing [13]. The carbon to nitrogen ratio of these biodegradable solid wastes generated from beamhouse operations ranges from 1.16:1 to 4.11:1. Therefore, In addition to anaerobic digestion, composting method of solid waste management options can be used to prepare compost by mixing with some other carbon reach organic wastes.

On the other hand, 29kg of solid waste is generated per ton of raw hide processed from re-tanning and finishing processes as crust and finished leather trimmings waste. Similarly, 18kg of the same solid waste is generated per ton of raw skin processed from the same leather processing stages. These solid wastes have an average moisture content and calorific value of 8% and 18,164KJ/kg respectively. The moisture content of the solid wastes was found to be much lower than the average moisture content of solid wastes generated from beamhouse operations due to the fact that crust and finished leather trimmings wastes are generated at dry leather processing stages. As reviewed in literature survey, higher calorific value indicates the combustion of waste with a lesser amount of auxiliary fuel support. The amount of energy generated at a waste to energy facility depends primarily on the calorific value of the waste. To facilitate self combustion of waste, the calorific value of the waste should be at least 5000kJ/kg and approximately 6000KJ/kg for power generation [23]. Therefore, thermo chemical conversion technologies such as incineration and pyrolysis/gasification can be used for crust and leather trimmings waste to generate energy. But, in order to implement these two technologies the solid wastes have to be segregated and collected separately.

The physico-chemical characterization indicates that the chromium content of chrome shavings wastes generated from the tannery was found to be 16,943ppm which is much higher than the safe limit to be in the soil (100 – 150ppm) due to the fact that chromium sulphate is used during chrome tanning process. Therefore, this solid waste has to be separately collected and disposed in secured landfill as the chromium metal is highly toxic.

5. Conclusion and Recommendations

5.1. Conclusion

From the study made at Ethio-Leather Industry private Limited Company (ELICO) on tannery solid waste management and characterization the following conclusions were drawn.

The physical composition of the solid waste generated from the tannery are found to be de-dusted salt, raw skin trimmings, hair waste, fleshings, splitting waste, chrome shaving, crust trimmings, finished leather trimmings and sludge from the wastewater treatment plant. The assessment on the existing solid waste management of ELICO Tannery indicates that the solid wastes generated from the tannery is being disposed to an open dumping area commonly called koshe which was being used by Addis Ababa city administration for municipal solid waste disposal. Therefore, as industrial solid waste contains hazardous components, it should be managed separately.

In processing 7,251 ton of cattle hide and sheep skins annually, the tannery generates a total of 4048.96 ton of solid waste from beamhouse, tanning, re-tanning and finishing processes and this is found to be 55.8% of the raw hide and skin processed.

The study made on the generation rate of tannery solid waste shows that beam house operations contribute 61.70% during hide processing and 82% in skin processing. This indicates that more than 60% of the solid wastes are generated during beamhouse operations and except pickle trimmings wastes the others are alkaline in nature.

The physico-chemical characteristics of the solid waste indicate that on average 92.22% of the solid waste is organic. The average moisture content and calorific value of crust trimmings and finished leather trimmings waste is found to be 8.24% and 18,164KJ/Kg respectively which is much higher than the minimum value required to implement thermo-chemical technology.

The moisture contents of the solid waste generated from beam house operations (skin trimmings, hair, fleshings and pickle trimmings) fall in the range of 57 to 80 percent. On the other hand, the carbon to nitrogen ratios of these solid waste ranges from 1.16:1 to 4.11:1 which is less than the minimum value required for composting. Therefore, these wastes can be converted to compost by mixing with some other organic waste like animal dung so that it can be used as soil conditioner.

The chromium content of chrome shaving waste was found to be 16,943ppm which is much higher than the safe limit of the metal in soil. Therefore, as chromium metal is highly toxic, the solid waste has to be segregated, collected separately and disposed to secured landfill.

In general, the results of this study have revealed that the tanning industry generates solid waste with different characteristics according to the process steps from which it is generated. Therefore, in order to determine the most appropriate solid waste management strategies, it is highly important to acquire the information concerning the process steps from which these solid wastes are generated, the target product desired to be produced through these processes, and the characteristics of the wastes.

5.2. Recommendations

Base on the study made at Ethio-Leather Industry Private Limited Company, the following recommendations are given.

- Practically oriented training has to be given to the concerned bodies of the tannery on how to implement solid waste management strategies (source reduction, recycling and composting, waste transformation/waste to energy and landfilling) to manage solid waste generated from tannery.
- The federal and regional environmental protection authorities have to formulate an incentive scheme to motivate those tanneries managing the solid waste generated from tannery.
- Environmental laws have to be strictly enforced by the federal and regional environmental protection authorities to control improper tannery solid waste disposal.
- Based on the solid waste proclamation number 513/2007, enabling conditions has to be created to promote entrepreneurs on utilization of tannery solid wastes to produce valuable products and generate energy.

- There must be solid waste management division lead by professionals in the organizational structure of tanning industry which has the responsibility of managing the solid wastes generated from the tannery.

- There is no environmental standard prepared by Environmental protection Authority of Ethiopia on tannery solid waste disposal. Therefore, this standard should be prepared and enforced.

- New coming investors on tanning sector should be enforced to show detail solid waste management strategies on his/her project proposal before issuing investment license.

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Annexes

Annex 1: Daily soaking capacity of Tanning Industries

S.No	Name of Tannery	Soaking Capacity (pieces/day)		Soaking Capacity (tonne/day)	
		Skin	Hide	Skin	Hide
1	Ethiopia Tannery Share	14500	1300	21.75	33.28
2	Dire Tannery	6000	600	9	15.36
3	Hafde Tannery Plc	9000	500	13.5	12.8
4	Wallia Tannery Plc	7000	300	10.5	7.68
5	Batu Tannery Plc	3000	700	4.5	17.92
6	Modjo Tannery Share Company	5700	200	8.55	5.12
7	ELICO	15000	800	22.5	20.48
8	Bahir Dar Tannery Plc	3000	100	4.5	2.56
9	Blue Nile Tannery	5000	0	7.5	0
10	Debrebrehan Tannery	6500	0	9.7	0
11	Addis Ababa Tannery	900	0	1.35	0
12	Sheba Tannery	6000	300	9	7.68
13	Kolba Tannery Plc	9000	400	13.5	10.24
14	Mersa Tannery Plc	10000	500	15	12.8
15	Bale Tannery Plc	0	600	0	15.36
16	Kombolcha Tannery	5000	0	7.5	0
17	Hora Tannery Plc	4700	0	7.05	0
18	Gellan Tannery PLc	4000	0	6	0
19	Dessie Tannery Plc	5000	0	7.5	0
20	Abay Tannery PLc	4000	0	6	0
21	Mesaco Global Tannery	3000	0	4.5	0
22	Shoa Tannery Plc	6000	500	9	12.8
23	Crystal Tannery	7000	1000	10.5	25.6
24	China Africa Tannery	8224	0	12.336	0
Total		147524	7800	221.24	199.7

Annex 2: Raphi or Koshe (Addis Ababa City Solid Waste Dispossl site)

Annex 3: Emissions Limits To Air of Waste to Energy Technologies

Emission	EU standard (mg/Nm^3)	US EPA standard (mg/Nm^3)
Particulate matter (PM)		11
Sulphur dioxide (SO_2)	50	63
Nitrogen oxides (NOx)	200	264
Hydrogen chloride (HCl)	10	29
Carbon monoxide (CO)	50	45
Mercury (Hg)	0.05	0.06
Total organic carbon	10	n/a
Dioxins (TEQ)	0.1	0.14

Annex 4. Experimental work to determine the Weight of a Single Piece of Wet Salted Hide

Sample Nº	1	2	3	4	5	6	7	8	9	10
Lot Nº (NX)	119-2	119-5	118-6	118-1	118-4	117-5	117-3	116-4	116-3	115-6
Nº of pieces of wet salted hides in the lot	429	401	398	350	429	367	352	358	447	352
Total weight of the lot	4000	4000	4000	4120	4000	4000	4000	4000	4000	4000
Weight of one piece of wet salted hide (kg)	9.3	10	10.1	11.8	9.3	10.9	11.3	11.2	8.9	11.4
Average weight of one piece of wet salted hide (kg)	10.42									

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any University, and that all the source of materials used for the thesis has been duly acknowledged.

Declared by:

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Date: 23 November 2012

Advisor

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