Addis Ababa University
School of Graduate Studies
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Department of Chemical Engineering

Cleaner Production Options for Solid Waste Management in the Leather Industry

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A thesis submitted to the Graduate Studies of Addis Ababa University in partial fulfilment of the Degree of Master of Science in Chemical Engineering (Process Engineering)

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Approved by Board of Examiners

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ABSTRACT

The leather industry is characterized as an industry that uses moderately large types and quantities of chemicals and water. The wastes generated in tannery processes include wastewater effluent, solid waste, and hazardous waste. These wastes create pollution problems in the environment.

Most leather industries in Ethiopia discharge wastes into the environment prior to any proper treatment. An alternative approach to this is to eliminate or reduce the problem at the source using Cleaner Production (CP) approach. In this paper, a study is performed at Addis Ababa Tannery Sh.Co.(AAT) by implementing CP Methodologies. The solid waste inventory of the factory has been carried out. The major problems have been identified. The possible CP options for the existing problems are also suggested. Technical and economic aspects of the best three CP options have been evaluated. Result of the study indicates that the implementation of the suggested CP options gives significant benefit for the factory.

1.Introduction

1.1 Ethiopian leather industry

Ethiopia is relatively well endowed in its livestock base in the continent with a share of 15.7 percent in cattle and nine percent in sheep and goats. However, being one of the poorest countries in the region, it has the lowest off-take rate. Annual production is only too million pieces of hides and 13.6 million pieces of skins. This amounts to only 21 percent of the country's livestock population [4].

The fact that production of hides and skins heavily relies on the demand for meat makes the rate of expansion of the leather sector dependent on the rate of growth of the economy. Though Ethiopia has a large livestock population, its leather sector significantly lags behind many countries that are less endowed.

According to a survey carried out by the Ethiopian Economic Policy Research Institute, the tanning industry in Ethiopia operates, on average, at two-thirds of its full potential. Though various reasons are provided for this under-capacity utilization, the major ones include

- Shortage of hides and skins due, inter alia, to low level of domestic livestock production,
- The high traditional human consumption of hides and skins for traditional clothing, furnishing and handicrafts,
- Low off-take rate and low recovery rate (damage) of hides and skins arising from the process of flaying preservation.

Moreover, the poor quality of their semi-processed leather, which resulted in low export demand, also contributed to this low capacity operation.

Most tanning firms are operating at much below full capacity due mainly to lack of demand and partly to lack of raw material inputs. The latter is due to absence of effective marketing networks

between households who supplied the great proportion of raw materials throughout the country and factory gate points.

Table 1.1:Livestock Bases of Ethiopia and Others (in millions)

Economic Zone	Cattle	Sheep	Goats	Livestock
World	1323	1056	705	3117
Developing countries	1007	678	681	2366
Developed Countries	331	391	29	751
Africa	223	234	206	669
Ethiopia	35	22	17	74

Source: FAO, Production Year Book

One of the major advantages that could give a competitive edge to the Ethiopian leather sector is its large livestock base. However, maximizing the benefit from this resource requires expanding the leather products industries including footwear and accessories, leather garments, auto upholstery, etc., and fully integrating it into the domestic upstream industry. This, primarily, necessitates establishing a tanning sub-sector that is capable of producing high-grade finished leather to feed the downstream industries. This is so because in this sector relatively higher value added can be attained by processing raw hides and skins to the finish and further proceeding to the leather product industry than being limited to semi-processing for export. It is this network the linkage between the tanning and leather products industries, which is missing most in Ethiopia and also in many African leather sectors.

Labor is currently Ethiopia's most abundant factor, and that activities in the leather sector are relatively labor intensive, such a significant livestock resource potential provides the opportunity for substantially expanding the leather products out-put for the external market.

The supply of hides and skins is constrained by the production of animals for their meat and milk, which is a high-income consumption item. Given the low level of income of the majority of the population, the effective demand formeat is very low. This dispite the fact that meat is the most preferred consumption item in the Ethiopian diet. Second, its export share in meat

production is insignificant, hence unable to exploit the external market. Third, cattle in traditional Ethiopian agriculture are also largely used as a means of production.

Fourth, hide recovery is very low for a variety of reasons, including low hide quality caused by a variety of traditional animal husbandry practices as well as poor slaughter treatment. These factors collectively result in low supply of hides and skins relative to the available livestock potential. So Ethiopia's share in the export market for leather and leather products is from the outset constrained, at least partly, by internal factors associated with inadequate raw material supply.

In a leather sector where the downstream industries are expanded, the prime role of the tanning sub-sector is to feed these industries. Where the former remains a dwarf and less efficient, the export performance of the tanning sector would be, at least partly, a measure of its competitiveness.

The tanning sub-sector in Ethiopia, as noted above, is not yet fully developed. It is mostly limited to production wet blue, and even that not of high quality. On average, exports account for about 70 percent of production value. Production declined consistently over the second half of the 90s. Though not consistently, the general trend of export too is one of a decline. As can be calculated, export earning fell, on average by 9.1 percent annually. This is largely due to a decrease in the volume of export. The latter declined by an average of 8.6 percent annually.

1.2. Addis Ababa Tannery S.C. (AAT)

Addis Ababa Tannery was established in 1925, and is Ethiopia's oldest tannery. The tannery is located in the Gulele area, approximately 10 kilometres from Addis Ababa town center on the Ambo road. Addis Ababa Tannery has an attainable processing capacity of approximately 1,350,000 kg of cow hides per annum, and is currently producing at the level of approximately 951,277 kg of hides per annum, representing capacity utilization of approximately 70%. Addis

Ababa Tannery currently employs approximately 222 permanent staff. The tannery's principal products are shoe uppers, lining, unsplit wet blue hides, and natural and dyed crust.

The main objectives of the enterprise are:

- To process hides and skins of domestic animals.
- To process all kinds of semi-processed skins and hides and to manufacture leather for local and foreign markets.
- To import all required items for the use in the manufacturing of leather.
- To engage generally in any other business activities conductive to the attainment of its purpose mentioned above.

1.3. Waste treatment in AAT

Leather processing generates many wastes including wastewater effluent, solid wastes, air emmissions and hazourdous wastes. The nature of the waste generated depends on the type of leather facilities, the process and technology implemented and chemicals used.

Most Ethiopian leather industries don't treat their waste before they discharge it out. As the cost of implementing and running the treatment plant is high, most industries do not bother about the environment.

Addis Aababa Taneery Sh.Co is a potentially pollution-intensive industry. Environmental concerns in this tannery include solid waste, wastewater, air pollution, soil protection and health and safety aspects. The Factory releases its wastes directly to the nearby river without any pretreatment .The releases potentially contain toxic, persistent or otherwise harmful substances, which can directly affect the aquatic environment & even the surroundings.

1.4 Objective of the study

This research study focuses on environmental impact assessment in AAT, identifying CP options that are environmentally & economically viable.

The specific objectives of this study are:

- Preassemement of Addis Ababa Tannery Sh.Co.
- In-depth evaluation of the processes that generate solid wastes in AAT
- Identifying problems existing in the process
- Generating Cleaner Production Options
- Identifying the best options that are economically and technically viable
- Estimation of cost-saved by these CP options

1.5.Scope & limitation of the study

This study mainly concentrates on solid waste management in Addis Ababa Tannery Sh.Co. In this paper, solid waste of Addis Ababa Tannery Sh.Co. was audited and possible waste reduction mechanisms were suggested.

1.6. Methodology followed

Some of the basic methodologies followed in conducting this research were:

1. Review of clean production technologies
    - Literature review

2.Pre-Assessment

3.Auditing/Assessment

- Data collection,
- Analysis
- Evaluation

5.CP options generation and feasibility study

2. Literature review

2.1. Leather technology

2.1.1. General description of tanning process

Leather tanning is the process of converting raw hides or skins into leather. Hides and skins have the ability to absorb tannic acid and other chemical substances that prevent them from decaying, make them resistant to wetting, and keep them supple and durable. The surface of hides and skins contain the hair and oil glands and is known as the grain side. The flesh side of the hide or skin is much thicker and softer. The three types of hides and skins most often used in leather manufacture are from cattle, sheep and pigs.

Tanning is essentially the reaction of collagen fibers in the hide with tannins, chromium, alum, or other chemical agents. The most common tanning agents used in most tanneries are trivalent chromium and vegetable tanning extracted from specific tree barks. Alum, syntans (man-made chemicals), formaldehyde, glutaraldehyde and heavy oils are other tanning agents.

2.1.2. Process description

Trimming, soaking, fleshing, and unhairing, the first steps of the process, are referred to as the beam house operations. Bating, pickling, tanning, wringing and splitting are referred to as tanyard processes. Finishing processes include conditioning, staking, dry milling, buffing, spray finishing, and plating. Production of leather by both vegetable tanning and chrome tanning are described below. Most tanneries use chrome as a tanning agent.

Figure 2.1. Presents a general flow diagram for the leather tanning and finishing process.

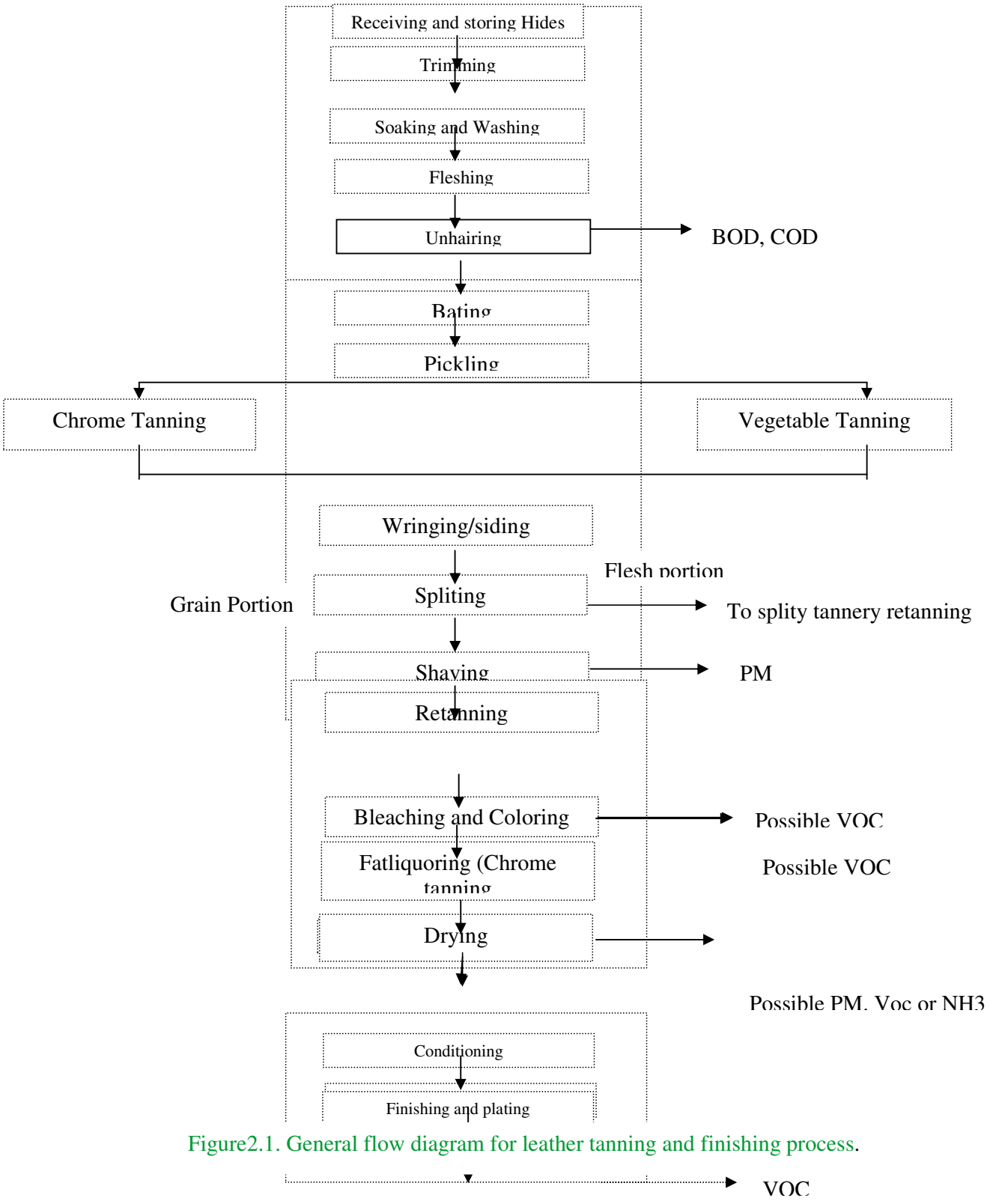


Figure2.1. General flow diagram for leather tanning and finishing process.

2.1.3. Vegetable Tanning

Heavy leathers and sole leathers are produced by the vegetable tanning process, the oldest of any process in use in the leather tanning industry. The hides are first trimmed and soaked to remove salt and other solids and to restore moisture lost during curing. Following the soaking, the hides are fleshed to remove the excess tissue, to impart uniform thickness, and to remove muscles or fat adhering to the hide. Hides are then dehaired to ensure that the grain is clean and the hair follicles are free of hair roots. Liming is the most common method of hair removal, but thermal, oxidative, and chemical methods also exist. The normal procedure for liming is to use a series of pits or drums containing lime liquors (Calcium hydroxide) and sharpening agents. Following liming, the hides are dehaired by scraping or by machine. Deliming is then performed to make the skins receptive to the vegetable tanning. Bating, and enzymatic action for the removal of unwanted hide components after liming, is performed to impart softness, stretchability and flexibility to the leather. Bating and deliming are usually performed together by placing the hides in an aqueous solution of an ammonium salt and proteolytic.

In the vegetable tanning process, the concentration of the tanning materials starts out low and is gradually increased as the tanning proceeds. It usually takes 3 weeks for the tanning material to penetrate to the center of the hide. The skins or hides are then wrung and may be cropped or split, heavy hides may be retanned and scrubbed. For sole leather, the hides are commonly dipped in vats or drums containing sodium bicarbonate or sulfuric acid for bleaching and removal of surface tannins. Materials such as lignosulfate, corn sugar, oils, and specialty chemicals may be added to the leather. The leather is then set out to
smoothen and dry; and may then undergo further finishing steps. However, a high percentage of vegetable-tanned leathers do not undergo retanning, coloring, fat liquoring, or finishing.

Leather may be dried by any of the following five common methods;

(i). Air-drying is the simplest method. The leather is hung or placed on racks and dried by the natural circulation of air around it.

(ii). A toggling unit consists of a number of screens placed in a dryer that has controlled temperature and humidity.

(iii). In a pasting unit, leathers are pasted on large sheets of plate glass, porcelain, or metal and sent through a tunnel dryer with several controlled temperature and humidity zones.

(iv). In vacuum drying, the leather is spread out, grain down, on a smooth surface to which heat is applied. A vacuum hood is placed over the surface, and a vacuum is applied to aid in drying the leather.

(v). High frequency drying involves the use of a high frequency electromagnetic field to dry the leather.

2.1.4. Chrome tanning

Chrome-tanned leather tends to be softer and more pliable than vegetable-tanned leather. It has higher thermal stability, more stable in water, and takes less time to produce than vegetable-tanned leather. Almost all leather made from lighter-weight cattle hides and from the skin of sheep, lambs, goats, and pigs is chrome tanned. The first steps of the process (Soaking, fleshing, liming/dehairing, deliming, bating, and pickling) and the drying/finishing steps are essentially the same as in vegetable tanning. However, in chrome tanning, the additional processes of retanning, dyeing, and fatliquoring are usually performed to produce usable leathers and a preliminary degreasing step may be necessary when using skin, such as sheepskin.

Chrome tanning is a process that is based on the reaction between the hide and a trivalent chromium salt, usually a basic chromium sulfate. In the typical one bath process, the hides are

in a pickled state at a PH of 3 or lower, the chrome tanning materials are introduced, and the PH is raised. Following tanning, the chrome-tanned leather is piled down, wrung, and graded for the thickness and quality, split in to flesh and grain layers and shaved to the desired thickness. The grain leather from the shaving machine is then separated for retanning, dyeing, and fatliquoring. Leather that is not subject to scuffs and scratches can be dyed on the surface only. For other types of leather (i.e., shoe leather) the dye must penetrate further into the leather. Typical dyestuffs are aniline-based compounds that combine with the skin to form an insoluble compound.

Fatliquoring is the process of introducing oil into the skin before the leather is dried to replace the natural oil lost in beam house and tanyard processes. Fatliquoring is usually performed in a drum using an oil emulsion at temperature of about 60 to 66 ^{o}C for 30 to 40 minutes. After fatliquoring, the leather is wrung, set out, dried, and finished. The finishing process refers to all the steps that are carried out after drying.

2.1.5 Leather Finishing

Leather may be finished in a variety of ways: buffed with fine abrasives to produce a suede finish; waxed, shellacked, or treated with pigments, dyes, and resins to achieve a smooth, polished surface and the desired color, or lacquered with urethane for a glossy patent leather. Water-based or solvent-based finishes may also be applied to the leather. Plating is then used to smooth the surface of the coating materials and bond them to the grain. Hides may also be embossed.

2.2.Cleaner Production

2.2.1. A brief background

Before the advent of pollution control methodologies, production and consumption patterns had the format shown in Fig. 2. 2 below.

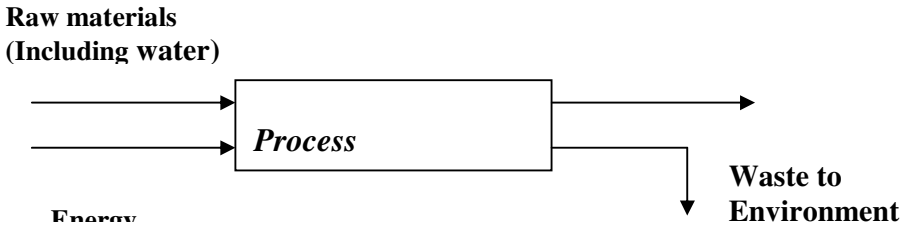


Figure 2. 2. Past production pattern

As shown in Figure 2.2 there are no procedures that take into consideration the reduction or treatment of the generated wastes. This led to increased waste production, growing environmental pollution and degradation, problems of disposal, and ultimately the associated health hazards on the living populace. These emanated not only from increased production capacities due to rising needs, but also due to processes performing below the optimum. With the discovery of the negative environmental impacts of this open loop and unchecked system came the birth of "Pollution Prevention". The concept of pollution prevention introduced a new dimension into waste management practices. As opposed to the traditional method of waste generation, this concept brought in the elements of the hierarchy of pollution prevention; i.e. source reduction, reuse, treatment and disposal as shown in Fig 2.3. (IISD, 1997).

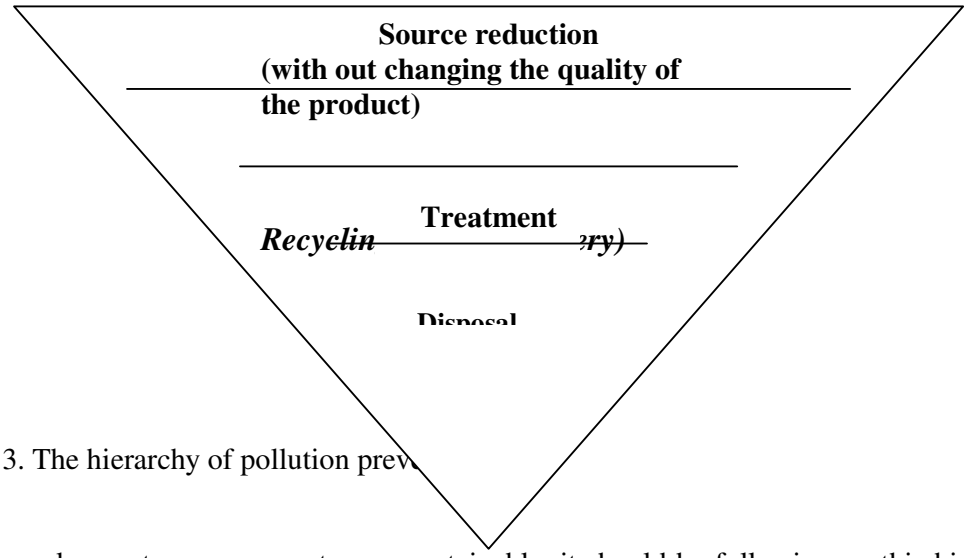


Figure 2. 3. The hierarchy of pollution prev

In order to make waste management more sustainable, it should be following up this hierarchy (Reduction –Recycle (Reuse, Recovery)-Treatment-Disposal) to a new hierarchy without disposal facilities approaching zero pollution referred to as Cleaner Production Hierarchy for Zero Pollution (CPHZP) (El-Haggar, 2000).

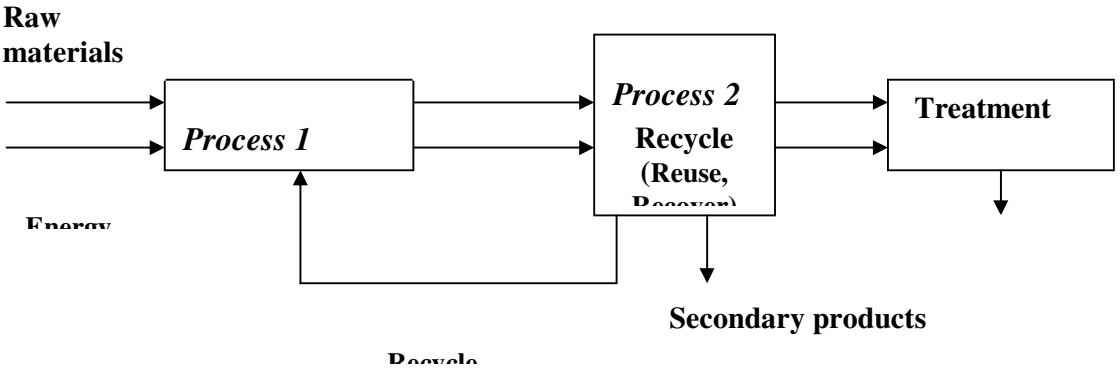


Figure 2. 4. Preferred industrial practices

The concept of industrial ecology is just a version of the system above. There are checks on the processes with the goal of optimizing their operational parameters. These parameters are system dependent and rely on the production pattern being practiced. The industry is to be taken to an ecosystem with the idea of minimizing or completely reusing wastes.

2.2.2. Definition of Cleaner Production

Cleaner Production describes a preventive approach to environmental management. It is neither a legal nor a scientific definition to be dissected, analyzed or subjected to theoretical disputes. It is a broad term that encompasses what some countries/institutions call eco-efficiency, waste minimization, pollution prevention, or green productivity, but it also includes something extra.

Cleaner Production refers to a mentality of how goods and services are produced with the minimum negative environmental impact under present technological and economic limits.

Cleaner Production does not deny growth, it merely insists that growth be ecologically sustainable. It should not be considered only as environmental strategy, because it also relates to economic considerations.

In this context, waste is considered as a 'product' with negative economic value. Each action to reduce consumption of raw materials and energy, and prevent or reduce generation of waste, can increase productivity and bring financial benefits to enterprises.

Cleaner Production is a 'win-win' strategy. It protects the environment, the consumer and the worker while improving industrial efficiency, profitability, and competitiveness.

The key difference between pollution control and cleaner reduction is one of timing. Pollution control is an after-the-event, 'react and treat' approach. Cleaner Production is a forward-looking, 'anticipate and prevent' philosophy.

The definition of Cleaner Production that has been adopted by UNEP as follow:

“Cleaner Production is the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to

humans and the environment. Cleaner Production can be applied to the processes used in any industry, to products themselves and to various services provided in society."

Production processes: Cleaner Production results from one or a combination of conserving raw materials, water and energy; eliminating toxic and dangerous raw materials; and reducing the quantity and toxicity of all emissions and wastes at source during the production process.

Products: Cleaner Production aims to reduce the environmental, health and safety impacts of products over their entire life cycles, from raw materials extraction, through manufacturing and use, to the 'ultimate' disposal of the product'.

Services: Cleaner Production implies incorporating environmental concerns into designing and delivering services.

2.2.3. Cost-benefits of Cleaner Production

As cleaner production is the continuous application of an integrated preventive environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment, it has the following general benefits:

- Leads to improved products and process
- Saves on raw materials and energy, reducing production costs
- Reduces the need for environmental regulation
- Reduces risk from on-and off-site treatment, storage and disposal of toxic wastes.
- Improves the health and safety of employees
- Improves staff moral, leading to better productivity
- Improves company public image

2.2.4.Planning and Organization of CP

Planning and organization of CP starts by one or a few persons in the company who become interested in. A Cleaner Production assessment can be initiated after a conscious decision has been made by the management to take action.

Experience from a growing number of companies shows that the following elements are important for the successful start of a Cleaner Production programme: ·

- **Management commitment:** Plant management has to set the stage for Cleaner Production activities, in order to ensure collaboration and participation. Management commitment may be reflected in environmental policy statements, however, the actual behavior of the management is at least equally important as written statements. ·
- **Employee involvement:** Management should set the stage, but whether or not good Cleaner Production opportunities are found is largely dependent on the collaboration of employees. Employees, in particular those involved in the daily operations and maintenance on the shop-floor, have often key understanding of why wastes and emissions are generated, and are often able to come up with solutions.
- **Cost awareness:** is important in the sense that proper cost information can convince management, as well as employees, that producing cleaner can make money. Unfortunately, many companies, in particular small and medium sized enterprises, do not know that a lot of money is wasted. Typically, only costs charged by external waste contractors are taken into consideration, whereas actual waste costs could be significantly more.

An organized approach is necessary to identify, evaluate and implement Cleaner Production opportunities.

Cleaner Production assessments are undertaken with a view to avoid or at least reduce the generation of waste and emissions. Moreover, it is expected that these options will in turn change existing management and information systems, and thus support and facilitate further Cleaner Production activities.

- **Organize a project team:** The project team initiates, co-ordinates and supervises the assessment activities. In order to be effective, the project team should have enough process knowledge to analyze and review the present production practices, enough creativity to develop and evaluate changes for the current production practices, and enough authority to implement and maintain the proposed changes in the production practices.
- **Identify barriers and solutions:** In order to develop workable solutions, the project team should identify the site-specific barriers to Cleaner Production implementation that might exist.
- **Set plant-wise goals:** Plant-wise Cleaner Production goals set the stage for the assessment and should challenge the project team. The tendency of companies to underestimate the Cleaner Production potential in the first place is often reflected in comparatively low goals.

Cleaner Production planning is a systematic, comprehensive method for identifying options to reduce or avoid the generation of waste. The Cleaner Production planning process itself also has its own results and benefits:

- A careful planning process can ensure the selection and implementation of the most cost-effective Cleaner Production options.
- Systematic planning ensures that Cleaner Production objectives and activities are consistent with those identified in the organization's broader planning process.

- Effective Cleaner Production planning facilitates broader business planning investment analysis and decision-making (such as capital budgeting and purchasing).
- A documented Cleaner Production plan may be a condition for receiving financing or insurance at better rates.

2.2.5.Assessment Procedure

A Cleaner Production assessment is a methodology for identifying areas of inefficient use of resources and poor management of wastes, by focusing on the environmental aspects and thus the impacts of industrial processes.

During the assessment phase the material balance is studied, and appropriate measures are proposed to reduce or prevent loss of materials and the best cleaner production options are generated. The ideas for options may come from literature search, discussions with suppliers, examples in other companies, specialized data bases, personal background or some further R&D. Brainstorming is an indispensable tool to ensure creative intellectual environment to think of all possibilities.

Generating options is a creative process that relies more on inspiration than on logical deduction (although logic remains important). The brainstorming session is a combination of creativity and 'common sense'. Before starting a brainstorming session, literature or other organizations and companies should be consulted, and a site inspection should take place so that the generation of options will be more plausible and productive. One should, hereby, focus on all influences of the process that could lead to the generation of wastes and emissions.

Brainstorming sessions have proved to be most effective when managers, engineers, process-operators and other employees as well as some outside consultants work together without hierarchical constraints.

It should be noted that during a Cleaner Production assessment, a number of obvious possibilities for immediate improvements may already have been identified. In order to go further, it is often helpful to conceptually divide the process into three essential elements: source identification followed by cause diagnosis, and option generation.

- For the source identification, an inventory is made of the material flows, entering and leaving the company with the associated costs. This results in a process flow diagram, allowing for the identification of all sources of waste and emission generation.

Next is the cause diagnosis: which is an investigation of the factors that influence the volume and composition of the waste and emissions generated. A checklist of possible causes of waste generation is used to assess all possible factors influencing the volume and/or composition of the waste stream or emissions. A material and energy balance is needed

- For the evaluation of the relative importance of each of the possible waste generation causes.

The purpose of the next logical step (option generation) is to create a vision on how to eliminate or control each of the causes of waste and emission generation. The generic prevention practices specified before are used to develop appropriate Cleaner Production options. After Cleaner Production options have been identified, they are evaluated following the same procedure used for evaluation of other investments or technical innovation options. The option generation consists of several elements, as shown in figure 2.5. The option generating process then considers each element in turn.

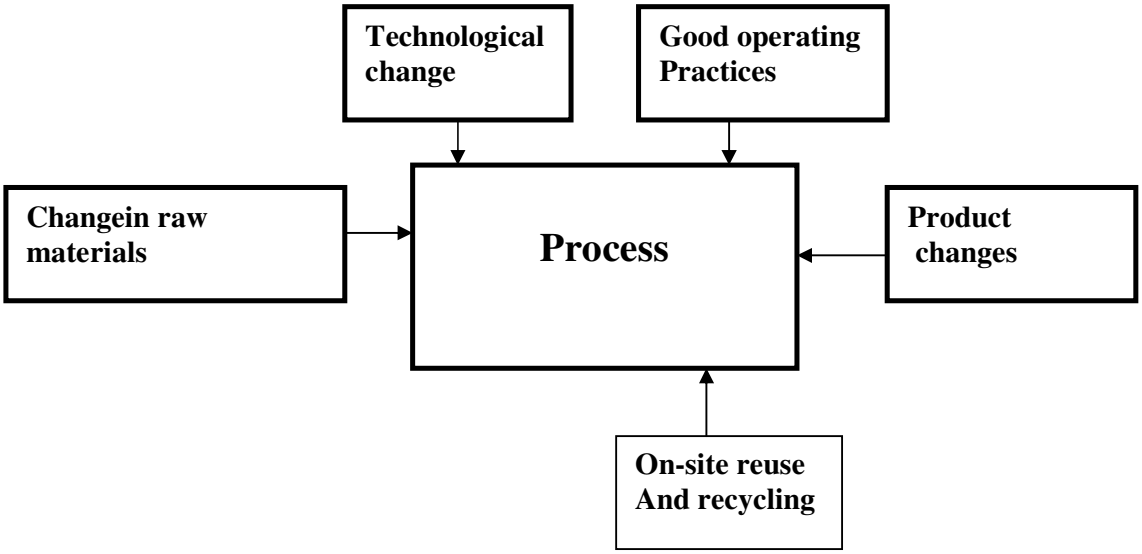


Figure2.5. Generation of CP options

Change in raw materials: Changes in raw materials accomplish Cleaner Production by reducing or eliminating the hazardous materials that enter the production process. Also, changes in input materials can be made to avoid the generation of hazardous wastes within the production process. Input material changes include material purification and material substitution.

Technology change: Technology changes are oriented towards process and equipment modifications to reduce waste and emissions. Technology changes can range from minor changes that can be implemented in a matter of days at low cost, to the replacement of processes involving large capital costs. These include the following:

- Changes in the production process .
- Modification of equipment, layout, or piping .
- Use of automation .
- Changes in process conditions, such as flow rates, temperatures, pressures, and residence times.

Good operating practices: Good operating practices also referred to as good housekeeping practices, imply procedural, administrative, or institutional measures that a company can use to minimize waste and emissions. Many of these measures are used in industry largely as efficiency improvements and good management practices. Good operating practices can often be implemented with little cost. These practices can be implemented in all areas of the plant, including production, maintenance operations, and in ray material and product storage. Good operating practices include the following:

- Management and personnel practices: Includes employee training, incentives and bonuses, and other programmes that encourage employees to conscientiously strive to reduce waste and emissions.
- Material handling and inventory practices: includes programmes to reduce loss of input materials due to mishandling, expired shelf life of time-sensitive materials, and proper storage conditions.
- Loss prevention minimizes wastes and emissions by avoiding leaks from equipment and spills.
- Waste segregation: these practices reduce the volume of hazardous wastes by preventing the mixing of hazardous and non-hazardous wastes.
- Cost accounting practices: include programmes to allocate waste treatment and disposal costs directly to the department or group that generates wastes and emissions, rather than charging these costs to general company overhead accounts.
- Production scheduling: By anlaysing these factors, the departments or groups that generate wastes and emissions become more aware of the effects of their treatment and disposal practices, and have a financial incentive to minimize their wastes and emissions. By judicious scheduling of batch production runs, the

frequency of equipment cleaning and the resulting wastes and emissions can be reduced.

Product changes: Product changes are performed by the manufacturer of a product with the intention of reducing waste and emissions resulting from a product's use. Product changes include:

- Changes in quality standards
- Changes in product composition
- Product durability
- Product substitution

Product changes can lead to changes in design or composition. The new product can thus have less environmental impact throughout its life cycle i.e.from raw material extraction to final disposal.

On-site reuse and recycle: Recycling or reuse involves the return of a waste material either to the originating process as a substitute for an input material, or to another process as an input material. Generating appropriate prevention options is a creative step; the information collected is used as guidance in this creative process. The most important items to consider within this process are:

- Find facts (seek all information relevant to the problem)
- Identify the problem (gradually broadening the problem formulation by asking questions how and why)
- Generate ideas to solve the problems (traditional brainstorming)
- Define criteria to be used to select solutions/ideas
- Screening of ideas/options
- Select all ideas/options that may be implemented immediately

2.2.6.Evaluation of CP options

The CP options generated are evaluated from five prospective sides as discussed below:

Preliminary evaluation: The options are sorted in order to identify additional evaluation needs. Managerial options do not always require a technical evaluation, while equipment-based options do. Similarly, simple options normally do not require an environmental evaluation, while complex options do. Finally, cheap options do not require a detailed economic evaluation, while expensive options may.

Technical evaluation: The technical evaluation consists of two interrelated parts. First, it should be evaluated whether the option can be put into practice. This requires a check on the availability and reliability of equipment, the effect on product quality and productivity, the expected maintenance and utility requirements and the necessary operating and supervising skills. Second, the changes in the technical specifications can be converted into a projected materials balance, reflecting the input and output material flows and energy requirements after implementation of the cleaner production option. The options that do not need capital expenditure, e.g. housekeeping measures, can often be implemented quickly. It is a typical fast-track approach. If capital investment is needed for the chosen option, it is advisable to appoint an ad-hoc group of experts, to make a technical evaluation based on selected evaluation criteria. Raw material, equipment or process changes are expensive and may effect changes in production line or product quality. Therefore, technical evaluation of such option requires more complex investigation.

Economic evaluation: The economic evaluation consists at least of data collection (regarding investments and operational costs, and benefits), choice between evaluation criteria [pay back period. Net Present Value (NPV) or Internal Rate of Return] and feasibility calculations. The

economic data collection builds upon the results of the technical evaluation. In order to properly incorporate the long term economic advantages of cleaner production, it is highly recommendable to apply Total Cost Assessment principles to the economic evaluation (especially for high cost options).

Environmental evaluation: The objective of environmental evaluation is to determine the positive and negative impacts of the option for the environment. An environmental evaluation must take into account the whole life-cycle of a product or service. There are essentially two types of life-cycle analyses: quantitative and qualitative. The quantitative method involves developing a set of criteria against which the environmental impact of a product can be measured and then actually measuring it against these criteria. Criteria may be developed using parameters such as: the cost of disposal or clean-up of the wastes generated at all stages in the life-cycle; the amount or cost of energy used at all stages in the life cycle, etc. The other, qualitative approach is more useful for this assessment. It involves drawing up a matrix of environmental issues vs life cycle stages.

Selection of feasible options: First, the technically non-feasible options and the options without a significant environmental benefit can be eliminated. All remaining options can in principle be implemented. However, a selection is required in case of competing options or in case of limited funds.

2.2.7.Implementation of CP in industry

In the last phase, the feasible prevention measures are implemented and provisions taken to ensure the ongoing application of Cleaner Production. The development of such an ongoing programme requires monitoring and evaluation of the results achieved by the implementation of the first group of preventive measures.

The expected result of this phase is threefold:

1. Implementation of the feasible Cleaner Production measures
2. Monitoring and evaluation of the progress achieved by the implementation of the feasible options
3. Initiation of ongoing Cleaner Production activities

To achieve this result, the following tasks should be implemented:

- **Prepare Cleaner Production Plan:** The measures are organized according to the expected date of implementation. Additionally, the person or department with the prime responsibility for the implementation should be identified.
- **Implement feasible Cleaner Production measures:** The effort needed to implement Cleaner Production measures can vastly differ substantially. Simple measures (like good housekeeping) can easily be implemented. However, the focus should be on complex measures, which require a substantial investment (high cost options). Implementation of these options can require a detailed preparation such as planning the installation and funding requirements. Next, the installation of equipment requires supervision in order to safeguard optimal use of the new facilities.
- **Monitor Cleaner Production progress:** Simple indicators should be used to monitor progress and to keep the management as well as other interested parties frequently informed. The choice of the measurement method is crucial. It can be based on changes in waste (and/or emission) quantities, changes in resource consumption (including energy) or changes in profitability. The evaluation of the monitoring data should include changes in the production output and/or changes in the product mix.

- **Sustain Cleaner Production:** The ongoing application of the Cleaner Production concept may require structural changes in the organization and management system of the company. The key areas are: integration into the technical development of the company, proper accountability of waste generation, and employee involvement. The integration into the technical development could include preventive maintenance schedules, integration of environmental criteria (such as energy and resource consumption) in the selection of new equipment or integration of Cleaner Production into long-term research and development plans. Employee involvement can be achieved by staff education, creation of regular opportunities for two-way internal communication and employee reward programmes.

Barriers for Cleaner Production from the perspective of industries despite attractive economics and significant reductions in environmental impacts, the widespread adoption of Cleaner Production still remains limited. Several studies have addressed the barriers for the adoption of Cleaner Production at the level of individual enterprises, and most often categorized these as given in Table 2.1.

Table 2.1.Barriers for the adoption of Cleaner Production

TYPE OF CONSTRAINTS	SUB-CATEGORIES
1. FINANCIAL	• High cost of external capital for investments in industry • Lack of funding mechanisms (lending schemes etc.) appropriate for Cleaner Production investments • Perception that investments in Cleaner Production present a high financial risk due to the innovative nature of Cleaner Production • Cleaner Production not properly valued by credit providers in their evaluation procedures for lending, equity participation etc
2. ECONOMIC	• Cleaner Production investments are not sufficiently cost effective (compared with other investment opportunities), given present resource prices • Immaturity of the company's internal cost calculation and cost allocation practices • Immaturity of the company's internal capital budgeting and capital allocation procedures

Table2.1 (Continued)

3. POLICY-RELATED	• Insufficient focus on Cleaner Production in environmental, technology, trade and industry development and strategies • Immaturity of the environmental policy framework (including lack of enforcement, etc.)
4. ORGANISATIONAL	• Lack of leadership for environmental affairs • Perceived management risk related to Cleaner Production (e.g., no incentives for managers to put their efforts into implementation of Cleaner Production) • Immaturity of the environmental management function in the company's operations • General immaturity of the organization structure of the company and its management and information systems • Limited experience with employee involvement and project work

Table2.1 (Continued)

5. TECHNICAL	• Absence of a sound operational basis (with well established production practices, maintenance schemes etc.) • Complexity of Cleaner Production (e.g,. need to undertake comprehensive assessment to identify appropriate Cleaner Production opportunities) • Limited accessibility of equipment supportive to Cleaner Production (e.g., high quality engineering small wares for process instrumentation) • Limited accessibility of reliable technical information tailored to the company's needs and assimilative capacities limited experience with employee involvement and project work
6. CONCEPTUAL	• Indifference: perception regarding own role in contributing to environmental improvement· • Narrow interpretation or misunderstanding of the Cleaner Production concept • General resistance to change

3. Preassesement of Addis Ababa Tannery Sh.Co.

3.1 Process description of Addis Ababa Tannery Sh.Co. (AAT)

The production processes in the tannery can be split into four main categories: hide and skin storage and beam house, tanning, post-tanning, and finishing operations. Operations carried out in the beam house, the tanyard, and the post-tanning area are often referred to as **wet processes**, as they are performed in processing vessels filled with water. After post-tanning the leather is dried and operations are referred to as **dry processing**.

3.1.1Storage & Beam house operations

1. **Reception**: Salted hides are temporarily stored. The application of salt (NaCl) is done outside the factory to preserve the hides from decay. All hides are weighed for calculating the amount of needed chemicals.
2. **Soaking**: It is carried out to allow salted hides to re-absorb any water, which may have been lost after flaying, to clean the hides and skins (removal of dung, blood, salt, air, etc), and to remove interfibrillery material. The soaking methods depend on the state of the hides. The process is mostly carried out in two steps. A dirt soak, to remove the salt and dirt and a main soak. The process is carried out in processing vessels, such as mixers, drums, paddles, and pits. Depending on the type of raw materials used soaking additives can be used.
3. **Dehairing /Liming**: Soaked hides undergo the deharing/ Liming process lead through in a rotating, wooden drum. Each batch has an average size of two tons. And the effluent is directly discharged into the near by river without treatment.
4. **Fleshing:** This step is conducted to remove the residual flesh from the hides by mechanical means (fleshing machine). The removed flesh sludge containing a high amount of fat is discharged in to the near by river.

5. **Trimmings:** It is the removal of loose, raggy end of hides and skins usually by hand knife. The limed trimmings are old to glue manufactures.

3.1.2Tanyard operations

1. **Deliming**: After a manual treatment the deliming takes place also in rotating drums. The fleshed hides are still in a limed condition and contain alkali reactive agents. To make the hides suitable for tanning, the pH value is brought back first from 11 to 6 with a solution of $(NH_4)_2SO_4$ (1%) and $NaHSO_3$ (0.5%), (3 hours/ 1hr agitation with another lead of chemicals).All wastewater is drained off to the nearby river.
2. **Pickling**: For further pH adjustment to 3.5, fresh water, formic acid (0.4), sulfuric acid (1%) and Sodium Chloride (5%) are added and mixed with the skin for approximately 4 hours in rotating drums. This step is important for the penetration of tanning agents into the hides. The solution is not changed before the pretanning / tanning steps.
3. **Pretanning/ Tanning**: Before tanning the leather, a pretanning step with pretanning agent is carried out for 1 hr. In the tanning process the collagen fiber is established by the tanning agents such that the hide is no longer susceptible to putrefaction or rotting. In this process the collagen fibers are stabilized by the cross- linking action of the tanning agents. The tanning is worked out with the addition of $Cr_2 (SO_4)_3$ (10%) at a pH of 3.8 in a rotating drum. All wastewater (incl. Cr^{+3}) is discharged in to the near by river.
4. **Draining, Samming, and Setting**

   After tanning, the leathers are drained, rinsed and either horsed up to age, or unloaded in boxes and subsequently sammed to reduce the moisture content prior to further mechanical action, such as splitting and shaving.

The setting out operation can be carried out to stretch out the leather. After samming and setting, hides and skins can be sorted out into different grades after which they are processed further or sold in the market.

5. **Splitting**: The function of the splitting operation is to cut through skins or hides at a set thickness. If the hide/ skin is thick enough, splitting can yield a grain split and a flesh split, which could both, be processed into finished leather.

6. **Shaving**: The shaving process is carried out to achieve an even thickness through out the skin/ hide, and it can be carried out on tanned or crusted leather. Shaving is carried out where splitting is not possible or where minor adjustments to the thickness are required.

3.1.3 Post- tanning operations

Post- tanning involves neutralization and washing followed by retanning, dyeing and fat liquoring, mostly done in a single processing vessel. At this stage of the process, special operations may also be carried out to add certain properties to the leather such as water repellence, or resistance, oleophobing, gas permeability, flame retarding, abrasions and anti-electrostatics.

3.1.4 Finishing

The over all objective of finishing is to enhance the appearance of the leather and to provide the performance characteristics expected of the finished leather with respect to:

- Color, Gloss, Handle, Flex, Adhesion, Rub fastness, as well as other properties including extensibility, break, light and perspiration fastness, water vapor permeability and water resistance as required for the end use.

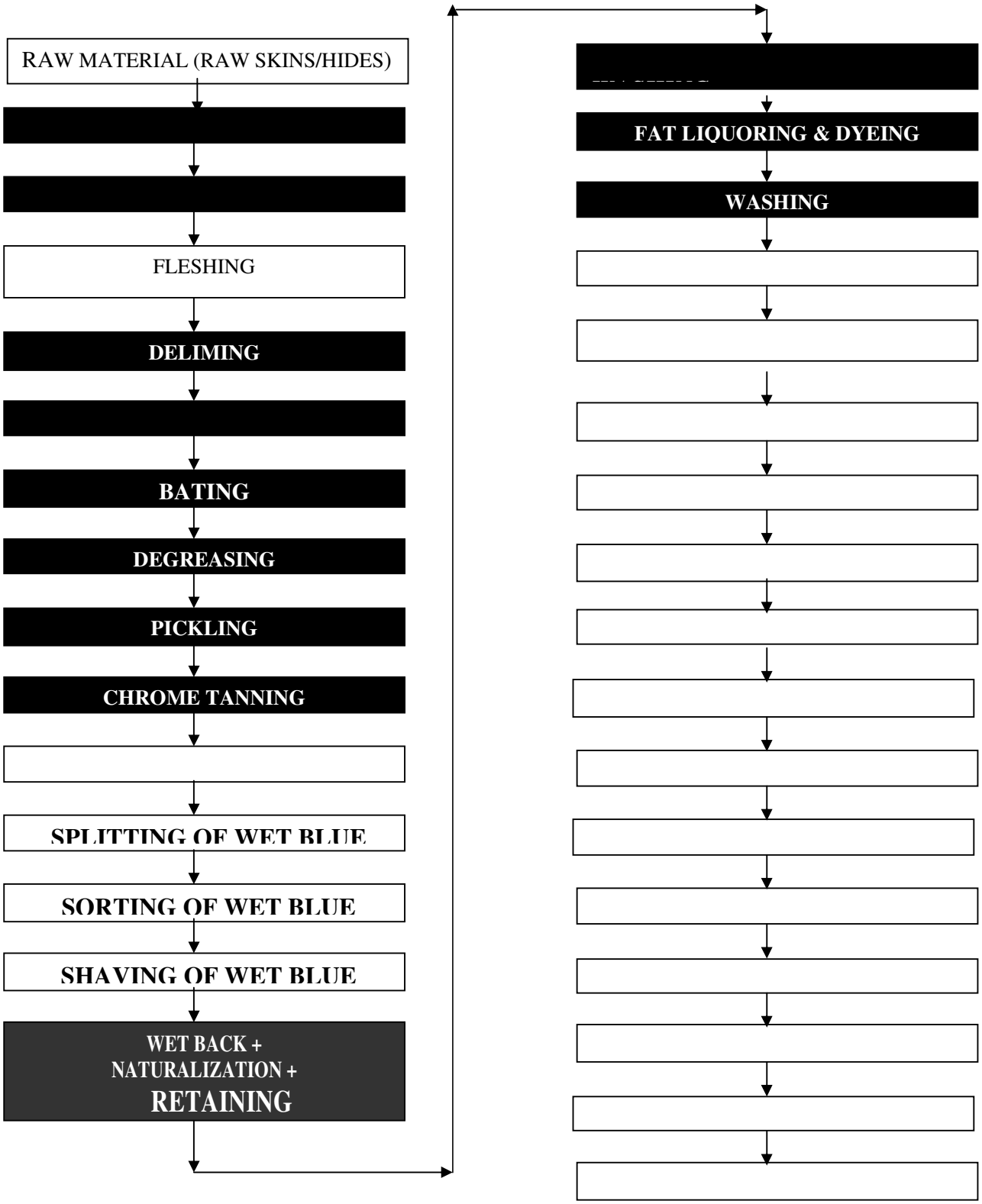


Figure 3.1: General processes flow diagram of AAT,

3.1.5 Major types of Products/Services of AAT

Addis Ababa Tannery is mainly engaged in the production of the following products:

- Shoe upper and lining from hides and skins
- Garments and Napsa both in sheep skin and hides
- Sole leather from hides
- Bag leather from hides
- Upholstery leather from hides
- Wet Blue, Crust and Finished Leather (For export)

3.2 Sources of solid waste in AAT

The tanning industry is a potentially pollution intensive industry. The environmental impacts of Addis Ababa Tannery originate from liquid, solid and gaseous waste streams and they arise from the consumption of raw materials such as raw hides, chemicals, water and energy. Furthermore, the nature of some of the processes and the materials consumed in those processes may potentially have an impact on health and safety at work, and possibly on soil and ground water contamination. Also, the use of certain techniques for production processes and abatement may result in some cross-media effects.

The main releases to waste water originate from wet processing in the beam house, the tanyard and the post-tanning operations. The main releases to air are due to the dry finishing processes, although gaseous emissions may also arise in all other parts of the tannery.

Two types of solid wastes (tanned and untanned) are generated from leather production processes of AAT. Solid waste includes dusted curing salts, trimmings, and splitting, shavings, buffing and packaging materials.

Table 3.1 Types of untanned solid waste in AAT

Types of Solid Waste	Source	Composition
Dusted Salt	Desalting of hides	Nacl, blood, dirt, bacteria and bactericides
Limed Fleshing	Fleshing Machine	Moisture, proteins, fats, lime , sulphides
Limed hide Trimmings	Trimmings	Moisture, proteins, fats, lime, sulphides

Table 3.2 Types of tanned solid waste in AAT.

Types of solid waste	Source	Composition
Wet blue splitting	Splitting machine	Cr_2O_3, moisture, protein, fat.
Wet blue shaving	Shaving Machine	Cr_2O_3, Moisture, protein, fat.
Crust and finished leather trimmings	Finishing section	Fats, proteins, Cr_2O_3, syntans and dyes
Buffing dust	Buffing Machine	Fats, protein, Cr_2O_3, syntans, and dye.

3.3 Problems observed in solid waste management of AAT.

Some of the main problems observed in solid waste management of AAT are:

1. The hides are not selected in size on arrival
2. The salted hides are not properly desalted/dedusted
3. No well calibrated beam balance in the beam house and tanning sections, which results in improper weighing.
4. The fleshing is directly discharged into the nearby river.
5. Lack of skill in trimming hides.
6. Generation of solid waste such as unused splits, shavings, lime trimmings, crust and finished leather trimmings.

4. Solid waste generation in AAT

4.1. Solid waste inventory in AAT.

In performing the solid waste inventory of AAT, the following duties are carried out ,

- Material flows in each unit operations is identified
- The hides are weighed before and after each unit operation
- Data measuring is done three times for each unit operation and an average value is taken

Material balance was made based on the existing production process condition of Addis Ababa Tannery Sh.Co. The main material inputs in the tanning processes are given in the following Tables 4.1 & 4.2.

Table 4.1 Recipe based annual consumption of process chemicals per unit operation of AAT.

Unit operation	***Chemicals descriptions***	***Tons/yr***
Reception	Salted rawhides	951.277
Soaking	-Sandozin -Soda ash -Sodium Silicoflorid	4.76 14.26 1.9
Unhairing /Liming	-Sodium Sulphide Flakes -Sodium Sulphydrates -Lime powder	23.78 4.76 66.6
Fleshing	-	-
Trimmings	-	-
Deliming	- Ammonium Sulphate - Sodium Bisulphate - Sando clean MW	9.5 4.76 1.9
Table 4.1 (Continued)	. Epnse	1.9
Pickling	- Denatured Salt - Formic acid - Sulfuric acid	52.3 3.8 9.5
	- Tankrom. AB	33.3

Tanning	- Pervental WB - Tankrom. QB - Sodium Bicarbonate	2.8 28.5 .95
Draining, Samming & Setting	-	-
Splitting	-	-
Shaving	-	-
Post tanning	- Tanicor As b-p - Lipson EMK - Sodium Formate - Sodium Bicarbonate - Mapnopal PGN - Relugan-RE - FISFOL-SO - Lipsol J-622 - Mimosa - Retanal-SF - Fastal AR-75 - Lipsol J-622 - Formic acid	14.3 4.75 9.5 3.8 14.27 9.5 19 19 38 19 9.5 4.76 5.7
Crust trimming	-	-
Buffing -	-	-
Finishing section	- Pigment - Water - Melio Filler NF - CPU 8011 - CPU 8099 - Melio Resin 5-935 - Binder A-12 - Wax 185 - ICA Driver-150	1.7 5.9 2.85 1.7 1.7 8.85 3.5 2.85 4.38
Finished Leather trimmings	-	-
Total (chemicals)		469.78

Table 4.2. Actual annual consumption of process chemicals per operation of AAT

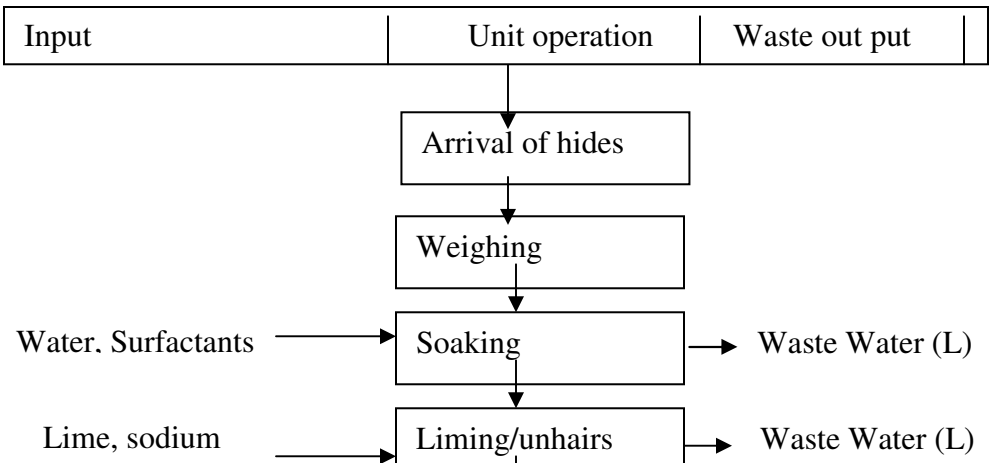
Unit operations	**Chemical description**	***Tons/yr***
Beam house	Salted rawhides	951.277
	Sandozin NIA	4.89

	Soda ash	14.03
	Sodium Silico Floride	3.42
	Sodium sulphhdrares	13.96
	Sodium Sulphide Flakes	35.765
	Lime powder	87.762
Subtotal 1		159.827
Tanning	Ammonium sulphate	44.125
	Sodium bisulphate	18.376
	Sandoclean. MW	1.5
	Recolose EP-1196	4.32
	Sodium formate	17.4
	Denatured Salt	139.84
	Formiciacid	15.2
	Sulphuric acid	23.276
	Tankrom AB	37.33
	Pervental WB	4.74
	Tankrom QB	20.39
	Sodium bicarbonate	13.897
Subtotal 2		340.394
Post Tanning	Tanicor As 6-p	0.76
	Lipsol EMK	9.078
	Magnopal PGN	1.265
	Relugan REC	18.51
	Fisfol 50	0.653
	Lipsol J-622	20.35
	Mimosa Powder	27.535
	Retanal CF	0.012
	Fasfal AR-75	0.519
Subtotal 3		78.682
Finishing Section	Pigment 0.811	1.7
	Water	5.9
	Melio Filler NF	0.105
	CPU 8011	0.14
	CPU 8099	0.114
	Melio Resin S-935	0.373
	Binder A-12	0.67
	Melio Wax 185	0.154
	ICA Driver 150	0.336
Subtotal 4		9.492
Total (chemicals)		588.395

Due to lack of a well-calibrated beam balance and improper weighing of chemicals, there was an over consumption of process chemicals.

4.2.Qualitative analysis of process input-output

The qualitative process input-output analysis from each tannery unit operation was given in Fig.4.1. & Table 4.3.



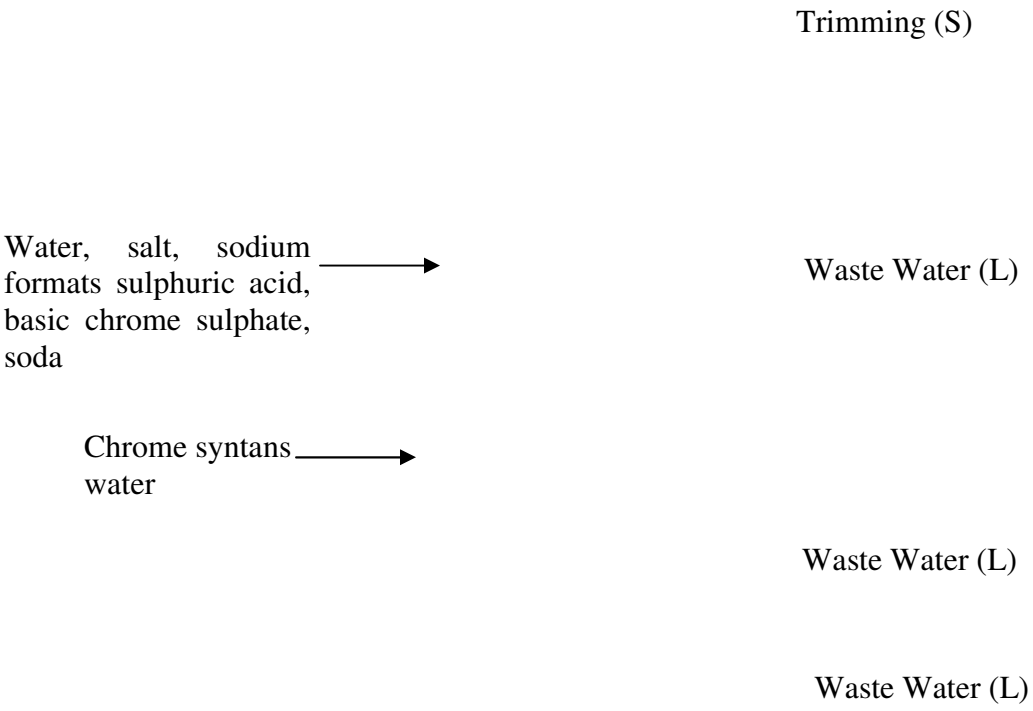


Fig 4. 1. Identification of process waste of AAT

Table 4.3. Input-Output analysis of AAT

Process unit	Inputs	Waste Water	Solid Waste	Air emission	Remark
Trimming			• Parts of the raw hides (trimmings)		
Reception & Storing	-	-	• Salt		
Soaking	• Water • Alkali • Sodium hypo- chlorite • Wetting agents, surfactants enzymes • Biocides	• BOD, COD, SS, DS from fat, etc • Salts • Org-N • AOX emulsifiers, surfactants, biocides			
Fleshing (*)	• (Cold) water	• BOD, COD, SS, DS from fat, grease	• Fat, connective tissue, lime		-undergoes lime fleshing
Liming & Unhairing	• Water • Lime, alkali sulphides • thioalcohols • enzymes • surfactants	• Sulphides, • BOD, COD, SS, DS emulsified and saponified fat, protein, degradation, products from hair • lime • high $_{P}H$, • Org. N, NH_4-N, • Biocides	• hair	• Sulphides • Odour	
Rinsing after Unhairing	• Water	• as from liming and unhairing			
Splitting (**)	• Water	• Same as liming	• lime split (flesh- side) • trimmings		• Problems in waste fractions pH-12 and sulphides • Splitting in tanned conditions
Tanyard operations and post- tanning operations					
Deliming/ Bating	• ammonium slats • org. and inor. acids and their salts • carbon dioxide • enzymes • water	• BOD, COD, DS from epidermis , skin and pigment residues, degradation products and excess bating agents • NH_4-N • Sulphides • calcium salts (mainly sulphates)		• NH_3 • H_2S • dust from bating agents	• NH_4-N depends on deliming method • Prior treatment using H_2O or (Na- bisulphate to oxidize the sulphides) • dust emission from bating agents depend on the agents and the method in which they are applied
Rinsing	• Water	• as from deliming / bating			-
Degreasing	• surfactants and water • Organic solvents	• BOD, COD, DS • Organic contents (fat, solvents) • surfactants			• Chlorinated / non-chlorinated hydrocarbons • Workplace conditions for VOCs
Pickling	• Water • Organic and inorganic acids, salt • fungicides	• DOD, COD, SS, DS • Salt • Low $_{P}H$		• hydrogen sulphide • acid fumes	• fungicides • addition of some hydrogen peroxide may be necessary

Table 4.3 (Continued)

Tanning	• Water • Organic and inorganic acids, salt • basifying salts • fungicides • completing agents	• SS, DS, BOD, COD, Low PH • Completing agents • fungicides	• hides due to operating errors • tanning liquors		• toxicity of tanning agents (aldehydes) • complexing agents: masking: sequestering agents for water treatment
Rinsing	• Water	• Same as in tanning			
Draining, samming & setting		• Same as in tanning			• noise as in all mechanical processes
Splitting & Shaving		• Leather fibres from shaving			
Rinsing		• Leather fibres from shaving			
Neutralization	• Water • Organic and inorganic acids, alkali salt • neutralizing tanning agents	• DS, SS, BOD, COD • rest of tanning agents		• ammonia and sulphur dioxide can be released into the air	
Rinsing	• water	• same as in neutralization			
Bleaching	• Water • Organic and inorganic acids, alkali salt	• Organic load • others, depending on the agents used		• Sulphur dioxide	-
Dyeing	• dyestuff • ammonia • organic solvents • auxiliaries, surfactans, chlorinated organic compounds • water	• high colur • organic solvents • dyeing agents • AOX	• residues of chemicals • dyeing agents	• NH_3 • Phenols • formaldehyde	• toxicity of dyestuff • toxicity of auxiliaries
Rinsing	• Water	• same in dyeing			

Table 4.3 (Continued)

Faltiquoring	• Synthetics- mineral based oils • (sulphonated) animal vegetable oil fish oil • chlorinated organic compounds • Surfactants • other auxiliaries • water	• high oil • Chlorinated organic compounds (AOX) • Surfactants			• chlorinated organic compounds (AOX) • surfactants • toxicity of auxiliaries
Finishing operations					
Staking/ other mechanical operations			• dust		• other mechanical operations like polishing, embossing, plating, rolling etc. • noise as I all mechanical processes
Drying	• energy • biocides			• heat • acid fumes	
Milling/ Buffing	•		• dust	• dust [tan/tm/03/UwH B-Stoffe	• noise as in all mechanical processes
Coating	• lacquers (solvent based) • lacquers (water based) • binder and cross- linking agents • auxiliaries • water	• finishing agents in water or in aqueous solutions (organic solvents, heavy metals • auxiliaries	• resideues from chemicals,	• organic solvent use and release: acrosols • formaldehyde as fixing agent [tan/ tm/03/uxHB - Abluft]	• workplace protection • toxicity and health effects of water blased agents and organic solvents, binders, cross- linking agents and auxiliaries
Trimming			• Final trimmings	•	• with or without finish
Abatement operations					
Air abatement	• filter matrices • water, acidic and basic agents for wet-scrubbers	• waste water from wet- scrubbers	• dust	• not abated cmisins	• depending o n the method of air abatement for various effluent streams
Waste water abatement	• energy • Precipitation agents • other treatment agents (flocculation, etc)		• Coarse material • filters (e.g from special treatment	• according to waste water stream and process (e.g sulphides, ammonia, odour	
Waste treatment	• energy • other treatment agents according to process	• according to waste fraction and process	• According to waste fraction and process	• according to waste fraction and process	

Notes:
(*) Fleshing can be performed before or after liming resulting in different releases.
(**) Splitting can be performed with limed or tanned hides and skins with crust resulting in different releases.

It was noted that no wastes were reused /recycled at the tannery. The only wastes that were recycled are trimmings, used by a local glue manufacturing company. These amounts to on average 635 kg/day. Fleshing & shavings were discharged to the nearby river and amounts to 1950 kg/ d.

A general material balance of data associated with operations within the tannery was first drawn up on an overall input/output materials basis. The information was tabulated as set out below.

Inputs	**kg/d**
Rawhides	5000
Chemicals (Other than curing salt present in raw hides)	3092.65
Water	512526.84
Total	520619.49

Overall Tannery Operations

Outputs	**kg/d**
Dusted Salts	25
Trimmings and Shavings	1225
Fleshings	1500
Pickled Split Layer	550
Finished Leather	1250
Wastewater	516069.49 (suspended solid is included)
Gaseous Emissions	Not quantified but not considered to be a major output

Table 4.4. Input - Output analysis per ton of salted hides of AAT.

Unit operation	**Chemical input per ton of salted hide**	**Out put per ton of salted hides (in kg)**			
		Finished Leather	**Liquid waste**	**Solid Waste**	**Air emission**
Soaking	Water Sandozin = 5 kg Sodash = 15 kg Sodium Silicoflorid = 2kg	250	Effluent	-	-
Unhairing /Liming	Water Sodium Sulplide =25 kg Sodium Sulphydrates = 5 kg Lime powder = 70 kg	-	Effluent	-	-
Fleshing	-	-	-	300 kg	-
Trimmings	-	-	-	127 kg	-
Deliming	- Water - Ammonium Sulphate = 10 kg - Sodium bisulphate -= 5 kg - Sando clean MW = 2 kg	-	Effluent	-	-Gas emission.
Bathing	- Reveslas. Epnse = 2kg	-	Effluent	-	-dust from bating agents
Pickling	- Water - Salt = 55 kg - Formic acid = 4kg - Sulfuric acid = 10 kg	-	Effluent	-	-Gas emission, acid fumes
Tanning	- Tankrom. AB = 35 kg - Pervental WB = 3 kg - Tankrom. OB = 30 kg - Sodium bicarbonate = 1 kg	-	Effluent	-	-
Draining, Samming & Setting	-	-	Effluent	-	-
Splitting	-	-	-	Unused split = 110 kg	-
Shaving	-	-	-	Shavings =90 kg	Dust if dry shaving is performed

Table 4.4 (Continued)

Post tanning	- water 700% - Tanicor As b-p = 15 kg - Lipson EMK = 5 kg - Sodium formate = 10 kg - Sodium bicarbonate = 4 kg - Mapnopal PGN = 15 - Relugan-RE = 10 kg - FISFOL-SO = 20 kg - Lipsol J-622 = 20 kg - Mimosa = 40 kg - Retanal-SF = 20 kg - Fastal AR-75 = 10 kg - Lipsol J-622 = 5 kg - Formic acid = 6 kg	-	Effluent	-	-
Crust trimming	-	-	-	Fleshing = 13 kg	-
Buffing -	-	-	-	Buffing dust	-
Finishing section	- Pigment 0.811 = 1.8 kg - Water = 6.2 kg - Melio Filler NF = 3kg - CPU 8011 = 1.8 kg - CPU 8099 = 1.8 kg - Melio Resin 5-935 = 9.3 kg - Binder A-12 = 3.7 kg - Wax 185 = 3 kg - ICA Driver-150 = 4.6 kg	-	-	-	Vapors (solvents)
Finished Leather trimmings	-	-	-	15 kg	-

Table 4.5. Summary of solid waste generated per ton of salted hide in AAT.

Solid waste type	kg/ton
Dusted Salt	5
Lime fleshing	300
Lime trimmings	127
Unused chrome split	110
Shaving	90
Crust trimmings	13
Baffing dust	Not quantified
Finished Leather trimmings	15
Total	660

Table 4.6. Typical an average quantities of solid waste produced in leather tanning

Component	Amount of solid waste per ton of salted hide (in kg)
Trimmings	120
Fleshings	230
Chrome Shaving	99
Chrome Split Waste	115
Buffing dust	2
Crust trimmings	32
Total	598

Source UK DOE 1977

As we can see from Tables 4.5 &4.6, the solid waste generated by AAT is 19% beyond the average value indicated in Table 4.6.

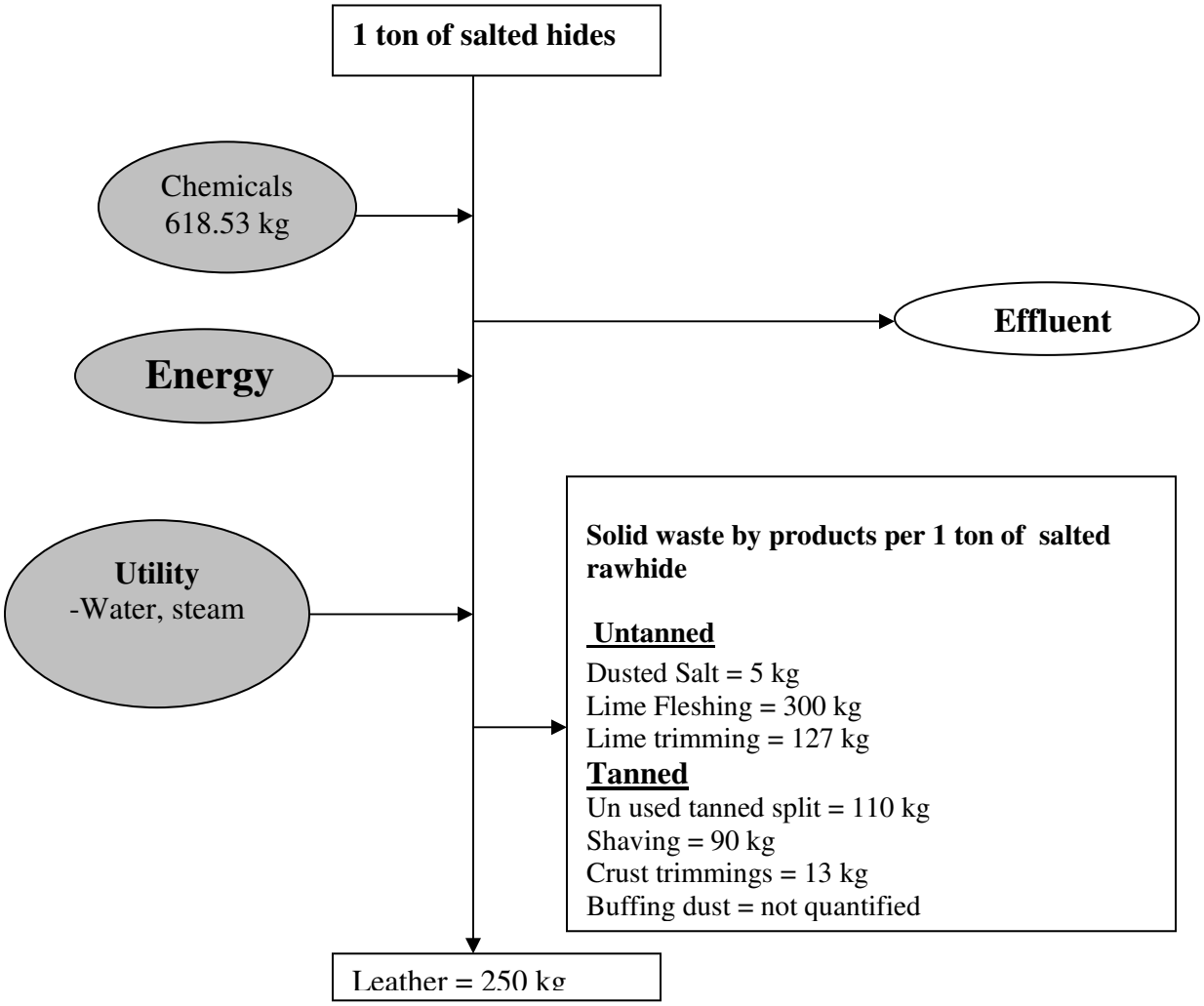


Fig 4.2. Input-Output overview of AAT

5. Priority selection for CP options at AAT

The cleaner production options are categorized

by technique, ranging from good housekeeping to technology change. Once CP options have been identified, they are subjected to techno-economic and environmental feasibility for implementation.

The techno-economic-environmental analysis provides an idea on the priority with which an option should be implemented. The entrepreneur must have a certain amount of subjectivity in deciding the implementation plan. As a broad rule of thumb, the options may be categorized as: (1) immediately implementable; (2) short-term implementable measures; and (3) long-term implementable measures, depending on the pay back period of the option. Here are given, the major CP interventions for solid waste management of AAT.

5.1 Audit focus on AAT

The first step in setting priority of implementation for the selected CP options is based on selection of priority setting criteria. Accordingly, the following three criteria were set.

Criteria –1: Environmental benefits achieved by implementing the selected CP options.

It is often taken for granted that reduction of a waste will have environmental benefits. In many cases the benefits may be obvious as the reduction in the total volume and degree of contamination of process waste. In other cases, the environmental benefits may be less tangible. Creating cleaner, healthier workplace will increase production efficiency but this may be difficult to quantify.

The environmental benefits has given the largest weight point range (1-50) relative to the two criteria for the waste has direct and indirect impact on the environment and the surrounding populations since they use the contaminated "Akaki-Tulu" river for their day to day activities.

Reduction in the total volume of solid waste and degree of contamination caused by process chemicals is taken as sub-criteria for evaluating the environmental benefits achieved by implementing the selected CP options. Accordingly, reduction in the total volume of solid waste has given a weight point range of 1-20 and reduction of environmental impact caused by process chemicals has given a weight point range of 1-30.

Reduction in the degree of contamination caused by chemicals was given a larger weight range for the process chemicals that are discharged out with the solid waste. Which was the main cause for the environmental pollution and contamination of the "Akaki-Tulu" river.

Criteria-2: Economic benefits achieved by implementing the selected CP options

Economic evaluations of waste reduction options should involve a comparison of investment cost where cost savings should be made.

The economic benefit was given a weight point range of 1-30 points. Even though the investment is large compared to the savings achieved by implementing the selected CP options, its environmental achievement is more significant compared to the economic benefits.

Low investment cost and cost saving are the sub-criteria considered in evaluating the economic benefits. Low investment cost was given a weight point range of 1-20 and that of cost savings from 1-10 points.

Criteria-3 Ease of implementation

Ease of implementation was given a weight range of 1-20 points. Even if the selected CP options is environmental friendly and economical viable, the availability of the technology and its ease of application to the respective industry should be considered. Accordingly, availability of technology and ease of application were given a weight range of 1-10 for each sub criterion.

The following are the suggested CP options for which the priority has to be set.

- Classification into small, medium, large sizes & dedusting the salt manually or mechanically
- Purchasing of a well calibrated beam balance and proper weighing of chemicals.
- Introducing green fleshing
- Installing lime splitting machine
- Training the workers how to trim
- Manufacturing leather board from the shaved leather

Table 5.1 Priority setup for the suggested CP options.

Operations	Focus	Criteria	Weight point	Total weight point	Priority
Hides classification and dedusting the salt	F1	<u>Environmental benefits</u> • Reduction in the total volume of solid waste • Reduction in environmental impact caused by chemicals <u>Economic benefits</u> • Low investment cost • Cost savings <u>Ease of implementation</u> • Availability of technology • Ease of application	5 20 15 3 8 8	59	4
Purchasing of a well calibrated beam balance and proper weighing of chemicals.	F2	<u>Environmental benefits</u> • Reduction in the total volume of solid waste • Reduction in environmental impact caused by chemicals <u>Economic benefits</u> • Low investment cost • Cost savings <u>Ease of implementation</u> • Availability of technology • Ease of application	15 28 18 9 9	88	1

Table 5.1 Continued.

Green fleshing	F3	<u>Environmental benefits</u> • Reduction in the total volume of solid waste • Reduction in environmental impact caused by chemicals <u>Economic benefits</u> • Low investment cost • Cost savings <u>Ease of implementation</u> • Availability of technology • Ease of application	15 25 10 5 8 7	70	2
Training workers how to Trim	F4	<u>Environmental benefits</u> • Reduction in the total volume of solid waste • Reduction in environmental impact caused by chemicals <u>Economic benefits</u> • Low investment cost • Cost savings <u>Ease of implementation</u> • Availability of technology • Ease of application	5 10 15 5 8 7	50	6

Table 5.1 Continued.

Lime splitting	F5	<u>Environmental benefits</u> • Reduction in the total volume of solid waste • Reduction in environmental impact caused by chemicals <u>Economic benefits</u> • Low investment cost • Cost savings <u>Ease of implementation</u> • Availability of technology • Ease of application	10 25 12 6 8 5	66	3
Leather board from shavings	F6	<u>Environmental benefits</u> • Reduction in the total volume of solid waste • Reduction in environmental impact caused by chemicals <u>Economic benefits</u> • Low Investment cost • Cost savings <u>Ease of implementation</u> • Availability of technology • Ease of application	15 23 5 5 5 5	56	5

Summary:

Based on the set criteria, Purchasing of a well-calibrated beam balance and proper weighing of chemicals, Green fleshing and Lime splitting took the 1st , 2nd and 3rd priority respectively.

The economical and technical evaluations of these options are made in detail.

6. Economical and Technical Evaluation of the selected CP Options

6.1 Technical and economical evaluation of proper chemical preparation.

Due to lack of a well-calibrated beam balance, awareness and improper weighing, the chemical consumption in the beam house and tanning operations of AAT are beyond the recipe which leads to an over consumption of chemicals, resulting in Economical and Environmental drawbacks.

In order to solve the problem, the company has to install a well-calibrated beam balance for the beamhouse & tanning sections and encourage the workers to prepare chemicals based on the company recipe.

Table 6.1. Cost saved by proper preparation of chemicals per ton of salted hide

Operations	Chemicals	Recipe based chemical consumption per 1 ton of salted hide (kg)	Actual chemical consumption per ton of salted hide. (in kg)	Difference between the actual & recipe based consumption per 1 tonof salted hide ▲(in kg)	Unit cost/kg (in Birr)	Cost saved per ton of salted hide (in Birr)
Beam house	Sandozin	5	5.136	0.136	13.58	1.8
	Soda ash	15	15	0	-	0
	Sodium Silico-Floride	2	3.6	1.6	7.69	12.3
	Sodium sulphydrates	5	14.67	9.67	8.33	80.55
	Sodium Sulphate Flakes	25	40	15	6.39	95.8
	Lime powder	70	92.24	22.24	0.502	11.2
Tanning	Ammonium sulphate	10	46.4	36.4	3.47	126.3
	Sodium bisulphate	5	19.3	14.3	7.53	107.67
	Recolose EP-1196	2	4.5	2.5	29.68	74.2
	Sodium Formate	15	23.3	8.3	4.32	35.8
	Denatured salt	50	142	92	1.12	103
	Formic acid	10	22	12	7.41	88.92
	Sulphuric acid	10	11.45	1.45	2.64	3.8
	Tankrom AB	35	39.2	4.2	9.78	41
	Pervental WB	3	5	2	50.59	101.2
	Sodium bicarbonate	5	14.6	9.6	3.64	34.9
Total						918.44

▲ = the difference between the actual and recipe based process chemical consumptions

Source: Inventory report of AAT& Company's recipe

6.1.1 Economic Benefits

If calibrated beam balances are installed and the workers are encouraged to weigh/prepare chemicals according to the recipe, the company can save 918.44 Birr per tone of salted hides. Since the Company has a capacity of processing 951.277 tons of salted hides per year, it can save a chemical cost of 873,690.00 Birr/yr.

6.1.2 Investment cost

In order to purchase two well-calibrated beam balances for the beam house and tanning operations, a total of 100,000 Birr is required.

6.1.3 Environmental Benefits

Implementing the project reduces the discharge of excess chemicals in to the nearby river. The reduction in the discharge of the process chemicals by implementing proper chemical preparation is given in Table 6.2.

Table 6.2. Environmental benefits of proper process chemical preparation

Description	**Reduction (in ton)/yr**
Sodium Silico Fluoride	1.52
Sodium Suphydrates	9.2
Sodium Sulphate Flakes	11.985
Lime Powder	21.16
Ammonium Sulphate	34.625
Sodium Formate	7.9
Denatured salt	87.54
Tankrom AB	4.03
Formic acid	11.4
Sulphuric acid	1.3776
Other chemicals	40.581

6.2 Economical and Technical Evaluation of Green Fleshing

Addis Ababa Tannery (AAT) fleshes the hides after it has been unhaired/limed. And the fleshing is directly discharged to the Akaki & Leku rivers. Which has a serious impact on the aquatic organisms and the surrounding residents for the lime fleshing which contains process chemicals from liming and unhairing, such as lime and sulphides. In order to reduce the environmental impact caused by lime fleshing, it is advisable to implement green fleshing. Addis Ababa Tannery (AAT) has to work in collaboration with abattoirs in order to get wet hides.

By implementing green fleshing the company benefits from:

- Better fleshing without lime contamination.
- Green fleshing can be utilized in poultry feeds, and in glue manufacturing.
- The fact that water is absorbed more readily from the flesh side while the epidermal layer tends to be more resistant.
- Better penetration of chemicals.
- Decrease of limed solid waste amount.
- Pollution load reduction in the effluent due to less chemical consumption in the unhaired liming.

In order to implement the green fleshing, the green-fleshing machine has to be installed.

Table 6.3. Chemicals cost saved/ton of salted hides by implementing green fleshing

Chemicals	**Chemicals saved per ton of salted hides (kg)**		**Cost-saving/ton of salted hides (Birr)**	
	Actual	**Reference***	**Actual**	**Reference***
Sodium Sulphides	12	7.5	76.8	48
Lime Powder	27.67	21	14	10.5
Sodium Sulphydrates	4.4	1.5	36.6	12.5
Total	44.07	30	127.4	71

Reference*: Based on recipe of Addis Ababa Tannery

Table 6. 4. Chemical cost saved/day by implementing green fleshing

Chemicals	**Chemicals saved/day (kg)**		**Cost-saving/day (Birr)**	
	Actual	**Reference***	**Actual**	**Reference***
Sodium Sulphides	60	37.5	384	240
Sodium Sulphydrates	22	7.5	183	62.5
Lime Powder	138.4	105	70	52.5
Total	220.4	150	637	355

Reference*: Based on recipe of Addis Ababa Tannery

Table 6. 5. Chemical cost saved/yr by implementing green fleshing

Chemical	**Chemicals saved/yr (kg)**		**Cost-saving/yr (Birr)**	
	Actual	**Reference***	**Actual**	**Reference***
Sodium Sulphides	11415.3	7134.6	72943.9	45661.3
Sodium Sulphydrates	4185.6	1427	34866	11891
Lime Powder	26323.7	19977	13214.5	9988.4
Total	41924.6	28538.6	121,024.4	67540.7

Reference*: Based on recipe of Addis Ababa Tannery

6.2.1 Equipment cost (FOB)

The process requires high capital expenditure; Birr, 1,565,650.00 and may be prohibitively expensive in the short term.

6.2.2 Environmental benefits

It will have reduced the environmental impact caused by direct discharge of fleshing that contain sulphides and lime into the nearby river.

6.3. Economical and technical evaluation of lime splitting.

In most cases, splitting of limed hides is more environmental friendly than splitting after tanning (blue-splitting).

Lime splitting has several advantages compared to tanned stock splitting.

- The area yield is improved composed with blue-splitting due to maximum relaxation of the grain surface (tun/tm/09/UNIDO)
- Chemical consumption in subsequent wet process is reduced.
- Processing time is reduced, due to a reduction in the overall thickness of the leathers
- Flexibility is obtained to carry out different tannages in split and grain layers.
- Reduction is attained in tanned solid waste.

Table 6.6. Chemical cost saved per ton of salted hide by implementing lime splitting in AAT

Chemicals	**Chemicals saved/ ton of hide salted (kg)**		**Cost- saved / ton of salted hide (Birr)**	
	Actual	**Reference***	**Actual**	**Reference***
Ammonium sulphate	5.1	1	17.7	3.47
Sodium Bisulphate	2.1	0.5	15.8	3.77
Sando clear MWQ	0.2	0.2	2.72	2.72
Bathing agent (Rucolase - EP- 1196)	0.5	0.2	14.75	5.9
Table 6.6 Continued.	2.5	0.5	10.8	2.16
Denatured salt	15.6	6	17.47	6.72
Formic acid	2.4	0.5	17.76	3.7

Sulfuric acid	1.2	1	3.17	2.64
Tankrom AB	4.3	4	42	39.12
Pervental WB	0.5	0.4	25.3	20.24
Tankrom QB	3.3	3.3	32.67	32.67
Sodium Bicarbonate	1.6	0.1	5.8	0.364
Total	39.3	17.7	205.94	123.5

Reference*: Based on recipe of Addis Ababa Tannery

Table 6.7. Chemical cost saved / day by implementing lime splitting in AAT

Chemicals	**Chemicals saved/ day of hide salted (kg)**		**Cost- saving / day of salted hide (birr)**	
	Actual	**Reference***	**Actual**	**Reference***
Ammonium sulphate	25.5	5	88.5	17.4
Sodium Bisulphate	10.5	2.5	79	18.9
Sando clear MWQ	1	1	13.6	13.6
Bathing agent	2.5	1	73.75	29.5
Sodium Format	12.5	2.5	54	10.8
Denatured salt	78	30	87.35	33.6
Formic acid	12	2.5	88.8	18.5
Sulfuric acid	6	5	15.85	13.2
Tankrom AB	21.5	20	210	195.6
Table 6.7 Continued.	2.5	2	126.5	101.2
Tankrom QB	16.5	16.5	163.35	163.4

Sodium Bicarbonate	8	0.5	29	1.8
Total	196.5	88.5	1029.7	617.5

Reference*: Base on recipe of Addis Ababa Tannery

Table 6.8. Chemical cost saved / yr by implementing lime splitting in AAT

Chemicals	**Chemicals saved/ yr of hide salted (Kg)**		**Cost- saved /yr of salted hide (birr)**	
	Actual	**Reference***	**Actual**	**Reference***
Ammonium Sulphate	4851.5	951.3	16837.6	3301
Sodium bisulphate	1997.7	475.6	15030	3586.3
Sando clear MWQ	190.2	190.2	2587.5	2587.5
Bathing agent	475.6	190.25	14031.3	5612.5
Sodium Format	2378.2	475.6	10273.8	2054.7
Denatured salt	14840	5707.6	16618.8	6392.6
Formic acid	2283	475.6	16894.6	3519.7
Sulfuric acid	1141.5	951.3	3015.5	2511.4
Tankrom AB	4090.5	3805.1	39953.6	37214
Perventol WB	475.6	380.5	24067.3	19,254
Tankrom QB	3139.2	3139.2	31078.2	31,078.2
Sodium Bicarbonate	1522	95.13	5517.4	346.3
Total	37385	23,010	195905.6	99,458.2

Reference*: Based on recipe of Addis Ababa Tannery

The company can save about 160,550 Birr per year if it implements lime splitting in place of tanned stock splitting. For purchasing the lime splitting machine Birr, 562250.00 is required.

6.3.1 Environmental benefits of lime splits

Contamination of soil and underground water, contamination of food, occupational health hazard such as perforation and bronchioperic carcinoma, contamination of poultry feed, reduce genetic biodiversity.

Table 6.9. Lime splitting as CP Option

Description	Ammonium Sulphate	Sodium - Bisulphate	Sand clean MWQ	Formic acid	Sulfuric acid	Tankrom AB	Perventol WB	Tankrom QB	Other chemicals
Reduction (kg) /yr	951.3	475.6	190.2	475.6	951.3	3,805.1	380.5	3139.2	12641.2

7. Discussions and Conclusion

In this thesis a cleaner production approach is used for identification of environmental & technical problems of solid waste management in leather industries. A case study was

performed in Addis Ababa Tannery Sh.Co. (AAT). Based on the thesis work the following are the major recommendations for solid waste management in AAT:

7.1 Result discussion

As we have seen, the main sources of waste in AAT are the beam house &tanning operations. The Company has to take an appropriate CP measures in order to overcome the problems. Otherwise, it has to look for some other ways of treating and converting the waste into useful products rather discharging it directly in to the near by river.

The top management group of AAT should consider the seriousness of the problem and implement the CP options suggested in this research. The following are the main sources of environmental pollution and resource lose of the Company.

7.1.1 Dusting salt

Addis Ababa Tannery Sh.Co. does not employ salt dusting prior to soaking however the salt is removed from the hides during handling. This salt is collected and later discharged to the near by river. The discharge of electrolyte into the environment might have a significant effect on both aquatic and plant life, with most fresh water species unable to tolerate even relatively low concentrations of electrolyte in the water. Discharge of electrolyte is even more of a problem in areas where fresh water is scarce, and contamination of the watercourse by salt can have a highly adverse effect. Salt substitutes mineral nutrients in Soil. Furthermore, monitoring of aquatic toxicity can be hindered by high salinity.Thus, Addis Ababa Tannery Sh.Co. has to properly dispose the dusted salt or should undergo the standard practice.

7.1.2 Chemical preparation

Due to improper weighing and handlings of process chemicals, the Company ha lost its resources and affecting the environment directly. Thus, the Company has to install a well-calibrated balance and train the workers how to prepare the process chemicals.

7.1.3 Lime fleshing

Addis Ababa Tannery discharges lime fleshings directly into the nearby river. Fleshing of skin and hides is carried out after the liming process. In this operation the adipose tissues are removed from plumed skins and hide by fleshing machine. Average composition of the waste generated in the fleshing operation contains: moisture; fat; and inorganic matter such as lime and sulphides. Sulphide flake, used in the unhairing process, is hazardous as the dust is very caustic and is an irritant. Sulphide solution is also toxic. However, the biggest problem is due to the release of hydrogen sulphide gas to the atmosphere and the oxygen depletion of water caused by sulphide oxidation. Sulphide can be transformed to highly toxic hydrogen sulphide gas.

Fatalities have occurred while opening drums during the deliming process, through cleaning operations/ sludge removal in gullies and pits, and bulk deliveries of acid or chrome liquors being pumped to containers holding solutions of sodium sulphide. There are dangers of low-level exposure over long periods of time. Typical effects are headache, nausea and eye irritation. One of the problems with the gas is that although the odour can be detected at low levels, these are often higher than levels acceptable for extended exposure. There is also a risk of formation of hydrogen sulphide under anaerobic conditions due to the action of sulphur- reducing bacteria.

Thus, the Company has to practice using lime fleshing in the production of methane gas, grease &protein recovery and fertilizer after composting.

7.1.4 Lime Trimmings

Addis Ababa Tannery discharges 12,0812 kgs/yr of lime trimmings as solid waste. After unharing/liming hides are trimmed from the edges to obtain the desired shape and to remove the undesirable corners of the hide. Trimming is done manually using a strong knife.

7.1.5 Wet-blue Shavings

After the chrome tanning process, hides are shaved to required thickness by the shaving machine. Water-soluble trivalent chromium compounds are normally salts of strong mineral acids and are themselves acidic including which may be changed to the carcinogenic chromium (VI) since the shaving materials are discharged to the near by river. Addis Ababa Tannery has to look for some standard practices of utilizing the shavings for leather board manufacturing.

7.2 Recommendations

Addis Ababa Tannery should work hard in order to create a good working environment for the workers and the people surrounding the factory.

Therefore, AAT has to consider the following recommendations as it plays a great role in creating a good working environment for the workers and the society.

1.Training the workers ,

- how to handle and prepare the chemicals
- how to trim , flesh, and shave the hides

In general, AAT has to practice good house keeping.

2. It is advisable to establish hide glue manufacturing plant in AAT.
3. AAT should work with the suppliers of the raw hides on the curing methods.

7.3 Conclusion

Commitment of the top management of AAT is a prerequisite for good environmental performance. Technology by it self is not sufficient, it needs to go together with good house keeping measure. A key to good performance is awareness of the inputs to and outputs of the process with regard to the characteristics of the materials, the quantities, and their potential environmental impact. Criteria that ensure a better environmental performance can then be taken into account as well as technological criteria that focus on the properties of the end product.

Reduction of solid wastes, spills, accidents, water wastage and chemical usage is achieved by the choice of appropriate techniques, good maintenance and operation control by monitoring and adjusting process parameters and good staff training.

Beside these, Addis Ababa Tannery Sh. Co. has to substitute those chemicals, which are known to be harmful to the environment by the less harmful ones. In order to do so, the Company has to maintain an inventory of inputs and outputs, their fate in processes and releases.

Implementing the CP option "proper chemical preparation" can save a total of about 873,690 Birr/yr. Besides this economic benefits, it contributes much in reducing the environmental pollution load caused by the discharge of the waste into the nearby river.

In order to implement the CP options "green fleshing and lime splitting" the Company has to seek for the best and affordable machine. Even though the new machines are a little bit expensive, there are reconditioned machines with less prices in the market. Besides the economic gain, it has big environmental achievements and even the fleshing and splits can be used in producing some useful products. In order to utilize the fleshing and trimmings, splits, it is advisable to establish a small-scale hide glue plant near to the factory. Which is feasible and valuable.

In general, as the suggested CP options are cost saving and reduce possible environmental pollutants at the source, the top management group of AAT, has to consider and implements it as much as possible.

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