Design of a Cleaner Production Framework to Enhance Productivity: Case Study of Leather Company

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Abstract: ***This research study explores environmental pollution problems in the leather processing industry. Chemicals used for hide tanning find their way into the environment resulting in salts being present in the effluent of the tanneries. The study seeks to reduce salts in the effluents by incorporating a chilling unit to the tannery system and many other Cleaner Production options available in the leather manufacturing sector.***

Keywords:tannery, leather industry, cleaner production, pollution

1. Introduction

Environmental compliance efforts principally looks at treatment of pollution once it has been released from a process rather than on prevention or recycling, two approaches that in many cases offer a lower cost means of attaining compliance [1]. Prevention and recycling investments often not only lower energy and material usage but also reduce end-of-pipe treatment costs, resulting in decreased disposal expenditures, possible reduced paperwork, and lower liability and insurance costs. Greater and continued emphasis on prevention and recycling, as endeavored by the Cleaner Production (CP) strategy, can thus lower environmental compliance costs for – process – industries [2]. Cleaner Production stands for a proactive and preventive approach to industrial environmental management and aims for process- and/or product-integrated solutions that are both environmentally and economically efficient ('eco-efficiency'). in additionto introducing these elements and their applications in the leather processing industry, this article presents plant-level assessment results to illustrate the possible benefits of CP in various leather processing sectors.Our environment has limited resources, i.e. the materials we convert into products, energy, water and air supply and the places where we dispose of old products, are limited [4].

2. Justification

The environmental benefits of Cleaner Production can be translated into market opportunities for 'greener' products. Companies that factor environmental considerations into the design stage of a product will be well placed to benefit from the marketing advantages of any future eco-labeling schemes [3]. The economic pressures that affect a company are to produce more so as to remain competitive. The company must produce a stated level of pollution for them to remain in business but due to poor, old processes and technology being used in companies more pollutants are produced being produced. Also due to shortage of raw materials companies opt for cheap available materials that contribute to damage the environment [3]. The company also faces the green pressures of having to use new methods of manufacturing which environmental friendly for the company to remain competitive on the market and also to be a world class manufacturing organization.

3. Leather tannery industry pollution

Leather industry pollutes through generation of huge amount of liquid and solid wastes, also emits obnoxious smell because of degradation of proteinous material of skin and generation of gases such as NH_3, H_2S and CO_2[6].

3.1 Types of pollution in leather industry

Soil pollution- Untreated wastewaters from tanneries have been applied on land merely to contain them at one place. The soils holding it directly and irrigated with contaminated groundwater lose productivity [8].

Atmospheric pollution [9]- Rehydration of salted hides and skins generally emit odor of volatile fatty amino acids evolved in the course of biological decomposition in presence of water. In addition, toxicity or hydrogen sulphide along with acids, fats, carbohydrates in liming, deliming and tanning processes is predominant within tanneries. The venting out of malodorous substances to ambient air and subsequent transports to further distance are responsible for atmospheric pollution. Ammonia escaping from deliming operation to atmosphere is odorous and pungent. Phenolics (monohydric, dihydric and trihydric) are emitted into the air during processing of hides in the post-tanning and finishing operations.

3.2 Waste types in leather industry [11]

Skin collagen

Animal skin is composed of proteins (90-95% of solids, 35% by weight), lipids, carbohydrates, mineral salts and water. Collagen fibers, enclosed in a connective tissue known as sarcolemma, are insoluble in water and in dilute solution of acids and alkalis and in organic solvents at ordinary temperatures [12].

Solid wastes

Out of 1000kg of raw hide, nearly 850kg is generated as solid wastes in leather processing. Only 150kg of the raw material is converted into leather. Tannery generates huge amount of solid waste as follows:

- Fleshing
- Chrome shaving
- Chrome splits and buffing dust
- Skin trimmings
- Hair
- Dusted salt
- Limed sludge

4. Cleaner production [13]

The goal of cleaner production is to avoid pollution by using resources and raw materials to the utmost possible. This means that a higher percentage of the raw materials are turned into valuable products instead of being wasted.

The Cleaner Production practices seek to use a collection of analytic tools to improve the efficiency of production processes and improve profitability. Other names for cleaner production are:

- Waste minimization
- Pollution prevention
- Green productivity.

These are fundamentally the same as cleaner production; with the basic idea to make companies more efficient and less polluting.

4.1 Cleaner Production and resource efficiency

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 enterprise. Resource efficient and Cleaner Production is a 'win-win' strategy. It protects the environment, the consumer and the worker while improving industrial efficiency, profitability, and competitiveness [12].

Resource Efficiency and Cleaner Production is a forward-looking, 'anticipate and prevent' philosophy.

4.2 Cleaner Production and Product recovery

This is mainly driven by the escalating deterioration of the environment, e.g. diminishing raw material resources, overflowing waste sites and increasing levels of pollution, hence need to recycle by looking at the life cycle of the products with view for material recovery [11].

Cleaner production seeks to assess and evaluate the environmental, occupational health and resource consequences of a product through all phases of its life, i.e. extracting and processing raw materials, production, transportation and distribution, use, remanufacturing, recycling and final disposal. Figure 1 depicts the interactions among the activities that take place in a product life cycle.

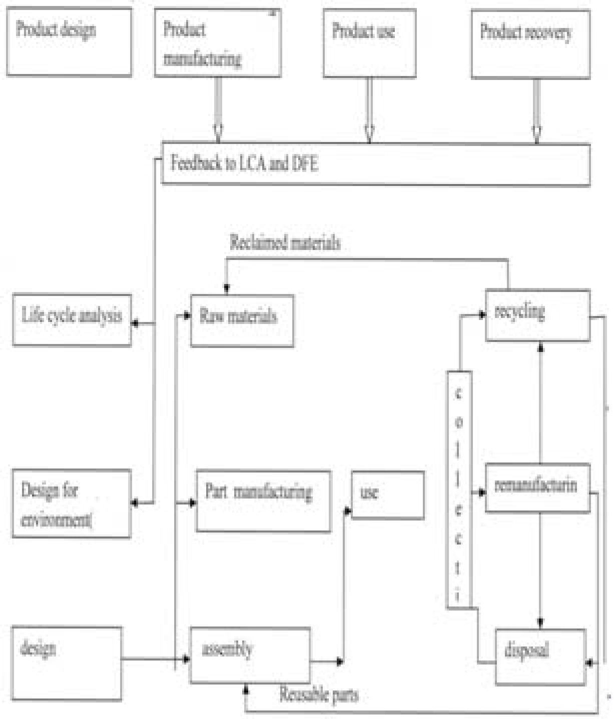


Figure 1: Interactions among the activities in a product life cycle [8]

Through a series of industrial processes in a factory environment, a discarded product is completely disassembled. Usable parts are cleaned, refurbished and put into inventory. Then the product is reassembled from old parts (and where necessary new parts) to produce a unit fully equivalent or sometimes superior in performance and expected lifetime to the original new product."

4.3 Sustainable development

Sustainable development thrust seeks to meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development is an extension of socio-economic development, including the environmental dimension. In order to avoid interpretation biases which could endanger one of the three dimensions of sustainable development – economic, social and environmental- the so-called 3-pillar model has been proposed in Figure 2.

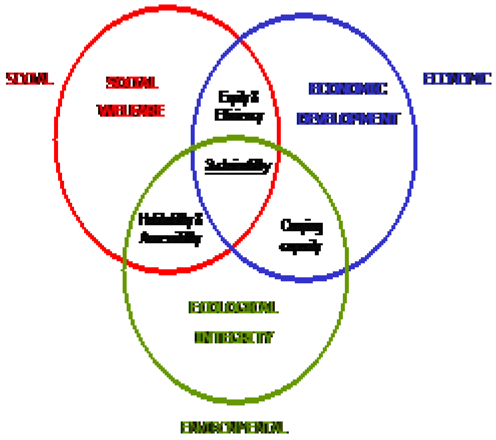


Figure 2: 3-pillar sustainable development model [1]

These goals can only be achieved through an accurate management of the interfaces between the spheres. Cleaner Production contributes to sustainable development, and it can reduce or eliminate the need to trade off environmental protection against economic growth, occupational safety against productivity, and consumer safety against competition in international markets.

4.4 Cleaner production and world class manufacturing

Globalization impacts and its associated demands in competitive environment have created a need for managers in manufacturing sectors to take decisive actions, responsive to the environmental changes, and implement strategies that continually improve quality, capability and process efficiency. The efficiency in continually improving the quality of products and its processes could be seen in term of cost reduction, improvement of customer satisfaction as well as minimize environmental impacts [7].

Cleaner Production should operate in partnership with quality and safety systems and should never be allowed to compromise them. As well, quality, safety and Cleaner Production systems can work synergistically to identify areas for improvement in all three areas. Lean manufacturing system a world class manufacturing system that maximizevalue adding operations, minimize non-value adding operations and eliminate wastes throughout the manufacturing processes is just work together with cleaner production on eliminating waste. It encourages collaboration amongst suppliers to achieve significant shop floor improvements through joint training and practical implementation in a sustainable way [5].

4.5 Cleaner production and technology

Cleaner production is based on continuous application of an integrated, preventive environmental strategy to products and services, as well as the production systems necessary to manufacture and deliver these, with the objectives of improving eco-efficiency and reducing risks to humans and the environment [10]. Therefore the processing and manufacturing industries had the lead in adopting cleaner production, and demonstrated that cleaner production can be achieved in many different ways, including modification of equipment or product, replacement of process technologies and better maintenance practices.

It is important to stress that Cleaner Production is about attitudinal as well as technological change. Technological improvements can occur in a number of ways:

- Changing manufacturing processes and technology;
- Changing the nature of process inputs (ingredients, energy sources, recycled water etc.);
- Changing the final product or developing alternative products;
- On-site reuse of wastes and by-products.

4.6 Cleaner Production assessment procedures

A Cleaner Production assessment identifies inefficient use of resources and poor management of wastes, by focusing on the environmental aspects and thus the impacts of industrial processes. The basic concept centre's around a review of a company and its production processes in order to identify areas where resource consumption, hazardous materials and waste generation can be reduced. The aim of the assessment phase is to collect data and evaluate the environmental performance and production efficiency of the company. Data collected about management activities can be used to monitor and control overall process efficiency, set targets and calculate monthly or yearly indicators. Data collected about operational activities can be used to evaluate the performance of a specific process.

The assessment phase has got four stages these include:

- Derivation of the material balance
- Conducting a cause assessment
- Generation of cleaner production options
- Screening of cleaner production options

4.7 Material Balance

A material balance is based on the principle of 'what comes into a plant or process must equal what comes out'. Ideally inputs should equal outputs, but in practice this is rarely the case, and some judgment is required to determine what level of accuracy is acceptable. A material balance makes it possible to identify and quantify previously unknown losses, wastes or emissions, and provide an indication of their sources and causes. Material balances are easier, more meaningful and more accurate when they are undertaken for individual unit operation.

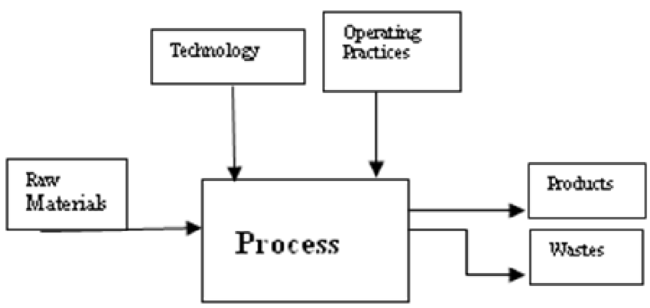


Figure 3: Material balance

4.8 Generation of Cleaner Production options

Cleaner production options are generated by having changes in the facets of the diagram above, Figure 3. One should 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 [12]. It is 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.
- **Cause diagnosis** 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.
- Next logical step **(option generation)** creates a vision on how to eliminate or control each of the causes of waste and emission generation. The option generation consists of several elements, as pictured below. The option generating process then considers each element in turn.

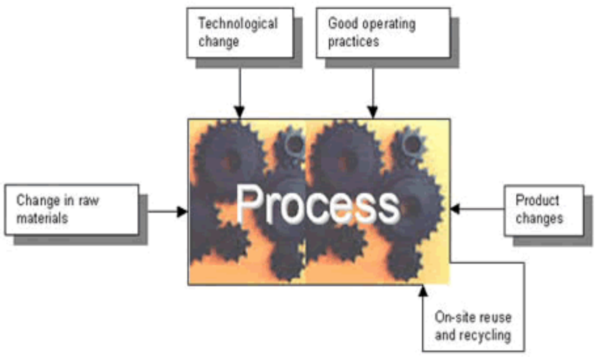


Figure 4: Option generating process [11]

Good housekeeping

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:

1. Management and personnel practices: Includes employee training, incentives and bonuses, and other programmes that encourage employees to conscientiously strive to reduce waste and emissions.
2. Material handling and inventory practices: includes programmes to reduce loss of input materials due to miss-handling, expired shelf life of time-sensitive materials, and proper storage conditions.
3. Loss prevention minimizes wastes and emissions by avoiding leaks from equipment and spills.
4. Waste segregation: these practices reduce the volume of hazardous wastes by preventing the mixing of hazardous and non-hazardous wastes.
5. Cost accounting practices: include programs to allocate waste treatment and disposal costs directly to the department or groups that generates wastes and emissions, rather than charging these costs to general company overhead accounts.
6. Production scheduling: By analyzing 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.

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, preliminary in a production setting. 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.

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:

1. Changes in quality standards
2. Changes in product composition
3. Product durability
4. Product substitution

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

On-site reuse and recycling

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 a 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

4.9 Feasibility of options

Each of the options is evaluated technically and economically for feasibility and whether it contributes to the environmental improvement.

The feasibility studies can be divided to five tasks 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 in 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 option. The options that do not need capital expenditure, e.g. housekeeping measures, can often be implemented quickly.

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.

Environmental evaluation

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.

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.

4.10 Implementation of options [13]

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 prevention measures. The expected result of this phase is threefold:

- *Implementation of the feasible Cleaner Production measures*
- *Monitoring and evaluation of the progress achieved by the implementation of the feasible options*
- *Initiation of ongoing Cleaner Production activities*

The role of enabling policy framework requires interweaving the concept of preventive strategies in all facets of the governmental policy framework to make it uniformly supportive and favorable to Cleaner Production concept.

Regulatory instruments may be appropriate and effective means of achieving a desired environmental outcome, a pertinent example being the control of hazardous materials through specified restrictions or banning.

4.11 Cleaner Production performance success factors

It is believed that Cleaner Production proves to be unrealistic without the support of human resources. There are a number of factors that appear to contribute most significantly to the success of company based programs, for example, getting top management support.

Support

Companies are more likely to succeed when:

- Management support the program for Cleaner Production / waste minimization.

- Top management drive change by communicating the benefits of Cleaner Production to all staff.
- Sufficient time and resources have been allocated to achieve the Cleaner Production objectives.
- The company has a challenging Environmental Policy that encourages source reduction and continuous improvement.

Acceptance

Companies are more likely to succeed when:

- Staff is aware of Cleaner Production.
- Staff understands the economic and environmental importance of reducing waste.
- Staff understands and supports their role in achieving the objectives of the program.

Planning

Companies are more likely to succeed when:

- The Cleaner Production project is formalized and well planned.
- The project has an established framework, with a team leader, team members and clear roles and responsibilities.
- When the budget, timeframe, goals and success criteria are clearly defined and measurable.
- When progress is regularly reviewed and drive is maintained (by top management, the CP team leaders and everyone in the company).

Knowledge

Companies are more likely to succeed when:

- The project is based on good information. This can be gained from Cleaner Production / environmental or efficiency audits for energy, water, trade waste, materials etc.
- The company can set reasonable priorities based on the full value and impact of waste generated by the company.
- The procedures for identifying, evaluating and implementing Cleaner Production options are well known, supported and widely practiced throughout the organization.
- Staff has sufficient training in correct waste minimization procedures and knows what to do with each type of waste (e.g. laminated signs posted around the site).
- Staff knows what to do with waste in the case of an accident / emergency.
- The company has an effective and timely materials accounting system in place - integrating purchasing, handling, inventory, process control and sales systems - to accurately track resource use, waste and produce variance reports (i.e. that compare actual and standard resource use and waste).
- Orientation programs for new employees include Cleaner Production.

Skills

Companies are more likely to succeed when key staff have the necessary skills to:

- Implement appropriate waste measuring and monitoring systems.
- Undertake Cleaner Production assessments / audits.
- Identify resources and product losses (emissions, wastewater and solid waste).
- Identify Cleaner Production improvement opportunities.
- Evaluate options (economic and non-economic analysis).
- Implement viable options.

Improvement and Feedback

Companies are more likely to succeed when:

- Progress is reviewed on a regular basis (e.g. annually) at a corporate level.
- Staff is fully involved in the suggestion and improvement process.
- Performance reviews include Cleaner Production goals.
- Two way communications exists between employees and management.
- Feedback about achievements and improvements is regularly reported (e.g. KPI progress reports and wall charts).
- Feedback is provided for all suggestions (even those that cannot be implemented).
- The cost of resource use (e.g. energy, water), waste generation, treatment and disposal and other overheads is allocated and charged to individual process units in accordance to the contribution of each.
- The goals of Cleaner Production are integrated into the overall business objectives of the organization.

5. Leather industry overview [12]

Leather Company is one of the three major tannery players in the country and more than 60% of their products are exported. Leather production uses raw material in the form of cow and buffalo hides and goat and sheep skins and a number of imported chemicals. The raw material is locally collected. About 130 different types of chemicals are used in leather manufacturing which ranges from common salt (sodium chloride) to very expensive Chrome Sulphate. Leather manufacturing involves following major steps:

- Pre-Process
- Pre-Tanning Process
- Tanning Processes
- Wet Finishing Process
- Dry Machining
- Finishing

In **pre-processing** skins/hides are received and salt is applied on the flesh side of the skins/hides. Skin trimming is done to remove unwanted parts. After pre-processing, **pre-tanning** process starts with the soaking process in which skin are made flaccid by soaking them in water. After soaking hair is removed, lime is used to make hair loose. Unwanted flesh is removed with the help of fleshing machines after liming process. To prepare limed skin for tanning, the skins are delimed using Ammonium Sulphate and then skins are washed. Bating is done for further purification of hide. After that degreasing is done with the help of detergents.**Tanning** process starts with pickling which is the treatment of skin with acids and salts to bring it to desired level of pH. Tanning may be defined as the treatment of skin for preservation. Chrome tanning uses Chromium Sulphate as tanning agent. Tanning process stabilizes the collagen network of skin. After tanning skins are called wet blue and are stored for some time and then they are sorted out according to quality. If hides of cows or buffaloes are being used for leather manufacturing, then after this they are sliced to give desired thickness. This process is not carried out on the skins of goats or sheep. After this the hair side of the wet blue is shaved to give the desired thickness. In order to give desired softness, color, strength, and quality to the leather wet blue skins are processed further through **wet finishing** process. Fat liquoring process is carried out to impart desired softness and dyeing is to give it a color. After wet process different **drying processes** are carried out to dry the processed leather. These processes consist of smaying/setting, vacuum drying, stacking/toggling, buffing/shaving, trimming, pressing, and segregation of the leather. Finally **finishing processes** are carried out to impart durability and beauty to the leather. The chemicals used in the leather industry can be divided into three broad categories:

- Pre-tanning Chemicals
- Tanning Chemicals
- Finishing Chemicals

Pre-tanning chemicals are used to clean and prepare skins for the tanning process and they are mostly washed away with the wastewater. Tanning chemicals react with the collagen fibers of the skin to convert them into leather. These chemicals are retained in the skin but a good amount of these is discharged into wastewater. Chrome Sulphate is the basic tanning chemical. Apart from being expensive, Chrome Sulphate is also a serious pollutant. Finishing chemicals are used to impart certain properties to the leather like softness, color, appearance etc. Like tanning chemicals finishing chemical also get discharged into wastewater. Only those chemicals are fully retained which are applied as surface coating. A large amount of water is used in whole manufacturing process. The collected data shows 50-150 liter water is used for conversion of one kg of raw skin into leather. In tanning process water is used as carrier to facilitate different chemical reactions and after completion of process the water leaves the system as wastewater in the same quantity as added to the system. Ground water is mainly used as processing water.

5.2 Tannery industry pollutants [4]

All the three categories of waste solid, liquid, and gaseous, are emitted by the leather industry in the form of:

1. Wastewater
2. Solid Wastes
3. Air Emissions

The results of environmental auditing are described below:

Wastewater [11]

Water is used as the carrier for chemicals to render the cleaning of raw hides and skins. The water after completion of the process is drained out in the same quantity as it was used in the process. Normally water consumption of 50 liter/kg is recommended for tanneries but it is found that tanneries generally consume more water and in some cases it is found to be as high as 150 liter/kg. Samples of water were taken from different processes of leather manufacturing and were analyzed. Tannery wastewater is highly polluted in terms of biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, total Kjeldhal Nitrogen, conductivity, Sulphate, Sulphide, and Chromium. The quantity of these pollutants in the water is very high as compared to the quantities mentioned in the NEQS (National Environmental Quality Standards) set by the government of Pakistan. Considerable quantity of sludge is also found in the waste water. Wastewater of each tannery process consists of pollution of varying pH values. Similarly a large variation exists in every parameter BOD, COD, Chloride, Sulphate, etc. Discharge of these chemicals into wastewater is hazardous for the environment. Tannery's wastewater is highly contaminated and the contamination observed is many times beyond the limits set by Environmental Quality Standards for all wastewater parameters. A comparison of average quantities of Pollutants from Tanneries with NEQS is shown in Table 1.

Table 1: Pollution levels in tannery effluents

Parameters	*Raw sheep & goat skin-finished leather mg/I	**Raw calf hides-finished leather mg/I	***Wet blue (goat& sheep)-finished leather mg/I	NEQS Mg/I
PH	9.33-9.88	7.35-7.67	3.52-3.55	6-10
BODs (Unfilled) at 60minutes Settling	11050-14827	840-1740	714-1346	80
COD(Unfiltered) at 60minutes Settling	41300-43000	1000-2680	2000-3500	150
Suspended solid at 0 time settling	4270-4650	820-1920	1970-6620	150
Sulphate as SO_4 at 0 time settling	1814-3146	800-860	5480-6480	600
Sulphate as (S) at 0 time settling	288-292	1.2-2.6	Nil	1.0
Chromium (Cr) at 0 time settling	64-133.3	41	160-194	1.0

*Quantity of Raw material:12000kg/day, volume of wastewater: 600m^3/day
**Quantity of raw material:5500kg/day, volume of wastewater: 814m^3/day
***quantity of raw material: 10000kg/day, volume of wastewater:110m^3/day

Solid Wastes [8]

The major solid wastes consist of dusted curing salt, wet trimmings, dry trimmings, wet shaving, buffing, etc. These wastes are generally separated at the source. During handling of raw skins, adhered dusted salt, which is contaminated with blood, hair, dirt and certain type of bacteria is removed and dumped. Trimmings are cuttings of edges of raw skins. Fleshing is the flesh material of the limed skins generated during fleshing operation. Chrome wet shaving is produced when skins are shaved for proper thickness after chrome tanning. Except dusted salt most of the solid wastes are sold in the local market to the poultry feed manufacturers due to the protein content of the solid wastes. The main problem with these wastes is their high Chromium content. The Chrome tanned waste contains Chromium in trivalent form but it was found that when the solid wastes are used in making poultry feed the Chromium is converted to hexavalent form which is carcinogenic. The mixing of this metal in poultry feed could produce serious human health problems. It is estimated that for a tannery producing on an average 10,000 kilograms of skins per day, a total of about 5,500 kilograms of solid waste would be produced per day. Table 2 presents a breakdown on this waste and its key characteristics with comments.

Table 2: Solid waste in tanneries

Type of solid waste	Rate of generation	Characteristics of solid waste	Comments
Dusted Salt	0.1 kg/skin	Contains around 120 gm/kg of moisture, 120 gm/kg of volatile matter, 450 gm/kg of salt.	Contaminated with blood, hair, dirt and bacteria. Partly reused in curing and the rest is indiscriminately dumped in undeveloped lands near the tanneries.
Raw Trimmings	0.024 kg/skin	Proteins	The skins are trimmed (especially at legs, belly, neck, and tail parts) in order to give them a smooth shape. The trimmings are usually sold to soap and poultry feed production
Fleshings	0.25kg/skin	Contains around 240 gm/kg of proteins, 200 gm/kg of fats, 3gm/kg of sulphide.	This is the flesh material of limed skins. It is usually sold to soap and poultry feed makers.
Wet Trimming/ Wet shaving	0.14 kg/skin	Contains around 240 gm/kg of proteins, 30 gm/kg of fats, 15 gm/kg of chromium oxide	After chrome tanning, skins or split hides are shaved to proper thickness. This operation produces solid waste containing chrome. Secondary users including poultry feed makers, usually collect these shaving from the tanners.
Dry Trimmings/ Dry Shaving/Buffing Dust	0.06 kg/skin	Contains around 300 gm/kg of proteins, 130 gm/kg of fats, 30 gm/kg of chromium oxide	Secondary users, including poultry feed makers, collect cuttings and dry trimmings and buffing dust of the leather from the tanneries.
Assorted Refuse	No consistent quantity	Primarily cartons, bags, drums, etc	This is normally sold separately (in bulk) in the retail market.

Air Emissions [4]

In tanneries air emissions are produced from the stacks of boilers and generators and during the processing of leather. Emissions from the stacks are well within the limits and pose no serious environmental impact. But hydrogen Sulphide and ammonia gases which are emitted during different processes are a health hazard for the workers.

5.3 Environmental impacts of leather industry pollution

Out of the three wastes mentioned, air emissions are very low as compared to the standards whereas the solid wastes are used in preparation of poultry feed which pose health problems. The wastewater is a serious threat to the environment [2]. Tanneries are disposing of their wastewater into drains, which finally find its way into natural water bodies. Therefore major environmental problems are linked with the wastewater of tanneries. The pH of directly discharged tannery effluent varies between 3.5 to 13.5. Water with a low pH is corrosive to water-carrying systems and can lead to metal dissolving in the water. The high pH water can cause scaling in the sewers. Also large fluctuation in the pH value is detrimental to some aquatic species. The large quantities of proteins and their degrading products forming a major part of the wastewater can effect Biochemical Oxygen Demand (BOD). The high value of BOD in extreme cases can kill natural life in the effected area. Tanneries discharge water having 10-190 times the recommended value of BOD. Chemical Oxygen Demand (COD) value in wastewater is in a range of 1000-43000 mg/liter which is 25-275 times more than the standard. Sulphide in the wastewater releases hydrogen Sulphide gas which has an objectionable smell even in trace amounts. It is highly toxic for many forms of life. In higher concentrations fish mortality may also occur. The recommended value of 1g/liter for Sulphidewhere as tanneries' wastewater contains 290mg/liter.

Trivalent chromium is released from chrome tanning process. This is much less toxic than Hexavalent Chromium. For plants and animals the toxicity of chromium is variable. Algae have been shown to very sensitive to the chromium levels. At present tanneries are discharging chromium 133mg/liter whereas Standards recommend a value of 1mg/liter. Suspended solids discharged in the wastewater forms a layer on the bottom of watercourse and covers natural fauna on which aquatic life depends. This can lead to localized depletion of oxygen supplies in the bottom waters. Suspended solids also reduce light penetration and thus photosynthesis in the water is reduced. Apart from these Sulphate and natural salt is also found in the wastewater. This can effect fresh water aquatic life if their concentration becomes too high. There is no economic way of removing them. Poultry feed manufacturers collect these materials from tanneries and use it due to the protein content of the solid wastes e.g. fleshing, raw trimming, chrome shaving, buffing dusts etc. These wastes contain chrome in the range of 14-26 gm/kg. Chromium in the waste is in trivalent form which is less toxic than hexvalent form. A recent survey under Tanneries Association showed that poultry feed made using solid wastes contain hexvalent form of chromium also. It seems that during feed preparation the transition of trivalent chromium to hexvalent chromium takes place. This poses a serious threat to human health.

5.4 Pollution mitigating measures

Several remedial measures are suggested to lessen the environmental impact of tanneries. In large and medium sized tanneries environmental management system must be developed [5]. Staff should be trained for occupational health and safety. Gaseous masks must be provided for workers in order to prevent inhalation of fumes. Proper arrangement must be made to stop use of tanneries solid waste to make poultry feed. Improvement in drainage system is needed to avoid the formation of hydrogen Sulphide in the tannery. Many options are available for reuse of chrome, discharged in the tanning effluent. This includes direct recycling of chrome tanning float, recycling of chrome after precipitation, and use of tanning products that improve the exhaustion rate. One feasibility study shows that in conventional chrome tanning process 25-30% chromium goes into wastewater. The recovery cost of this is only 30% of the chromium recovered; hence the entire system has a payback period of less than a year.

6. Research design

The walk through was done in the organization to get the overview of it. The objective of the pre-assessment is to obtain an overview of the company's production and environmental aspects. flow charts were developed at familiarization with the production facilities, waste treatment, and disposal facilities. Production processes are best represented by a flow chart showing inputs, outputs and environmental problem areas.

It involved the collection of data that enabled the evaluation of the environmental performance and waste generated. Water meters recordings of each month were documented and when necessary manual measurements of flow rates were used. Effluent samples were sent to a laboratory. This data resulted into key figures that could then be used as benchmarks against which to track improvement. data on the quantities of resources consumed and wastes and emissions generated was collected.

Information on cost data was obtained from:

- Council rates notices, trade waste statements and waste management contracts.
- Waste handling, treatment, and disposal costs.
- Water and sewage costs, including surcharges.
- Costs for non-hazardous waste disposal.
- Product, energy and raw material costs.
- Operating and maintenance costs.
- Purchasing, invoice and inventory records.
- Wages.
- Treatment cost records.
- Licensing Costs.

7. Cleaner Production at Leather Company

Leather Company has always been associated with quality footwear for ladies, then diversified to include shoes for men and children, and the production of leather for a wide range of customers. It employs in excess of 470 staff. It exports leather and footwear products to Europe, South Africa, the Far East and Australia. It also belongs to the Leather Institute.

Leather Company is a world class manufacturer of leather and footwear. To ensure excellence in production and marketing the company implemented a quality management system guided by ISO 9001:2000 and an environmental management system guided by ISO 14001:2004

7.1 Purchasing procedures

When hides/skins arrive from suppliers are major abattoirs in the country, they are checked and any instance of non-conformance to the following criteria is reported [6]:

1. Quantity – the number and weight must be correct
2. Quality – the condition of the hides must be checked according to the grade, presentation, curing, and presence of flay cuts and odour.

7.2 Chemicals

Chemicals used at Leather Company include:

Sodium sulphide, sodium sulphydrate, tankrom AB (Chromium sulphate), sodium formate, BL 1220 and soda ash. All chemicals are stored in the chemical stores where temperatures are cool and dry, except sulphuric acid (98%) which is stored in a separate tank because of its toxicity and corrosiveness. Material Safety Data Sheets usually accompany the chemicals providing important information for storage and other dangers associated with that particular chemical.

The areas of interest to the tanner are the butt and shoulder. The most important is the butt. This is the part with the highest fibre density (strongest) and is used for making sole leathers. The shoulder, head and cheeks also have high fibre density but undesirable growth marks. The belly has the lowest fibre density (weakest) to permit breathing or expansion of stomach during the life of an animal. Bellies are usually used for shoe upper leather. A desirable hide should be perfect on the butt and bellies for production of high quality leather.

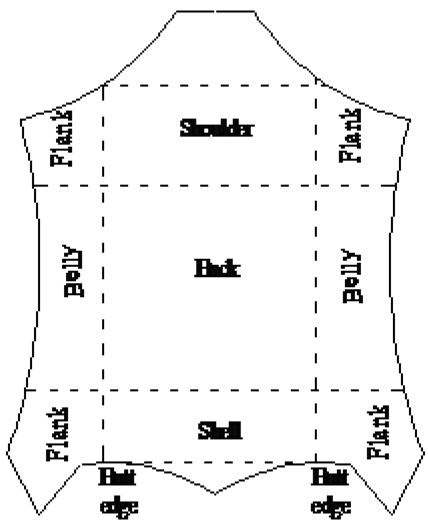


Figure 5: Diagram showing hide sections

- Shell, back and butt edge = bend or butt
- Shoulder, head, cheeks and face = neck
- Belly, flank, fore shank and hind shank = side or flank

7.3 Storage and preservation of hides

Hides and skins are proteineous in nature and if not properly preserved, they'll degrade or putrefy. Most conditions promote the culturing of putrefying agents such as bacteria and fungi, therefore most preservation methods are based on dehydrating the hides. Storeroom has to be water tight, well ventilated, and must cover hides from direct sunlight.

Methods of preserving hides and skins:

Air drying: Drying depends on temperature, relative humidity and movement of air which is particularly important as it swipes moisture away from the surface of the hide, increasing the rate of drying.

Wet salting: The hides are salted whilst wet but are not allowed to dry to a hard mass. Instead dehydration of hide to about 30% of its original moisture content occurs.

Dry salting: The hides are salted whilst fresh and are then allowed to lose almost all of its moisture forming a hard dry mass. This is usually achieved by salting followed by sun drying.

Hides and Skins Drying Sheds: *Worst* drying method as it produces hides which are hard and inflexible and prone to cracking on folding. Lack of air circulation underneath causes trapping of moisture and this encourages bacterial attack or irreparable physical damage.

Brining: Hides are suspended in brine and subsequently sprinkled with dry salt.

Suspension or frame dripping: The hides are dipped on frames and left to air dry.

7.4 Composition of skin or hide

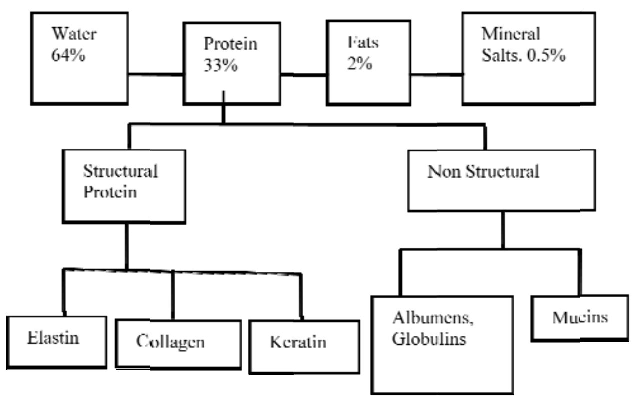


Figure 6: Composition of hide or skin

7.5 Beamhouse department processes

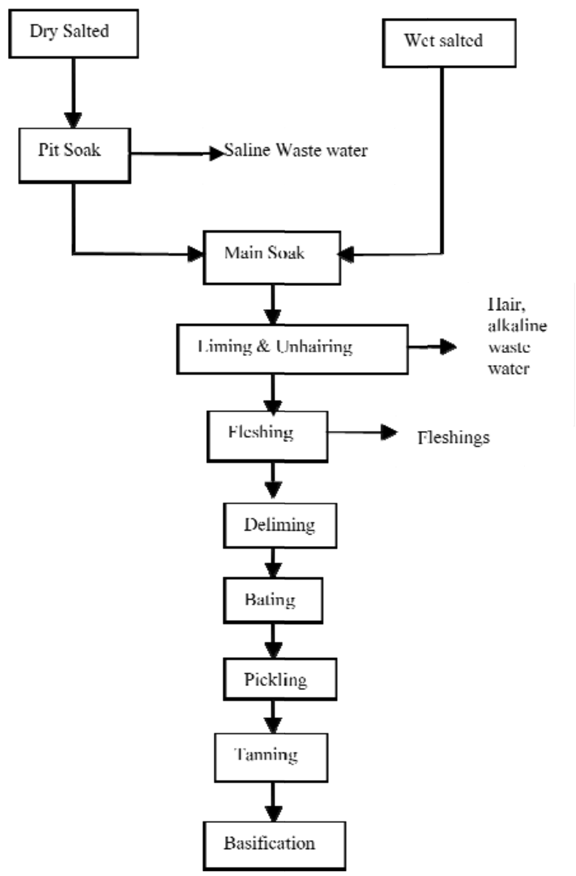


Figure 7: Beamhouse processes flow chart

Beamhouse refers to the processes in the tannery between the removal of the hides from storage and their preparation for tanning. These include soaking, liming fleshing, deliming, bating and tanning. The operations are carried out in wooden drums with a capacity of approximately 15 tonnes. Inside the drums are pegs which aid in mixing of the float and hides. Further mixing of hides and liquors is aided by continuous revolving of drums. The drums are rotated by electrically driven motors.

7.5.1 Soaking

For proper tanning process, the dry salted hides must be washed free of the salt. This is done by soaking the hides in water to which chemical wetting agents (similar to household detergents) and disinfectants are usually added for 8 to 20 hours, depending on the thickness of the hides. This soaking procedure rehydrates the hides to their original flaccid condition and removes the dirt.

7.5.2 Liming and unhairing

The hair is removed from the hides. This is done by soaking the hides in chemicals, or depilatory agents, which destroy the hair by attacking the hair root so it will release freely from the hides, loosen the epidermis, and remove certain soluble skin proteins that lie within the hide substance without destroying the desirable collagen of the hides.

7.5.3 Fleshing

Excess flesh, fat and muscle must now be removed from the hidesusig a fleshing machine

7.5.4 Tanning section

Tanning brings about the irreversible stabilization of the fibre structure of the hide through cross-linking reactions between Cr^{3+} ions and the free carboxyl groups in the collagen. The object of converting pelt into leather by tanning is to;

- Stabilize it against enzymatic degrading and increase its resistance to chemicals
- Raise its shrinking temperature and increase its resistance to hot water.
- Reduce or eliminate its ability to swell
- Enhance strength properties
- Lower its density by isolating the fibres
- Reduce its deformability
- Reduce its shrinkage in volume, area and thickness

This is accomplished by a number of steps which are; deliming, bating, pickling, chrome tanning and basification.

7.5.4 Deliming

Deliming is washing or rinsing of the liming chemicals out of the grain surface as well as on the flesh side. Deliming with water only would be too long, so industrially deliming agents are used. The normal pH range to get a good deliming is at pH 8-9. Control is made with phenolphthalein indicator. Too heavy deliming leads to loose grain. During the process lime in the pelts is solubilised as a soluble calcium salt thus lowering the pH. Calcium has a good solubility in ammonium sulphate; therefore it is used during the process.

7.5.5 Bating

This involves the purification of the hide prior to tanning using enzymes, to obtain proper grain texture and leather softness. The unwanted components are protein degradation products, interfibilliary proteins, and epidermis, hair, scud, elastin, reticulin and erector pilli muscles. The enzymes modify or weaken those fibre structures which by binding the collagen fibres tightly together would cause the grain to have no stretch. At the end of bating process, it is necessary to wash out the chemicals and the degradation products from the bating operation and to lower the temperature to stop enzyme activity.

7.5.6 Pickling

It is the treatment of the hide with acid, increasing the acidity of the hide to a pH of 2.8. The hides must be placed in an acid environment (low pH) so they will be ready to accept the tanning materials, because chrome tanning agents are not soluble under alkaline conditions. This is accomplished by adding salt and acid to the hides. This is a preserving process in itself, and hides can be kept in this state for extended periods of time without any deterioration.

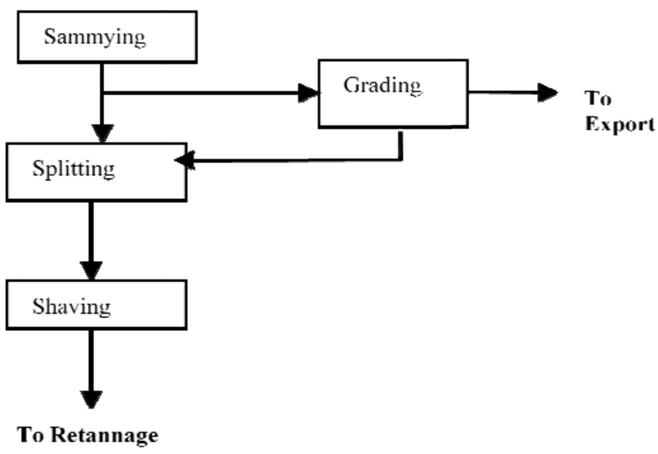
7.5.7 Chrome tanning

The raw collagen fibers of the hides are converted into a stable product which is not susceptible to rotting. This is done by adding chrome tanning agents to the hides in a revolving drum. These tanning agents also significantly improve the hide's dimensional stability, abrasion resistance, resistance to chemicals and to heat, the ability to flex innumerable times without breaking, and the ability to endure repeated cycles of wetting and drying.

7.6 Wet blue department processes

This is the second stage of processing after beamhouse operations. Wet blue hides from the tanning drums undergo a series of mechanical processes as shown below.

Figure 8: Process flow chart for wet blue department



7.6.1 Sammying

Wet blues from the beamhouse department are sammed or removed of excess tan liquor by use of a machine. The excess liquor is squeezed out of the hides by passing through large rollers under pressure. As the hides emerge from the other side of the sammying machine, defects become more visible and are graded.

7.6.2 Splitting

The hides must now be split into the desired thickness. Unsplit hides average to be 5mm thick. The thickness for upholstery leathers range from .9mm to 2.0mm. The hides are put through a splitting machine that is set to split the hides to the desired thickness. It cuts the top grain off first. Another layer, and sometimes two, is cut. These layers are called splits. Leather from small animals like goats, sheep and impalas are not splitted. The machine used is called a splitting machine.

7.6.3 Shaving

Shaving smoothens the leather to a pleasant feel as well as giving a final adjustment to the thickness initially set by the splitting machine. The thickness of the hides must be made uniform all over the hide. This is done with a shaving machine through which the hides are run. The helical shaped cutting blades level the overall thickness to exact specifications and open the fiber structure to better receive subsequent chemical processing.

7.7 Retannage department processes

This process is done to impart special end-use properties with other tanning chemicals. The substances used add solidity and body to chrome leather and help minimize variations in the character of the leather that may still exist between different parts of the hide.

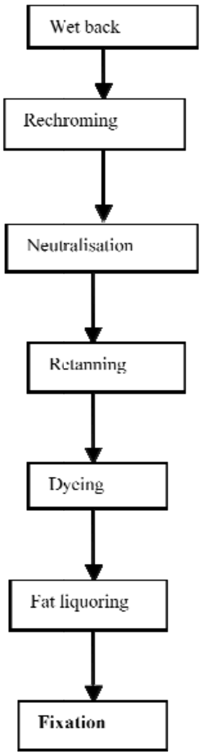


Figure 9: Process flow chart for retannage department

Purpose of retanning is to get desirable properties of more than one tanning agent are combined to obtain:

- Filling properties for the loose fibres around the veins
- Elastic grain
- Smoothness and fine grain
- Water proofness

7.8 Finishing department processes

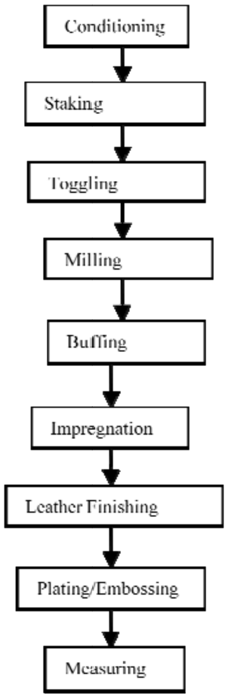


Figure 10: Process flow chart for the finishing department

7.8.1 Conditioning

This is the introduction of a little moisture into dry leather to prevent mechanical damage of the fibres. Purpose being to lubricate the fibre structure and thus prevent it from breaking down or cracking when vigorous mechanical action such as staking or milling is applied.

7.8.2 Staking

Stacking is a vigorous softening process whereby leather is stretched and pummelled by the machine. Purpose:

- To separate the leather fibres which would have become stuck and shrunken after the drying process
- To knead the leather, thus softening it to the desired temper and flexibility
- The mechanical pounding stretches and flexes the leather fibres reducing rigidity and increasing pliability

7.8.3 Toggling

The hides are stretched across a perforated frame and held in place with clips called toggles. One hide is clipped to each side of the frame. The frames are then slid into channels in drying ovens. The purpose of toggling is to stretch the leather and increase the yield by up to 10%.

7.8.4 Trimming

The ragged edges and frayed edges which are of no commercial value are trimmed off the pieces of the leather.

7.8.5 Dry milling

The hides are placed in a large dry drum and tumbled until the desired softness is obtained. The rotational motion of the drum and the beating action of the vanes against the leather serves to break the fibre allowing for moisture/chemicals to be easily absorbed and softness to be achieved.

7.8.6 Buffing

This process improves the final appearance of the hides by lightly sanding the surface to remove some of the natural imperfections such as scratches, healed scars, etc. It provides the hide with better cutting yield. Better efficiency is achieved at each stage by first buffing leather using coarse sandpaper.

7.8.7 Impregnation

Is the controlled penetration and deposition of low molecular weight resin material in sufficient quantities and to the desired depth? Purpose:

- To improve the break of the leather by filling the spaces between the fibre bundles with a resin
- To tighten the grain and impart a settled appearance and smoothness to the surface
- To compensate for the differences in the structure of the hide from back to belly area.
- To straighten the corium junction
- Increase scuff resistance

After impregnation, the leather pieces or sides are vacuum dried at 70-80^{o}C for 30s to obtain a flat grain and remove moisture.

7.8.8 Leather finishing

This involves applying various coats of finish to the leather surface to protect the grain surface and give the desired properties needed by the finish. Purpose:

- To hide defects on the leather
- To give a uniformly or levelness of colour to the crust leather
- To make the leather more durable and long lasting

7.8.9 Plating

This is the final step in the leather process. During this process, heat presses a chosen grain into the surface of the hides.

7. Cleaner Production assessment at Leather Company

In-depth evaluation of the selected assessment focus generated alternate Cleaner Production options. This requires a quantification of the volume and composition of the various waste streams and emissions as well as a detailed understanding of the causes of these waste streams and emissions.The assessment phase involved the collection of data that enabled to evaluate the environmental performance, production efficiency and wastes generated by the company. Information was collected at the company level to allow overall performance to be measured, for targets to be set and for progress to be monitored.

8.1 Raw material consumption (January-April, 2012)

The raw material consumption of the company for four months is given in the table below. The cost per unit price is also represented and these figures were used for the evaluation of the material balance for the leather processes.

Table 3: Raw material consumption

Raw material	Jan/kg	Feb/kg	Mar/kg	Apr/kg	Cost/kg/US$
Hides	91996	118332	149287	223302	0.50
BL 1220/simsansta	140	186	232	562	2.26
Soda Ash	5	35	11	211	0.49
Lime	2954	5974	5001	6850	0.47
Feliderm LP/TRUP NF/simlime	1300	1747	1475	792	3.22
Feliderm SE/TRUPWET	92	163	169	223	2.71
Sod sulphide flakes	930	1974	1550	2433	1.07
Sod sulphydrate	552	865	930	1179	0.90
Ammonium sulphate	1990	2685	3439	4520	0.66
Sod meta bisulphate	315	433	543	711	0.94
Salt	3665	5055	6336	8963	0.19
Eskatan GLS/pellah hg	381	699	439	789	3.17
Busan 30lw/leathergard 30EC	262	361	468	591	10.67
Feliderm MGO/simbase 96	431	582	743	946	2.36
Chromosal B	5654	7797	9725	12755	1.66
Sod formate	628	866	1086	1417	1.03
Feliderm bate PB/ simzyme	64	545	724	951	1.45
Sulphuric acid	1466	2021	2187	3315	0.30
Superior D/VSD/simsperse	721	796	1590	1857	2.35
Caustic soda	-	135	29	56	1.20
Simlime NF	-	-	180	312	3.22
Simsoak UD	460	477	721	982	3.05
Simcal 80	524	631	905	1059	2.11
Simtoil SS100	-	-	142	-	Sample

8.2 Toxicity of raw materials

Table 4 below shows which chemicals are most poisonous and less harmful. Their grouping was according to the information obtained from the Material Safety Data Sheet that are drawn up in accordance to ISO11014-1:1994. Less harmful products are classified under that category because they only pose potential health effects after prolonged or repeated contact. And according to Material Safety Data Sheets those put under more toxic are hazardous to humans and the aquatic environment when inhaled or when reacting with acids releasing toxic gases.

Table 4: Toxicity of chemicals

More Toxic	Toxic	Less Harmful
Sodium sulphide	Sodium formate	Simsoak UD
Sulphuric acid	Ammonium sulphate	Simcal 80
Lime	Chromosal B	Simlime NF
Sodium hydrosulphide	Leathergard 30EC	Superior D
Caustic soda		Salt
		Bf300
		Eskatan

8.3 Pollutants from the tannery

Table 5: Sources of pollution

Source	Type of polluting material
Soaking	• Dirt from the hides • Salt from curing, soluble proteins, blood, manure. The effluent is very dark brown and very dirt but has little objectionable odour
Unhairing	• Has most suspended solids constituting 50% of the total BOD • Water discharge is very high due to the washing involved • Unused sulphide from the unhairing float that causes the obnoxious odour
Bating and pickling	• Ammonium salts from the deliming process • Soluble proteins, suspended solids, dissolved and undissolved lime • Oil and grease • Pickle liquors contains salt of about 50000mg/l and contributes strong acids
Tanning	• Trivalent unused chrome from tanning, 5g chrome/kg of hides • Hexavalent chromium in case the trivalent gets oxidised. In either case chromium is usually removed through precipitation at higher pH
Colouring and fat liquoring	• Dyes • Vegetable tanning material, syntans and other specialty chemicals • Fat liquoring oils and natural oils from hides and skins
Finishing	• Suspended resins and pigments • Solvents accumulated in the wash down system • To some extent volatile organic compounds from spraying machine

8.4 Beamhouse section

Figure 12 below shows the inputs and outputs for the beamhouse section or the material balance of the soaking and liming process, that is were the removal of the hides from storage and their preparation for tanning is done.

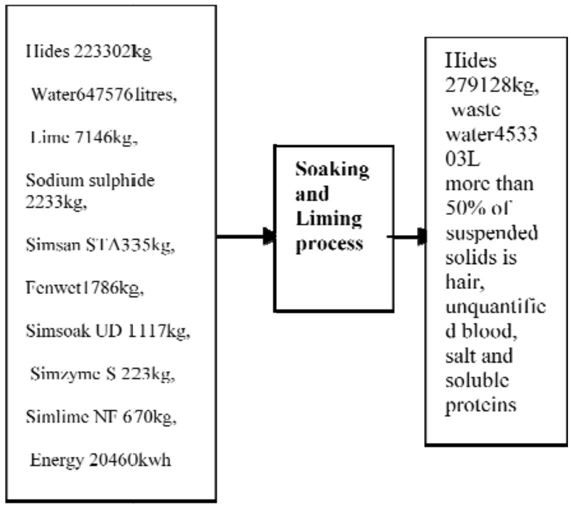


Figure 11: Beamhouse input/output chart

The material balance shows that a lot of waste water is resulting and hair from hides constitutes more than 50% of the suspended solids. A lot of water is being used at this section and there is no measurement of the discharged water to the effluent. Unused sulphide from the unhairing float that causes the obnoxious odour needs improving.

8.5 Bating, pickling and tanning process material balance

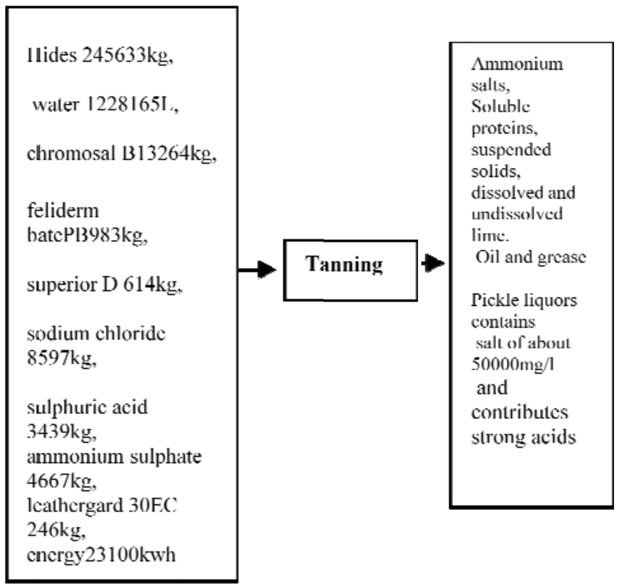


Figure 18: Tanning input/output diagram

After soaking and liming the hides under a process of fleshing whereby flesh is removed from the hides and about12% of the weight of the hides is lost. When proceeding to tanning the material will have lost 125 of its weight it will also gain around 10% after tanning and the rest will be lost as waste water.

8.6 Constituents of wastewater

The wastewater of leather industry which is one of the most widespread industries having large amount of water consumption and very high pollution loads, may be characterized by several key parameters including toxic pollutants exhibiting toxicity. Therefore the effluent of leather tanning industry must be handled carefully during both treatment plant design and operation. Composition of waste from the soaking and liming process and also of the tanning process is on the tables below. These were taken from the samples tested from the company.

Table 6: Wastewater from the effluent of the company

Sample	Temperature $<45^0C$	pH (6.5-9)	Chloride <500mg/l	Sulphates <1000	Settleable solids <10cc/l	Cr^{3+}	COD <3000
A	23	7,7	235	290	4	-	2110
B	22	7,9	240	375	4.2	-	2180

The wastewater samples were overloaded with organic and inorganic compounds, and measured concentrations of the chemical parameters as well as dilution factors estimating acute toxicity, although not exceeded the permissible limits for the discharge of wastewater from a tannery into the receiving stream they are high and need to be reduced.

Although the results of the chromium 111 compounds were not determined the particles are also found in the effluent samples. Chromium is highly toxic and carcinogenic to human beings, animals, plants and the general environment (soil and water sediment). It is found out that chrome is the primary threat when ever tanning industry comes in to practice. Treatment options are either; inefficient, complicated, energy demanding, costly or applicable to a certain parts of the world due to technology or skilled man power demand. Therefore, to tackle this serious challenge stringent environmental regulation with law enforcement has to be exercised to use better treatment system which is widely applicable.

Leather processing requires extensive use of chemicals to treat and soften hides. These chemicals are present in the firm’s wastewater and can contaminate community water sources. When chemicals are improperly or inefficiently used in production, costs rise and pollution increases. More efficient chemical use can both lower production costs and reduce pollution. Leather processing uses large amount of toxic and environmentally dangerous chemicals. CP techniques can prevent these chemicals from becoming a threat to public health and save money for the company.

8.7 Cleaner Production options

8.7.1Chemicals (Reducing salts

From the test done of the samples of the effluent above many chemicals where found and these includes sulphates, chromium and chlorides. When chemicals are improperly or inefficiently used in production, costs rise and pollution increases. More efficient chemical use can both lower production costs and reduce pollution. Leather processing uses large amount of toxic and environmentally dangerous chemicals. CP techniques can prevent these chemicals from becoming a threat to public health and save money for the company. In tanning chrome is always found in large quantities in the waste waters and it is very harmful to the environment and humans.

Some of the waste found in the effluents is suspended solids and hair from the hides. We can reduce the amount of solids if we use filters to screen out solid wastes and then set aside the solution to use it again. That is chrome and lime effluent can be reused in future production stages without loss of effectiveness.

8.7.2 Water use (reuse/ recycle)

Leather processing requires water in almost every stage of production, but certain production methods or machinery can lead to overuse. All the water of the company comes from the municipal of Harare. Water is mainly used in the beamhouse section that’s where the leather processing takes place. Borehole water can also be used to reduce costs of paying the city council.

Table 7: Water checklist

Water Use	Jan	Feb	Mar	Apr	Cost/m^3	Value
Water used	4999	6710	7157	8465	0.6	16398.60
Trade waste	-	-	-	-	-	-

Also, untreated wastewater (effluent) from processing operations contains organic wastes which can both pollute local water sources and degrade water quality for downstream communities. Using water more efficiently guarantees less costly production and ensures against water shortages that could interrupt production. If the enterprise pays by volume for the water it uses, reducing water usage can be expected to provide substantial savings.

Table 8: Energy checklist

Fuel Used	Jan	Feb	Mar	Apr	Cost/kwh/ton	Value /US
Electricity/USD	8000	8966,30	9595.70	9285.43		35847.43
Coal/ton	11	25	26	21	1008.24	83683.92

8.7.3 Worker Health Hazards (management and training)

Certain working conditions in leather processing such as exposure to chemicals in the air or in solution bath scan be hazardous to workers. Symptoms can include skin irritations, dizziness and breathing problems. Unhealthy workers may be less productive, miss work too often and make potentially costly mistakes. Chemicals such as sulphuric acid are harmful when inhaled and most workers in the tannery department did not mind working without face masks.

8.7.4 Odour(housekeeping)

Tannery effluent often contains highly odorous waste. Strong smells can damage the quality of life around the tannery site and may reduce or destroy community support for further production or expansion. Controlling odor through improved waste treatment techniques, or even recycling, can improve community relations and may reduce costs.

8.7.5 Reduce excess waste

From the company data it produces 12 tonnes per day of waste and that is excess waste that should be reduced. This may be contributed by inefficient or poor production methods to produce excessive waste and costly product loss. Tanneries with low-quality production processes may have to discard or rework an unnecessarily high proportion of their products. Improving production through maintenance and training can save costly reworking, reduce product loss, and thereby save money while reducing environmental impacts.

8.8 Evaluating CP options

Table 9: Evaluating CP Options using weighted sum method

Evaluation criteria	Weight	Chiller unit		housekeeping		Reuse/recycle		Rinsing Techniques		Management & Training	
		Score	Sum	Score	sum	Score	sum	Score	sum	Score	sum
Reduction in hazardous waste treatment	3	3	9	0	0	3	9	1	3	2	6
Reduce expenses for waste water treatment	2	3	6	1	2	2	4	1	2	2	4
Reduce exposure to chemicals at work place	1			1	1	0	0	0	0	1	1
Reduce amount of water consumption	3	1	3	1	3	3	9	3	9	1	3
Reduce odor problems	3	3	9	2	6	0	0	0	0	0	0
Reduce noise problems	1	0	0	0	0	0	0	0	0	0	0
Reduce amount of solid waste	3	3	9	1	3	2	6	0	0	2	6
Weighted sum			**36**		**15**		**28**		**14**		**20**

Key: 0=no change, 3= highest rank(preferred)

From the above evaluation substitution of salts with a chiller, followed by reuse/recycle and the management and training have the highest scores of the CP options focused upon.

Cleaner Production involves the conservation of raw materials and energy, the elimination of toxic raw materials, and the reduction in the quantities and toxicity of wastes and emissions.Environmental problems can be avoided by replacing hazardous materials with more environmentally benign materials. These options may require changes to process equipment. Leather Company always had to use clean water to maintain its operations instead of using recycling or reusing its waste water. Also due to the presence of sulphates in the waste water and other compounds it means the maintenance of the effluent plant was expensive. The COD of the company need to be reduced to reduce expenses of maintaining the effluent plant.

9. Recommendations

9.1Chiller unit (reducing sulphates and chlorides)

To deal with the problem of sulphates and chlorides found in the effluent waste the company had to install a chiller unit to reduce the amount of salt used in the tannery. Salt reduction: 40-50% salt on hide weight. For 1 tonne hide, it is possible that 500 kg less salt is used and discharged and disposed of as solid waste. For skins the salt savings are up to 80% salt on skin weight.

The company will also reduce the amount of water used in the pre-tanning for soaking and rinsing hides and skins. 1tonne of salted hides and skin need 2500 liters of water for soaking but with use of chilled hides that water will now be reduced by 30-45%. That is saving around 750-1125liters of water by the company. The cost per m^3 is 60cents and the company will save around 450-675USD per process. The salt use will be reduced by 80%. For the past 4months they used 24019kgs of salt at 19cents per kg. The company would have saved around $3651USD.

9.1.1 Costing of the project

Table 10: Costing of the chiller unit

Item description	Total cost in Indian Rupees	Total cost USD
Blast chiller plus chilled storage (5 tonnes hide)	1345000	30076.02
Tannery chilled storage (10 tonnes hide)	600000	13416.81
Total	**1945000**	**43492,83**

If the company runs the pre-tanning process for 15 days per month:

Water saved per month: {(750+1125)/2}15=14062.5litres

Money saved per year: 14062.5x0.6x12/1000= USD 101.25

Average salt money saved per year: 913x12= USD10956

Total project cost= USD 43492, 83

Savings from salt 10956+3000=USD13956

Payback period of the project= 38months

9.1.2 The economic benefits of implemented options

Chilling of hides and skins can replace salting and will greatly reduce TDS in tannery effluents and the problem of disposing of evaporated salt. Hides and skins are not salted before tanning but are chilled to preserve them for up to a week during transportation and storage. This eliminates the cost of salting and the environmental problems associated with the salt. There must be no deterioration in the raw material. If hides and skins are available in large numbers in a region within a relatively short drive from a tanning centre, chilling should be feasible. Once chilling of hides is established at Leather Company, refrigerated transport would enable transport over long distances. As soon as the skin is removed from the animal it is susceptible to bacterial degradation, and the rate of degradation increases with temperature. Therefore hides and skins must be brought to a chiller within a few hours of slaughter.

The main advantages of chilling are:

- No pollution. Salt reduction: 40-50% salt on hide weight. For 1 tonne hide, it is possible that 500 kg less salt is used and discharged and disposed of as solid waste. For skins the salt savings are up to 80% salt on skin weight.
- Suitable for all hides and skins
- No contamination of by-products with salt
- Hides and skins can be quickly chilled in a blast chiller
- Hides and skins are good insulators and after chilling only warm up slowly

The advantage of the developments is that salt use and effluent salinity can be reduced and the problem of recovered salt can be greatly reduced. Cleaner processes are better than end-of-pipe treatments.

9.2 Recycle

Recycling typically means a second utilization for the same purpose, reuse may mean utilization for different purposes and recovery incorporates an isolation step. Recovered material can then be recycled or reused. Simple recycling technologies need some control to prevent any deviation in the tannery process. A laboratory with basic analytical equipment is desirable.

9.2.1 Beamhouse Process

To reduce the volume of saline effluents, particularly if this segregated float needs to be evaporated or specifically processed, it is possible to reuse soaking floats in a counter current method, analogous to vegetable tanning. Here, the pelts progress into cleaner float and the contaminated floats move towards the dirt soak. Only the dirt soak liquor, in which dirt and salt are accumulated, are discharged to waste and treatment. This decreases the amount of water to be evaporated, when salinity is restricted, and reduces the presence of biocides in effluent. However, it does not solve the problem of what to do with the dirt soak solution. Lagooning where feasible, reduces the volume, but the salt remains. The unhairing-liming float can also be reused for the next process. It must be taken into account that the recovery rate of the liming float should not exceed 75 % in order to limit the nitrogen concentration. Besides recycling materials (pumps, fine screening, storage tanks), it is sometimes necessary to warm the float before reuse and also toscreen or skim it in order to eliminate undesirable floating solids and to remove hair and grease from the surface. Without any sedimentation, an industrial recycling process can save 35 to 40% of sodium sulfide and 40 to 45% of the lime (with classical process quantities of 2.5 %). Excessive quantities of lime should be avoided during the process; it is worth recalling in this regard that the theoretical requirement for bovine hide is about 1.2%.

9.2.2Degreasing float

When sheepskins are solvent degreased, recycling of the residual solvent after distillation is currently operated. Furthermore, the extraction brine is also easy to reuse, to save sodium chloride.

9.2.3 Pickling float

Recycling of pickling float has been proven to be highly satisfactory in terms of salt savings and partly for acid savings. There is no great difficulty if density and acidity of the float can be regularly controlled.

9.2.4Tanning float

The most common practice is to collect the residual tanning float, to filter it, to adjust its acidity, then to reuse it as a new tanning float before adding fresh chromium salt. The recovered volume may be more than required for subsequent tanning operations, but it is possible to reuse the liquor in post tanning. Another possibility is to use the tanning float for a pre-tanning process. In this case, 60% of the residual chromium can be recovered. When pickling and tanning are carried out in the same float, it is also possible to collect the residual tanning float, to filter and acidify it and reuse it as a pickling float.

9.2.5 Post-tanning process

It is much less feasible to recycle post-tanning floats, since the chemical condition required for the steps may be different and steps tend to be conducted sequentially in the same float. Therefore the problem of contamination is compounded, especially since these steps vary greatly, even in a single factory. Thus, recycling technology cannot be recommended.

9.3 Water management

Leather production is a water intensive industry, therefore measurement and control of consumption are important and essential points of water management In many countries water has become a scarce commodity and the costs for the consumption and discharge of water increase regularly. Water has to be managed properly and several options are available to minimize the overall consumption of water.

Reduction: The first step is reduction of water consumption, with strict measurement and control of consumption. Low float processing, batch-type washing instead of rinsing and combining processes (compact recipes) are practical examples of technologies to reduce water consumption by

30% or more. However, lower volume of water will result in higher pollutants concentration, but that will be partially offset by the greater efficiency of shorter float process steps. Limits to reducing float length must be borne in mind, since not all processes benefit from reduced float length.

Recycling: Certain specific processes are suitable for recycling of floats, although in most cases installations for treatment are necessary. Examples are; soaking, liming, unhairing, pickling and chrome tanning liquors, which can reduce the overall water consumption by 20-40%.

Re-use: Biologically treated effluent offers the opportunity of replacing a certain amount of the process floats, such as the beam house process floats, with treated water. Depending on the type

9.4 Reduction in Chemical Use

Processes should be optimised with regard to chemical use to minimise waste. Reduced floats allow reduction in chemical use (liming, deliming and pickling). However, due regard should be placed on the chemical and biochemical principles of processing, in order to avoid the unnecessary excessive chemical use, for example, lime, sulphide, salt, chrome, dyes, lubricants, etc.

9.5 Treatment technologies

9.5.1Reduction of BOD

Physico-chemical treatment requires initial balancing (homogenisation) of collected liquors followed by controlled addition of flocculants and sedimentation (or flotation) to remove sludge, which is, in most cases, then dewatered. Biological oxidation can provide a more effective treatment system for tannery effluent, although considerable land space is required. The oxidation ditch reduces BOD levels in tannery effluent from 500-1 OOO mg/l down to levels as low as 1-2 mg/l residual BOD, with almost complete elimination of suspended solids and of ammonia, some of which is derived from the use of ammonium salts used for lowering the pH to prepare the skins for enzyme treatment (bating). The fatty fleshings that have to be removed from hides can be used as a source of tallow, although profitable disposal of chrome shavings producedafter chrome tanning is difficult and often treatment of tannery effluenthas to be disposed to landfill. Excess chromium (111) in the effluent is strictly controlled.

9.5.2 Soaking

The consumption of fresh water can be minimised by using a countercurrent system of washing, to concentrate the salt (if present) and the other soluble materials, such as dirt and blood. Utilisation of all antiseptics used for preservation should be under regular review. Additional cleaner technology that can be applied at this stage is the fleshing of green hides after soaking. It yields a lower quantity of fleshings, with a neutral pH. Green fleshings are more valuable than limed fleshings with regard to tallow recovery, because the green fleshings are not subjected to the hydrolysing liming process. In this way, the amount of recovered tallow is greater and the content of undesirable free fatty acid is much lower, so the quality is better.

An associated problem with this approach is the presence of dung on hides, which causes the fleshing blade to cut into hide, thereby damaging the pelt in an economically unacceptable way. Removal of dried-on dung by methods other than soaking is difficult. However, dung removal is a pre-requisite to processing. The problems associated with dung contamination may be pre-empted by utilisation of hides and skins, where available, from animals that have been reared through a quality assurance or clean hide scheme. These schemes generally require animal husbandry practices that minimise dung contamination.

9.5.3 Classical unhairing-liming process

The enzymatic treatment of hides and skins can be considered as a cleaner technology only if the amount of sodium sulphide is reduced substantially. However it is not yet possible to replace totally sodium sulphide in processing skins and hides. There are other agents available that reduce the amount of sulphide in liming, e.g. organic sulphur compounds (mercaptoethanol, salts of thioglycolic acid, formamidinesulphinic acid) and amines based proprietary products. However, it should be borne in mind that all hair dissolving processes will contribute to the COD/BOD of tannery effluents.

9.5.4 Hair saving unhairing-liming methods

For traditional skin production, painting and sweating may be considered cleaner technologies. Recovery of hair before dissolution, either when it is separated during the liming, or at the end of hair saving process, can lead to a COD reduction of 15-20% for the mixed tannery effluent, and a total nitrogen decrease of 25-30%. It is an advantage to filter off the loosened hair as soon as possible and higher COD and nitrogen reduction can be obtained. This process can be considered as a cleaner technology if the hair is utilized, even as nitrogen source.

There are several established methods of hair saving, routinely used in industry. However, it is recognized that they do not provide a complete effect, since each incorporates a hair dissolving step, to deal with residual short hairs.

9.5.5 Splitting limed hides

Faced with the difficulties of upgrading the chromium-tanned split waste, splitting in the lime can be considered as a cleaner technology, as it saves chromium and yields a by-product that can be used for casings or for the production of gelatine.

9.5.6 Carbon-dioxide deliming

Up to 40% of a tannery`s production of ammoniacal nitrogen comes from the use of ammonium salts during the deliming process. Carbon dioxide deliming can be considered as a cleaner technology giving good results on light bovine pelts (thickness less than 3mm). for thicker hides. It is necessary to increase float temperature (up to 35^{0}C) and/or process duration and/or to add small amounts of deliming auxiliaries. In order to effectively eliminate the creation of hydrogen sulphide as the pH of the deliming solution falls, 0.1%

hydrogen peroxide can be used to scavenge residual sulphide. The grain enamel should be allowed to delime for perhaps 5minutes, to guard against oxidation damage, then the peroxide can be added safely.

If the pH falls below, in the case of black or red hides they may appear dirty due to the retention of melanin in the depleted grain layer. If the pH of CO_2deliming float is lower compared to common procedure, special bates can be used. Also with a lower content of ammonium are available.

9.5.7 Other Ammonium-Free Deliming

Ammonium-free deliming agents, such as weak acids or esters, can totally or partially replace ammonium salts used for conventional deliming. However, in comparison with CO_2deliming the resulting COD is often higher due to the contribution from the reagent. Cost and slowness of reaction make them less viable.

9.5.8 Good Operating Practices And Staff Training

Improvements to work practices and proper maintenance can produce significant benefits. These options are typically low cost. It is important to stress that Cleaner Production is about attitudinal as well as technological change. In many cases, the most significant Cleaner Production benefits can be gained through lateral thinking, without adopting technological solutions. A change in attitude on the part of company directors, managers and employees is crucial to gaining the most from Cleaner Production. Applying know-how means improving efficiency, adopting better management techniques, improving housekeeping practices, and refining company policies and procedures. Typically, the application of technical know-how results in the optimisation of existing processes.

There are many opportunities within the leather industry for the promoting of cleaner production technology. When Cleaner Production and pollution control options are carefully evaluated and compared, the Cleaner Production options are often more cost effective overall. The initial investment for Cleaner Production options and for installing pollution control technologies may be similar, but the ongoing costs of pollution control will generally be greater than for Cleaner Production. Furthermore, the Cleaner Production option will generate savings through reduced costs for raw materials, energy, waste treatment and regulatory compliance.

10. Conclusion

Installation of a chiller unit at Leather Company is the project that needed attention for the company to reduce its wastes and save its salts to enhance productivity. Cleaner Production can contribute to sustainable development. Cleaner Production can reduce or eliminate the need to trade off environmental protection against economic growth, occupational safety against productivity, and consumer safety against competition in international markets. Setting goals across a range of sustainability issues leads to ‘win–win’ situations that benefit everyone. Cleaner Production is such a ‘win–win’ strategy: it protects the environment, the consumer and the worker while also improving industrial efficiency, profitability and competitiveness.Leather Company and other leather companies will be able to compete as world class manufacturers.However, special attention should be paid to the need for training staff. The project could be a failure if not backed

11. Further research

Besides the use of chiller unit as an option of reducing waste in the tanneries, further study is required in leather manufacturing companies for sustainable development. Further research should look at solid waste at Leather Company. Solid waste is a big problem for tanneries anywhere in the world.

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