ADVANCED CLEAN TECHNOLOGY (JLS 603)

Introduction

Due to industrialization, quantity of solid and liquid wastes are generated from industrial operations is increasing day by day, causing pollution of environment. Leather processing industries is not exception to this. Tanneries also generates considerable amount of wastes out of which some portion of chromium containing hazardous wastes are also generated.

Zero waste is now a strongly emerging issue for sustainable industrial development where minimisation and utilisation of waste are a priority in the leather industry. In a tannery hides and skins converted in to leather through various processes. Approximately 20% (w/w) of the chrome containing tannery solid waste (TSW) is generated from one tonne of raw hides and skins. However, tannery solid waste may also be a resource if it is managed expertly as we move towards zero waste.

Tanning; Tanning is the process that converts the protein of the raw hide or skin into a stable material which will not putrefy and is suitable for a wide variety of end applications. The principal difference between raw hides and tanned hides is that raw hides dry out to form a hard inflexible material that can putrefy when wetted (*wetted back*), while tanned material dries out to a flexible form that does not become putrid when wetted back.

Tannery Processes and Wastes

The manufacturing of animal products for human consumption (meat and dairy products) or for other human needs (leather), leads inevitably to the production of waste. Under traditional conditions, the quantities of products processed in a certain area used to be small and by-products were better utilized. This resulted in the production of smaller quantities of waste than at present.

Nature is able to cope with certain amounts of waste via a variety of natural cleaning mechanisms. However, if the concentration of waste products increases, nature's mechanisms become overburdened and pollution problems start to occur. Usually, small-scale home processing activities produce relatively small amounts of waste and waste water. Nature can cope with these. Yet as a consequence of the increasing emphasis on large scale production (e.g. for reasons of efficiency, increase in scale of production and hygiene) considerably greater amounts of waste will be produced and steps will have to be taken to keep this production at acceptable levels.

Also methods will have to be found or developed for a more efficient use of by-products and for improved treatment of waste products. Because large scale processes are not easy to survey, the checking of waste production is a problematic undertaking and special efforts are needed to find out where in the production process waste is produced.

Waste water

An important environmental impact of the animal processing industry results from the discharge of wastewater. Most processes in slaughterhouses, tanneries and dairy plants require the use of water. This water and water used for general cleaning purposes will produce wastewater. The strength and composition of pollutants in the wastewater depend on the nature of the processes involved. Discharge of wastewater to surface waters affects the water quality in three ways:

1. The discharge of biodegradable organic compounds (BOC's) may cause a strong reduction of the amount of dissolved oxygen, which in turn may lead to reduced levels of activity or even death of aquatic life.
2. Macro-nutrients (N, P) may cause eutrophication of the receiving water bodies. Excessive algae growth and subsequent dying off and mineralisation of these algae, may lead to the death of aquatic life because of oxygen depletion.
3. Agro-industrial effluents may contain compounds that are directly toxic to aquatic life (e.g. tannins and chromium in tannery effluents; un-ionized ammonia).

Parameters for the amount of BOC's are the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and the concentration of Suspended Solids (SS). The BOD and COD are overall parameters that give an indication of the concentration of organic compounds in wastewater. The concentration of suspended solids represents the amount of insoluble organic and inorganic particles in the wastewater.

Biochemical Oxygen Demand (BOD)

Agro-industrial wastewater generally contains fat, oil, meat, proteins, carbohydrates, etc., which are generally referred to as bio-degradable organic compounds (BOC). This term is a denominator for all organic substances used and degraded by micro-organisms. For most common organisms present in the aquatic environment, degradation requires oxygen. The BOD is the amount of oxygen required by micro-organisms to oxidize the organic material in the wastewater.

Chemical Oxygen Demand (COD)

The COD represents the oxygen consumption for chemical oxidation of organic material under strongly acid conditions. The COD test yields results within a period of a few hours and therefore provides direct information. In this test biodegradable as well as non-biodegradable compounds are oxidized. The COD therefore only provides an indirect indication of the potential oxygen depletion that may occur from the discharge of organic material in surface waters. Use of the BOD is preferred to that of the COD because it provides a more reliable indication of the degree of pollution of wastewater in terms of bio-degradable matter. Nevertheless, the COD is still a widely used parameter for wastewater in general because of the short period of time within which it can be determined.

Suspended Solids (SS)

Suspended solids are insoluble organic and inorganic particles present in wastewater. SS is mainly material that is too small to be collected as solid waste. It does not settle in a clarifier either. Discharge of SS increases the turbidity of water and causes a long term demand for oxygen because of the slow hydrolysis rate of the organic fraction of the material. This organic material may consist of fat, proteins and carbohydrates. The natural biodegradation of proteins (from for instance skin trimmings), will eventually lead to the discharge of ammonium. Ammonium oxidation into nitrite and nitrate by nitrifying bacteria, leads to an extra consumption of oxygen.

Problems resulting from the discharge of biodegradable organic compounds may be addressed by means of biological wastewater systems, either of the aerobic or of the anaerobic type.

In aerobic systems the organic compounds are oxidized by aerobic micro-organisms (oxygen required) into CO_2, H_2O and new bacterial biomass.

Anaerobic systems are based on the capacity of anaerobic bacteria (no oxygen required) to degrade the organic material into CO_2, CH_4 and small quantities of biomass. (*Eutrophication)*

Nitrogen (N)

In wastewater Nitrogen is usually present as fixed in organic material or as ammonium. Kjeldahl developed a test to measure the nitrogen content of wastewater. The Kjeldahl - nitrogen (NKj) is the sum total of organic and ammonia-nitrogen.

Phosphorus (P)

The presence of Phosphorus (P) is determined photometrically. It concerns inorganic phosphate (mostly ortho-phosphate) and organically fixed phosphate. Nitrogen and phosphorus removal can be achieved through special wastewater purification systems, which are based on either biological or physic-chemical processes.

Toxic compounds

Ammonia particularly in un-ionized form is directly toxic to fish and other aquatic life (NH_3 is 300-400 times more toxic than NH_4+). Chromium and tannins are toxic compounds. At neutral pH only 0.4% of the sum total of ammonia and ammonium is present as ammonia.

Detoxification of wastewater may be reached by the use of special wastewater purification systems.

Solid waste

By-products that are not used in any way will be referred to as solid waste. They must be dumped. The following types of solid waste may be distinguished:

- Toxic compounds. These compounds require special attention, e.g. special dumping grounds.
- Organic compounds. These compounds may require attention under certain conditions because of hygienic reasons or because during decomposition ill odour or leaching problems may arise.
- Non degradable compounds. These may be dumped at regular dumping grounds.

Air pollution

Air pollution may cause problems of various kinds:

- Global warming, as a result of emissions of CO_2;
- Changes in the ozone-layer, as a result of emissions of NOx, CH_4, N_2O etc;
- Acid rain, as a result of emissions of SO_2 and NH_3;
- Health conditions

Dust (for instance as a result of emission of powdered chemicals) and/or bad odour, as a result of emissions of VOC;

The use of energy leads to the discharge of gasses such as CO_2, CO, NO_x and SO_2. Chilling and freezing (CFC's and NH_3) activities, smoking of meat products and singing/scorching of pigs also lead to emissions into the air.

The discharge of volatile organic compounds (VOC) may occur in the leather industry when leather finishing substances are used.

RESOURCE MANAGEMENT

Resource management is the efficient and effective deployment of resources when they are needed. This involves processes, techniques and philosophies and the best approach for allocating available resources. Environmental resource management is the management of the interaction and impact of human societies on the environment. Environmental resource management aims to ensure that ecosystem services are protected and maintained for future human generations, and also maintain ecosystem integrity through considering ethical, economic, and scientific (ecological) variables. Environmental resource management tries to identify factors affected by conflicts that rise between meeting needs and protecting resources. It is thus linked to environmental protection and sustainability.

Waste management is the collection, transport, processing, recycling or disposal, and monitoring of waste materials. A typical waste management system comprises collection, transportation, pre-treatment, processing, and final abatement of residues. The waste management system consists of the whole set of activities related to handling, treating, disposing or recycling the waste materials.

The leather industry on one side boasts of a country's local economic development, on the other side however leads to the tremendous environment pollution and biological chains destruction. The waste management model has to be developed as a way of dealing with effluent from raw materials, water and energy consumption reduction in the leather industry. Reduce, Reuse, Recycle and Recover of the tannery effluents have to be separately identified at different operation processes. The successful treatment approaches with analysis in the aspects such as wastewater, solid waste, sulfide, Chemical Oxygen Demand (COD), ammonium salt, chloride and chrome of the leather tannery.

MATERIAL BALANCE

Chemical processes are often very elaborate, with many types of equipment used to obtain a desired product. Chemical engineers are interested in many of the physical parameters associated with each process, such as the flow rate of material that enters and leaves a piece of equipment, as well as several other parameters including the temperature of the material, and the pressure exerted by material. Learning to keep track of the materials and their physical properties in chemical processes is integral to an organization.

Material balances on processes involving chemical reactions may be solved by applying;

1. Molecular Species Balance – a material balance equation applied to each chemical compound appearing in the process
2. Atomic Species Balance – the balance applied to each element appearing in the process.
3. Extent of reaction – expressions for each reaction written involving the extent of reaction.

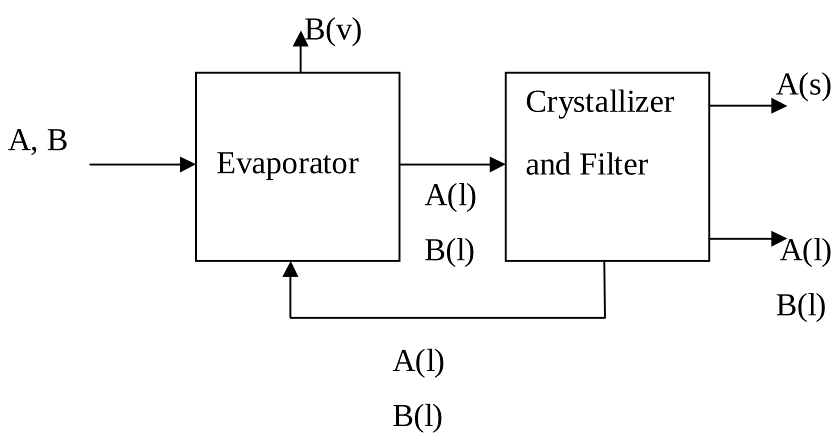
Chemical reaction: A chemical reaction is independent if it cannot be obtained algebraically from other chemical reactions involved in the same process.

Molecular Species: If two molecular species are in the same ratio to each other wherever they appear in a process, then these molecular species are not independent.

Atomic Species: If two atomic species occur in the same ration wherever they appear in a process, balances on those species will not be independent equations.

Therefore, mass balances are used widely in engineering and environmental analyses. For example, mass balance theory is used to design chemical reactors, to analyse alternative processes to produce chemicals, as well as to model pollution dispersion and other processes of physical systems. Closely related and complementary analysis techniques include the population balance, energy balance and the more complex entropy balance. These techniques are required for thorough design and analysis of systems such as the refrigeration cycle. In environmental monitoring the term budget calculations is used to describe mass balance equations where they are used to evaluate the monitoring data (comparing input and output, etc.) In biology the dynamic energy budget theory for metabolic organisation makes explicit use of mass and energy balances.

Recycle and Bypass processes: (the purpose of the recycle stream could be to reuse A, say water, and the purpose of the bypass would be to have some B, such as a natural juice, skip the process to give the final produce better flavoring.)



Chemical equation

In - Out + Generation - Consumption = 0

The essential part of any tannery waste audit is assessing the efficiency of existing operations carried out during the leather manufacturing process. Typically, tannery staffs have a good idea of, and comparatively accurate figures on, the waste resulting from specific operations such as fleshing, splitting, trimming or chrome tanning. Only rarely, however, do they have a proper overview of the entire range of waste generated. Thus, when considering various cleaner technologies or waste treatment systems, having access to a complete computation of the overall mass balance certainly makes it easier for a tanner facing arduous choices. Dialogue with environmental authorities is also simpler if such figures are readily available.

Weight ratios and yields

Wet salted weight	1000kgs
Limed (pelt) weight	1100kgs
Shaved weight grain	262kgs
Shaved weight split	88kgs
Finished leather grain	195kgs
Finished leather split	60kgs
Total finished leather produced	255kgs

LIFE CYCLE COST ANALYSIS

Life-cycle cost (LCC) is the total cost of ownership over the life of an asset. Costs considered include the financial cost which is relatively simple to calculate and also the environmental and social costs which are more difficult to quantify and assign numerical values. Typical areas of expenditure which are included in calculating the life cycle cost include, planning, design, construction and acquisition, operations, maintenance, renewal and rehabilitation, depreciation and cost of finance and replacement or disposal.

The life cycle cost of wastewater collection and treatment systems includes design and construction, repair and replacement (R&R), and operation and maintenance (O&M). To avoid financial problems in the future, differences in the costs for each technology under consideration must be evaluated during the selection process and planned for in the management and rate-setting process.

A good example of the importance of life cycle cost analysis is the trouble caused by inadequate rate structures for systems that were installed with Clean Water Act grants. Repair and replacement costs were overlooked in the rate structures, and today, decades later, as this infrastructure reaches the end of its useful life, cities cannot afford to repair/replace them.

It is also important to consider costs from all four parts of a community wastewater system: On-lot, Collection, Treatment, and Dispersal. For example, effluent sewer collectionemploys passive digestion in on-lot interceptor tanks; this allows significant reduction in treatment capacity (and cost) requirements downstream, a feature not offered by grinder or gravity sewer systems. Effluent sewer systems provide primary treatment, reducing solids by at least 70%. They are often followed by less costly secondary treatment facilities such as packed-bed filters, constructed wetlands, or lagoons.

Life Cycle Assessment allows for a holistic approach to the problem of assessing the environmental performance of a product or system, and has been widely accepted as a decision support tool for government bodies, local authorities, and areas of the industrial sector. The application of LCA to examine the performance of Waste Water Treatment Plants (WWTP) is particularly suitable due to the nature of the relationship between a plant's technosphere and the surrounding ecosphere.

ENVIRONMENTAL HEALTH AND SAFETY LEGISLATION

Environmental, health and safety (**EHS**) departments, also called **SHE** or **HSE** departments, are entities commonly found within companies that consider environmental protection, occupational health and safety at work as important as providing quality products, and which therefore have managers and departments responsible for these issues. EHS management has two general objectives: prevention of incidents or accidents that might result from abnormal operating conditions on the one hand and reduction of adverse effects that result from normal operating conditions on the other hand.

The EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)

The EHS Guidelines contain the performance levels and measures that are normally acceptable to International Finance Corporation (IFC) that are generally considered to be achievable in new facilities at reasonable costs by existing technology.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects will be required to achieve whichever is more stringent. If less stringent levels or measures than those provided in the EHS Guidelines are appropriate in view of specific project circumstances, a full and detailed justification must be provided for any proposed alternatives through the environmental and social risks and impacts identification and assessment process. This justification must demonstrate that the choice for any alternate performance levels is consistent with the objectives of Performance Standard.

The technical reference documents for environment of EHS Guidelines with general and industry-specific examples of Good International Industry Practice (GIIP) are:

1. Air Emissions and Ambient Air Quality
2. Energy Conservation
3. Wastewater and Ambient Water Quality
4. Water Conservation
5. Hazardous Materials Management
6. Waste Management
7. Noise
8. Contaminated Land and Remediation
9. releases to water
10. releases to land
11. use of raw materials and natural resources
12. energy emitted, heat/radiation/vibration
13. waste and by-products

HIERARCHICAL APPROACH TO WASTE MANAGEMENT SYSTEMS

Because no single waste management approach is suitable for managing all waste streams in all circumstances, EPA developed a hierarchy ranking the most environmentally sound strategies for municipal solid waste. The hierarchy places emphasis on reducing, reusing, and recycling the majority of wastes and demonstrates the key components of EPA's Sustainable Materials Management Program (SMM).

SMM is an effort to protect the environment and conserve resources for future generations through a systems approach that seeks to reduce materials use and their associated environmental impacts over their entire life cycles, starting with extraction of natural resources and product design and ending with decisions on recycling or final disposal.

Source Reduction and Reuse

Source reduction, also known as waste prevention, means reducing waste at the source. It can take many different forms, including reusing or donating items, buying in bulk, reducing packaging, redesigning products, and reducing toxicity. Source reduction also is important in manufacturing. Light-weighting of packaging, reuse and remanufacturing are all becoming more popular business trends. Purchasing products that incorporate the following features supports source reduction. Source reduction can:

- Save natural resources;
- Conserve energy;
- Reduce pollution;
- Reduce the toxicity of our waste; and
- Save money for consumers and businesses alike.

Recycling/Composting

Recycling is a series of activities that includes the collection of used, reused or unused items that would otherwise be considered waste; sorting and processing the recyclable products into raw materials and remanufacturing the recycled raw materials into new products. Consumers provide the last link in recycling by purchasing products made from recycled content. Recycling also can include composting of food scraps, yard trimmings and other organic materials.

Recycling prevents the emission of many greenhouse gases and water pollutants, saves energy, supplies valuable raw materials to industry, creates jobs, stimulates the development of greener technologies, conserves resources for our children's future, and reduces the need for new landfills and combustors.

Energy Recovery

Energy recovery from waste is the conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, anaerobic digestion, and landfill gas (LFG) recovery. This process is often called waste-to-energy (WTE).

Treatment and Disposal

Landfills are the most common form of waste disposal and are an important component of an integrated waste management system. Landfills that accept municipal solid waste are primarily regulated by state, tribal, and local governments. EPA, however, has established national standards these landfills must meet in order to stay open. The federal landfill regulations have eliminated the open dumps of the past. Today’s landfills must meet stringent design, operation, and closure requirements. Methane gas, a byproduct of decomposing waste, can be collected and used as fuel to generate electricity. After a landfill is capped, the land may be used for recreation sites such as parks, golf courses and ski slopes.

ENZYMOLOGY APPLIED TO LEATHER MAKING.

Since the beginning of human history, man has used enzymes indirectly. The fermentation of sugar to ethanol in the preparation of beer and wine, production of vinegar by the oxidation of ethanol, curdling of milk by lactose fermentation are thousands of years old processes where catalytic activities of enzymes are responsible for chemical transformations. Probably the first application of cell free enzyme was in cheese making where rennin obtained from calf stomach was used. The protease rennin which coagulates milk protein, has been used for hundreds of years in cheese preparation. The first commercial enzyme was probably reported in Germany in 1914. Use of trypsin, the protease isolated from animals, was shown to improve washing power of detergent over traditional products. Success in the formulation of improved quality of detergent triggered efforts towards the selection of proteases suitable for application in detergents.

Subsequently, a breakthrough in the commercial use of enzyme occurred with the introduction of microbial protease in washing powder at an affordable cost. The first commercial alkaline protease from *Bacillus* sp. was marketed in 1959 and production of enzyme added detergent soon became a big business within a few years. During the period when use of alkaline protease in detergent became popular, use of enzymes in food processing industries also gained momentum in parallel. Fruit clarifying enzyme, called pectinase, was used in fruit juice manufacturing units since 1930. Enzymes hydrolyzing starch into dextrin and glucose largely entered the food industry in 1960 and more or less completely replaced acid process of starch hydrolysis. Starch hydrolyzing enzymes (α-amylase and amyloglucosidase) for the production of glucose soon became the second largest used group of enzymes in industry after detergent protease.

Enzymes may be extracted from any living organism. Sources of commercial enzymes cover a wide range, from microorganisms to plants to animal sources. But for various reasons, microorganisms became the major source of enzymes. In commercial enzyme production, fungi and yeast contribute about 50%, bacteria 25%, animal 8% and plant 4% of the total. Microbes are preferred to plants and animals as they are cheap sources, their enzyme contents are predictable and growth substrates are obtained as standard raw materials. In addition, genetic engineering has opened a new era of advanced enzyme technology. Recombinant DNA technology has made it possible to obtain enzymes present in valued sources, to be synthesized in easy growing microorganisms and also to produce tailor-made enzyme proteins with desired properties as per customers' requirements. Enzymes retaining activity under extreme conditions of temperature, pH and salt concentrations, partially active inorganic solvents are all becoming a reality. The prospects of the enzyme industry look very bright with increased market position for existing use, new use of known enzymes and new enzymes having novel industrial applications.

Enzymes in leather industry

One of the oldest industrial uses of enzyme activity is in leather processing. Before raw hide is transformed into leather, it undergoes a series of operations whereby leather making protein collagen present in hides and skins is freed or partially freed from non-collagenous constituents. Hides and skins contain fat as well as globular proteins, viz.albumin, globulin, mucoids and fibrous protein such as elastin, keratin and reticulin between collagen fibers. In industry, raw material is processed through a series of operations including soaking, liming, dehairing, deliming, bating, degreasing and pickling. In pre-tanning operations, skins and hides are subjected to a water soak, which cleans the raw material and loosens the hair. The conventional and most widely used method for dehairing is the treatment of soaked raw material with lime and sodium sulphide. Subsequent deliming is also done to remove adsorbed lime from the hide. Fat present in skins is usually removed with degreasing agents such as soluble lime soap, kerosene, chlorinated hydrocarbons or spirit. In the traditional processing, a large numbers of pollution causing chemicals, lime, sodium sulphide, and solvents are released in effluents, which are toxic and cause environmental pollution.

In addition of chemical treatment, an enzymatic treatment, known, as 'bating' is an essential step to obtain optimum results. During bating, the scud is loosened and many unwanted proteins are removed. Bating makes the grain surface of the finished leather clean, fine and glossy. The traditional practice of bating is an unhygienic process where uncontrolled fermentation of leather is conducted with manures of dog, pigeon or hen as sources of microorganisms. This process gives a desired character to the finished leather. No chemical process has been developed which can substitute the fermentation.

The leather industry has a major problem regarding industrial pollution due to the use of huge amounts of toxic chemicals and biological pollution by addition of unknown microbial load to the environment. Use of enzyme in pre-tanning processes appeared to be a viable alternative technology where pollution problems resulting from tannery effluent could be significantly regulated or restricted.

Enzymes in pre-tanning

Proteolytic enzyme is the most important enzyme used in pre-tanning process. Enzymes from plant, animals and microbial sources were known to leather industry for a long time. But development of enzyme-based process became bright with the success of production of enzymes at commercial level and availability of enzymatic formulations at cheap rate.

Animal proteases and microbial proteases from bacteria and fungi are used in leather industry. The physicochemical properties of the enzyme such as substrate specificity, temperature and pH stability and pH activity range are very important factors in the application of enzymes in different steps of pre-tanning operations. Microbial enzymes appeared to be ideal source of the proteases. Enzymes with wide pH range of activities could be produced economically from different microbes. Now various commercial enzyme preparations are available for use in leather industry.

Enzymes in soaking

Proteolytic enzyme combinations (Aspergillus parasiticus, Aspergillus flavus, Bacillus subtilis, and Aspergillus awamori) active in natural or alkaline pH ranges are usually used.

Enzymes in dehairing

Use of enzyme in dehairing is highly desired in leather processing. It would eliminate the use of sodium sulphide, one of the most toxic chemicals with obnoxious odour. A large number of proteases from A. flavus, A fumigatus, A. chraceus, A.effuses, *Bacillus sp*., *Streptomyces sp*. have dehairing or hair loosening effects. Potential use of specific protease keratinase from Streptomyces fradiae, for dehairing was also indicated. Enzymes from fungal or bacterial sources are allowed to act at pH 10.0 for about 12 – 16 hours, and hair is removed by mechanical means.

Enzymes in bating

The process of bating is a method for softening hides by treating them in a warm infusion of animal dung. Deliming and proteolytic actions take place simultaneously in bating. A 'bate' usually contains a proteolytic enzyme, a carrier like wood flour and deliming agents like NH_4Cl or $(NH_4)2SO_4$. Pancreatic enzymes, bacterial and fungal proteases of neutral and alkaline types are used in bating.

PARTIALLY PROCESSED LEATHER

The leather manufacturing process is divided into three sub-processes: preparatory stages, tanning and crusting. All true leathers will undergo these sub-processes. A further sub-process, surface coating may be added into the sequence. The list of operations that leathers undergo varies with the type of leather. But leathers which do not undergo all the sub processes are said to be semi/partially processed. There are three stages where hides or skins and leathers can be marketed as semi processed;

1. Pickled skins or hides – Hides or skins preserved in a pickling liquid (acidic) by preventing from decaying or spoiling and preserved for future use.
2. Wet blue – Chrome tanned leather, known as wet-blue for its color derived from the chromium. The chrome tanning method usually takes a day to finish and the ease and agility of this method make it a popular choice.
3. Crust leather – Crusting sub-process is the drying and softening operations. Crusting may include the following operations: wetting-back, sammying, splitting, shaving, rechroming, neutralization, retanning, dyeing, fatliquoring, filling, stuffing, stripping, whitening, fixation, setting, drying, conditioning, milling, staking, and buffing.

CLEANER PRODUCTION

Cleaner production is a preventive, company-specific environmental protection initiative. It is intended to minimize waste and emissions and maximize product output. By analyzing the flow of materials and energy in a company, one tries to identify options to minimize waste and emissions out of industrial processes through source reduction strategies. Improvements of organization and technology help to reduce or suggest better choices in use of materials and energy, and to avoid waste, waste water generation, gaseous emissions and also wasted heat and noise.

The concept was developed during the preparation of the Rio Summit as a programme of UNEP (United Nations Environmental Programme) and UNIDO (United Nations Industrial Development Organization). The programme was meant to reduce the environmental impact of industry. The programme idea was described "...to assist developing nations in leapfrogging from pollution to less pollution, using available technologies". Starting from the simple idea to produce with less waste Cleaner Production was developed into a concept to increase the resource efficiency of production in general. UNIDO has been operating a National Cleaner Production Center Programme with centres in Latin America, Africa, Asia and Europe.

Examples for cleaner production options are:

1. Documentation of consumption (as a basic analysis of material and energy flows)
2. Use of indicators and control (to identify losses from poor planning, poor education and training, mistakes)
3. Substitution of raw materials and auxiliary materials (especially renewable materials and energy)
4. Increase of useful life of auxiliary materials and process liquids (by avoiding drag in, drag out, contamination)
5. Improved control and automatization
6. Reuse of waste (internal or external)
7. New, low waste processes and technologies

CLEAN TECHNOLOGY

Clean technology is a general term used to describe products, processes or services that reduce waste and require as few non-renewable resources as possible. **Clean technology** includes recycling, renewable energy (wind power, solar power, biomass, hydropower, bio-fuels, etc.), information technology, green transportation, electric motors, green chemistry, lighting, grey water and many other appliances that are now more energy efficient. It is a means to create electricity and fuels, with a smaller environmental footprint and minimize pollution. To make green buildings, transport and infrastructure both more energy efficient and environmentally benign. Environmental finance is a method by which new clean technology projects that has proven that they are "additional" or "beyond business as usual" can obtain financing through the generation of carbon credits. A project that is developed with concern for climate change mitigation (such as a Kyoto Clean Development Mechanism project) is also known as a carbon project.

WASTES RELATED TO TANNERY PROCESSES

The chemicals traditionally used for tanning were derived from plants, whereas the most common process nowadays is a combination of chrome salts (chrome tanning) and readily usable vegetable extracts (vegetable tanning). While chrome tanned shoe leather is the most widely produced leather, this kind of leather will receive most attention environmentally. In most cases raw hides produced at slaughterhouses are preserved by pickling and drying for transport to tanneries and further treatment. In the very few cases where the hides are instantly tanned there is no need for preservation. During the tanning process at least ±300 kg chemicals (lime, salt etc.) is added per ton of hides.

Pre-tanning (Beamhouse operations)

Soaking:

The preserved raw hides regain their normal water contents. Dirt, manure, blood, preservatives (sodium chloride, bactericides) etc. are removed.

Fleshing and trimming: Extraneous tissue is removed. Unhairing is done by chemical dissolution of the hair and epidermis with an alkaline medium of sulphide and lime. When after skinning at the slaughterhouse, the hide appears to contain excessive meat, fleshing usually precedes unhairing and liming.

Bating: The unhaired, fleshed and alkaline hides are neutralised (deliming) with acid ammonium salts and treated with enzymes, similar to those found in the digestive system, to remove hair remnants and to degrade proteins. During this process hair roots and pigments are removed. The hides become somewhat softer by this enzyme treatment.

Pickling: Pickling increases the acidity of the hide to a pH of 2.5, enabling chromium tannins to enter the hide. Salts are added to prevent the hide from swelling. For preservation purposes, 0.03 - 2 weight percent of fungicides and bactericides are applied.

Tanning

There are two possible processes:

1: Chrome tanning: After pickling, when the pH is low, chromium salts (Cr^{3+}) are added. To fix the chromium, the pH is slowly increased through addition of a base. The process of chromium tanning is based on the cross-linkage of chromium ions with free carboxyl groups in the collagen. It makes the hide resistant to bacteria and high temperature. The chromium-tanned hide contains about 2-3 dry weight percent of Cr^{3+}. Wetblue, i.e. the raw hide after chrome-tanning process, has about 40 percent of dry matter.

2: Vegetable tanning: Vegetable tanning is usually accomplished in a series of vats (first the rocker-section vats in which the liquor is agitated and second the lay-away vats without agitation) with increasing concentrations of tanning liquor. Vegetable tannins are polyphenolic compounds of two types: hydrolysable tannins (i.e. chestnut and myrobalan) which are derivatives of pyrogallols and condensed tannins (i.e. hemlock and wattle) which are derivatives from catechol. Vegetable tanning probably results from hydrogen bonding of the tanning phenolic groups to the peptide bonds of the protein chains. In some cases as much as 50% by weight of tannin is incorporated into the hide.

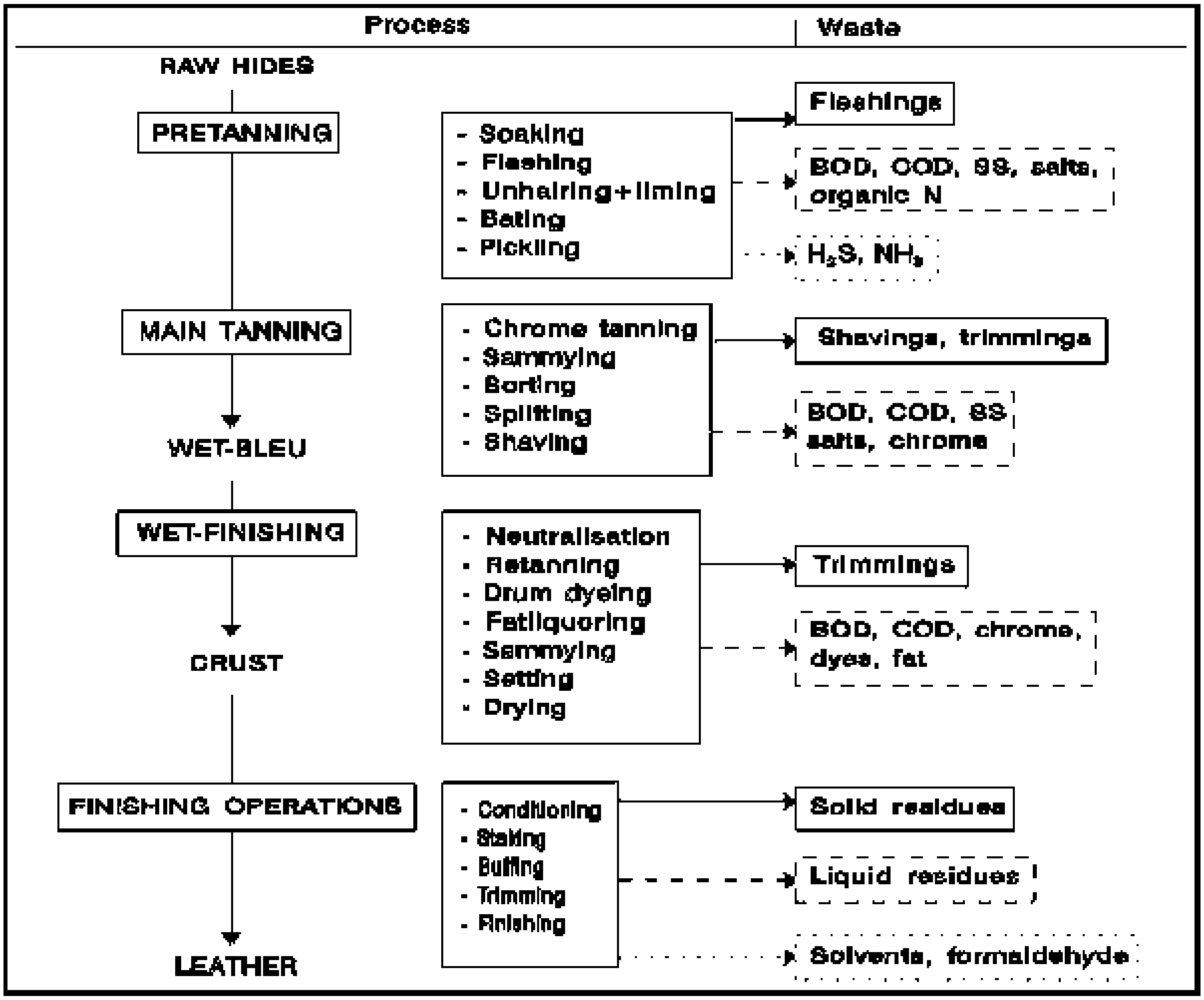
Finishing

Wetblue: Chromium tanned hides are often re-tanned - during which process the desirable properties of more than one tanning agent are combined - and treated with dye and fat to obtain the proper filling, smoothness and colour. Before actual drying is allowed to take place, the surplus water is removed to make the hides suitable for splitting and shaving.

This is done to obtain the desired thickness of the material. The most common way of drying is vacuum drying. Cooling water used in this process is usually circulated and is not contaminated.

Crust: The crust that results after retanning and drying, is subjected to a number of finishing operations. The purpose of these operations is to make the leather softer and to mask small mistakes. The hide is treated with an organic solvent or water based dye and varnish. The finished end product has between 66 and 85 weight percent of dry matter

Hides are a by-product of slaughter activities and can be processed into a wide range of end products. For each end product, the tanning process is different and the kind and amount of waste produced may vary enormously.



ANALYSIS AND CONTROL OF AIR EMMISSIONS FROM A TANNERY

The tests required for an effective air analysis program depend primarily on the air source and intended use. Examples of typical air sources include: natural outdoor air, indoor air (i.e. industrial, commercial, medical, residential, aircraft cabin), synthetic air, container, manifold, or compressor supplied air. Examples of intended use include: general outdoor or indoor air quality, hospital breathing air, specialized breathing air for Fire-Rescue Department SCBA (*self-contained breathing apparatus*) functions, as well as air used for combustion/welding, manufacturing/packaging, laboratory instrumentation, pharmaceutical applications, break systems, etc. Each air source involves a unique set of analytical challenges that must be met in order to satisfy an air quality specification. The analytical programs recommended to each client are designed to detect and quantify the critical components associated with their air. This air analysis strategy ensures that all undesirable contaminants have been monitored and that all the important air gases are present at acceptable levels for the intended application.

Pollution monitoring can provide an important aid in the choice of the strategy to control the level of some dangerous elements, whether in water or in the air. The difficulties of detecting polluting sources from experimental data are related not only to the adoption of systematic and suitable measuring procedure, but also to a correct management of the available information. From the theoretical point of view, the use of simplified models, coupled with classical regularization techniques, shows that, in general, the problem is badly posed and consequently, numerically ill-conditioned.

Control of air pollution

Air is considered to be polluted when it contains certain substances in concentrations high enough and for durations long enough to cause harm or undesirable effects. These include adverse effects on human health, property, and atmospheric visibility. The atmosphere is susceptible to pollution from natural sources as well as from human activities. Some natural phenomena, such as volcanic eruptions and forest fires, may have not only local and regional effects but also long-lasting global ones. Nevertheless, only pollution caused by human activities, such as industry and transportation, is subject to mitigation and control.

Air pollution control, the techniques employed to reduce or eliminate the emission into the atmosphere are aimed at eliminating substances that can harm the environment or human health. The control of air pollution is one of the principal areas of pollution control along with wastewater treatment, solid waste management and hazardous waste management.

Pollution control equipment can reduce emissions by cleaning exhaust and dirty air before it leaves the business. A wide variety of equipment can be used to clean dirty air. There are other ways to reduce emissions besides using pollution control equipment--prevent emissions to begin with. Air quality permits help minimize, reduce or prevent emissions as much as possible by placing requirements on how things are done.

Permits can specify the quantity, type, or quality of fuel or other substance used in a process. For example, a permit might specify the maximum percent of sulfur that can exist in the coal to reduce sulfur dioxide emissions. A permit may specify the quantity of volatile chemicals in paint, solvent, adhesive or other product used in large quantity during manufacturing. Permits can also help reduce the impact of emitted pollutants on local air by specifying smokestack height and other factors.

Engineers can also set combustion specifications to minimize emissions. For example, to help reduce nitrogen oxide formation, the combustion conditions in the furnace can be altered. The flame temperature can be lowered or raised, the amount of time air remains in the combustion chamber can be altered, or the mixing rate of fuel and air can be changed. These options are often reviewed, studied and best choices made depending upon cost, plant design and many other variables.

TANNERY EFFLUENT SYSTEMSAND END OF PIPE TREATMENTS

With the ever increasing legal and social pressures, no tanner can be said to be unfamiliar with the main issues and principles of environmental protection pertaining to tannery operations. Among these, preventing pollution and promoting cleaner leather processing, which ultimately leads to lower treatment costs, clearly remain a priority. Through the application of industrially proven low-waste advanced methods - such as using salt-free preserved raw hides and skins, hair-save liming, low-ammonia or ammonia-free deliming and bating, advanced chrome management system, etc. - it is possible to decrease the pollution load expressed as COD and BOD by more than 30%, sulphides by about 60 to 70%, ammonia nitrogen by 80%, total (Kjeldahl) nitrogen by 50%, chlorides by 70%, sulphates by 65% and chromium by 90%. Yet, despite all preventive measures, there is still a considerable amount of pollution load to be dealt with by the end-of-pipe methods, and all these pollutants can only be removed by,i.e. treating effluents discharged in the course of leather processing.

Costs of tannery waste treatment

Towards the end of the 20th century the tanning industry has made a considerable progress in controlling the environmental pollution caused by its activities, yet the situation varies from country to country and even from region to region within some large countries. Some tanners in industrialized countries hold the view that lax environmental regulations and poor enforcement account for lower production costs, higher competitiveness and hence further expansion of the tanning industry in developing countries.

Benchmarking in the Tanning Industry

The main technical issues with regard to benchmarking which is intended to assist those who are willing to admit to the fact that despite all explanations and definitions available, they are not quite sure what it is all about and whether and how it could be applied in the tanning industry. The check lists for ten areas are:

1. **Tannery location, infrastructure**
2. **Production parameters**

3. **Cleaner technologies**
4. **Energy management and consumption**
5. **Quality assurance, reprocessing, delivery time, failures**
6. **Product development, strategies**
7. **Occupational safety and health at work, maintenance**
8. **Effluent treatment, solid waste, air emissions**
9. **Financial indicators**
10. **Human resources and staff welfare,**

Life Cycle Assessment, Carbon Footprint in Leather Processing

There is need to have in place calculations of the Product Carbon Footprint (PCF) of the product Finished Leather together with recommendations for harmonization and the main elements needed to define system boundaries. The inherent complexity and inadequate exactness of carbon footprint analyses contrasts with the need to communicate the results in a simple, clear and unambiguous way.

International concern has increased over the years on Climate Change. The ten hottest years on record have all occurred since 1998. Out of the last 21 years 18 are among the 20 warmest years since 1880. Data and findings add weight to the common conclusion that the clear long-term trend is one of global warming. Most of the observed increase in global average temperature since the mid - 20th century is very likely due to the observed rise in anthropogenic greenhouse gas concentrations. Among these, particular attention is paid on CO_2 (carbon dioxide). Latest estimates show that global CO_2 emissions increased to 30,600 million tonnes in 2010. Industry and manufacturing contribute for 19% of all Greenhouse Gas Emissions. Interest has been developed in estimating the total amount of GHG produced during the various stages in the life cycle of products. The outcome of these calculations, are referred to as Product Carbon Footprints (PCFs). Currently, there is no single methodology and no agreement has been reached internationally on Leather PCF calculation methods.

Reed beds for the treatment of tannery effluent

Conventional technologies for treatment of tannery effluent are generally energy & chemical intensive; also, continuous process monitoring and control are required to achieve optimum results. In search for alternative robust, easy to operate and low maintenance treatment technologies, constructed wetland system, also known as root zone treatment system, using reeds for treatment of effluent, has been considered a possible option. This system is widely used in Europe and elsewhere to treat municipal sewerage. However, in absence of application of this system for treatment of tannery effluent anywhere in the world at present, doubts remained with regard to its efficiency and technical viability. Accordingly, in cooperation with willing tanneries and effluent treatment plants in Tamilnadu, India, UNIDO, under its Regional Programme, established four pilot and demonstration reed beds, each with different features, to deal with effluent of different characteristics.

Application of Ultrafiltration in Treatment of Tannery Waste Water

Under the Regional Programme for pollution control in the tanning industry UNIDO has been actively looking for methods to improve conventional treatment processes which simultaneously reduce the nitrogen content and give the possibility of dealing with TDS/chlorides present in the effluent. The following technologies relating to the issues mentioned were implemented in pilot demonstration units:

1. Mechanical/manual removal of excess salt from wet salted hides and skins
2. Reverse osmosis (RO) of treated tannery effluent
3. Improved solar evaporation,
4. Carbon dioxide (CO_2) deliming in a small scale tannery to reduce ammonical nitrogen,
5. Constructed wet land treatment system (reed beds) possibly resulting in nitrification/denitrification
6. Preliminary estimates of costs of multistage evaporation system to recover salt from reject generated by RO
7. Ultrafiltration.

This report deals specifically with ultra-filtration. A preliminary study had been conducted on the suitability of ultrafiltration for treatment of tannery effluent - replacement of secondary clarifier in the treatment process and the results are promising.

Multiple Stage Evaporation System to Recover Salt from Tannery Effluent

UNIDO through its Regional Programme for Pollution Control in the Tanning Industry in South East Asia has been actively looking for solutions to tackle saline tannery effluent. Currently the following technologies are implemented or being implemented in pilot demonstration units;

1. Mechanical/manual removal of excess salt from wet salted hides and skins,
2. Reverse osmosis of treated tannery effluent,

3. Improved solar evaporation,
4. Recycling of floats in beam house after filtration,
5. Use of ultra-filtration in tannery effluent.

A sixth technology which has been under consideration is the multistage evaporation system to recover salt from tannery effluent.

Accelerated Evaporation of Saline Streams in Solar Pans

Total dissolved solids (TDS), specifically chlorides, in effluent are a major concern for its discharge into surface waters and its use for irrigation. Conventional treatment systems do not help reduce TDS in the industrial effluent. Taking advantage of the sunshine available for most part of the year, tanneries in Tamil Nadu, India, were required by the regulatory authority to segregate highly saline effluent (soak and pickle streams) and evaporate it in solar pans. Due to very dissapointing results of evaporation in solar pans attempts have been made to accelerate the evaporation by simple means like combination of improved warming of the effluent and use of sprinklers.

Prospects and Problems of Establishing an International ECO-label for the Leather and Leather Products Industries

Presented publications documents UNIDO's involvement in promoting Eco-Labelling in the leather industry. Life-cycle assessments or the evaluation of the potential environmental impact of a product system from cradle to grave are fundamental features of some eco-labelling schemes and environmental management systems. Nowadays The environmental auditing protocol and reporting mechanism developed and maintained by the Leather Working Group aims to tackle important topical issues, and reflect improvements or changes of technology within the sector.

ENVIRONMENTAL IMPACT OF TANNERY WASTES

Environmental Impact Assessment (EIA) is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse. UNEP defines EIA as a tool used to identify the environmental, social and economic impacts of a project prior to decision-making. It aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decision-makers. By using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation and design, avoided treatment/clean-up costs and impacts of laws and regulations.

Although legislation and practice vary around the world, the fundamental components of an EIA would necessarily involve the following stages;

1. **Screening** to determine which projects or developments require a full or partial impact assessment study;
2. **Scoping** to identify which potential impacts are relevant to assess (based on legislative requirements, international conventions, expert knowledge and public involvement), to identify alternative solutions that avoid, mitigate or compensate adverse impacts on biodiversity (including the option of not proceeding with the development, finding alternative designs or sites which avoid the impacts, incorporating safeguards in the design of the project, or providing compensation for adverse impacts), and finally to derive terms of reference for the impact assessment;
3. **Assessment and evaluation of impacts and development of alternatives**, to predict and identify the likely environmental impacts of a proposed project or development, including the detailed elaboration of alternatives;
4. **Reporting the Environmental Impact Statement (EIS) or EIA report**, including an environmental management plan (EMP), and a non-technical summary for the general audience.
5. **Review of the Environmental Impact Statement**, based on the terms of reference (scoping) and public (including authority) participation.
6. **Decision-making** on whether to approve the project or not, and under what conditions;
7. **Monitoring, compliance, enforcement and environmental auditing**. Monitor whether the predicted impacts and proposed mitigation measures occur as defined in the EMP. Verify the compliance of proponent with the EMP, to ensure that unpredicted impacts or failed mitigation measures are identified and addressed in a timely fashion.

INTERNATIONAL CONVENTIONS AND PROTOCALS

One of the ways that WMO (World Meteorological Organization) contributes to sustainable development is through international environmental governance as enshrined in various United Nations and other international conventions. The data collected from

WMO's networks of ground and space-based systems, combined with the application of improved scientific knowledge and computing technology, provide the information products, services and assessments necessary for the formulation of relevant policy decisions on which international environmental governance may build.

WMO, with relevant partners, co-sponsors several programmes for scientific research and assessments to support intergovernmental legal agreements on major global environmental concerns such as ozone-layer depletion, climate change, desertification and biodiversity. WMO also coordinates the observing systems which provide the necessary data to assess atmospheric-ocean processes and interactions, such as El Niño/La Niña, and water-resources availability.

- UN Framework Convention on Climate Change
- United Nations Convention to Combat Desertification
- Vienna Convention on the Protection of the Ozone Layer
- Convention on Biological Diversity
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
- United Nations Economic Commission for Europe
- Convention on Long-range Transboundary Air Pollution
- Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)
- Convention on Early Notification of a Nuclear Accident
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency

GLOBAL ENVIRONMENTAL ISSUES

Climate Change – Global warming is the most systemic and long-range threat to environmental health. All concerns are now geared and working on ways to combat climate change, with a focus on developing legal tools and regulatory frameworks that will help move human societies toward energy sustainability and protect those most harmed by rising sea levels and changing weather patterns.

Human Rights and Environment – WHO knows that environmental health and human health are two sides of the same coin: human rights violations and environmental degradation are often closely related. In many cases, infrastructure development and natural resource extraction projects are some of the worst offenders. WHO identifies the biggest threats and leverages the law to defend fundamental human rights

Marine Protection – There is widespread legal advocacy to ensure that marine resources are being harvested sustainably, and that threatened ecosystems and marine species are being adequately protected. All countries of the World are encouraged to work towards strengthening laws that promote sustainable aquaculture and limit resource extraction in protected marine areas.

Environmental Governance – UN works to strengthen environmental governance and encourage public participation in the countries of the World. They are encouraged to educate local lawyers and provide informational materials to key decision makers. The most powerful change comes from the bottom up – by forging international alliances and equipping stakeholders with the knowledge and tools to get involved, UN builds capacity and expands citizen opportunities for participation.

Freshwater Preservation – Clean freshwater is a cornerstone of human health and biodiversity protection. UN litigates to safeguard freshwater from depletion and harmful contamination.

ISO 14000; BY-PRODUCTS FROM LEATHER INDUSTRY

The ISO 14000 standard series was developed since 1993 by the Technical Committee (TC) 207 of the International Standardization Organization (ISO) with the goal of supplying the enterprises and many organizations of the whole world with an environmental administration common boarding. As a whole, the series cares for the Environmental Management Systems (EMS), Environmental Audit, Environmental Performance Evaluation, Environmental Labeling, Life Cycle Evaluation and Environmental Aspects in Standards and Products, besides the terminology used for the comprehension of the set of standards.

The continued increase in social and environmental consciousness, coupled with an increasingly globalized marketplace, has fostered an increasingly important role for independent environmental standards. Among the most widely recognized and internationally accepted of such programs is the ISO 14000 environmental management standard (EMS). The intent of ISO 14000 is not to address specific, environmental issues such as green building, or green consumer product design and manufacture. Instead, its purpose is to provide firms guidance as to how they can: ‘identify and control the environmental impact of its activities, products or services’, systematically set and work toward environmental objectives and targets, and continually improve their environmental performance. Companies that become ISO 14000 certified must develop, document and implement an extensive list of internal operational procedures regarding issues such as: emergency preparedness, industry/government regulations and agency approvals, training, contract control, and monitoring and measurement. Through this process organizations become more efficient, and are more capable of responding to the needs of their customers. Further, while certification requires companies to be regularly reviewed by third-party auditors, current and potential customers are provided assurance that their suppliers do adhere to their stated internal procedures.

The potential benefits of this program are numerous and include production gains through reduced waste and more efficient use of energy and other inputs, and lower distribution costs. Of less tangible benefit, adherence to this standard is thought by some to be an effective tool to improve a corporation's image as a socially and/or environmentally conscious organization. Of particular value, this standard has been found to induce firms to progressively and meaningfully reduce their pollution output and better comply with government environmental regulations. Overall, it has been reported that ISO14000 can positively impact both the performance of the environmental management system (EMS) as well as overall corporate performance.

The main standards of the series ISO 14000 considered for adoption in the paper and cellulose sectors and the shoe and leather industry nowadays are the 14001, the14004 and standards which account for labeling. The ISO 14040 and ISO 14041, which care for life cycle analysis, demand a complex evaluation due to the wide range of variables, which must be considered. It has made it difficult to establish a general standard or driver because of diversity of demands, raw material and processes involved in footwear and leather, paper and cellulose production, for example. It makes standardization exercises, which allow definitions regarding life cycle, become complicated.

FINANCIAL COSTS OF TREATMENT OF WASTES

Waste is part of the economy – it is a by-product of economic activity, by businesses, government and households. Waste is also an input to economic activity – whether through material or energy recovery. The management of that waste has economic implications – for productivity, government expenditure, and, of course, the environment.

Firms' make decisions over how to manage waste impact on their profitability. Where the benefits outweigh the costs, firms can reduce their overall costs and improve productivity by reducing the use of expensive raw materials. Equally, costs can be reduced by optimizing the management of waste which arises. The decisions of consumers in demanding goods and services which lead to waste, impact not only on the environment, but also on the level of government spending required by local authorities to collect and manage household waste.

As well as the economy-wide impacts of waste, there are microeconomic themes around the formation of waste policy. Economics provides a framework in which to think about when intervention by Government might be desirable, as well as what type of policy intervention is appropriate. This paper sets out the key principles for public policy interventions in waste. The aim of applying these principles is to ensure that: there is a reason for Government intervening in a particular market; interventions are cost-beneficial; and any interventions are done in the most cost-effective way.

For example, an important rationale for Government intervention in the waste sector is because of the associated greenhouse gas (GHG) impacts. The management and disposal of waste produces GHG emissions, the full social cost of which is not taken into account either in the production and consumption decisions which lead to the generation of the waste, or in how that waste is managed. Ensuring that the amount of waste is reduced to the economically efficient level, and is optimally managed, will ensure that waste policy is delivering net benefits for society as a whole. Finally, choosing interventions, or a mix of interventions, which deliver emission reductions cost effectively will minimize costs to businesses, the Government (central and local), and the economy more widely – something which is especially important in the current economic climate. Waste policy interventions have particular impacts on public sector spending, through spending by local authorities on waste collection and management, and pursuing cost effective interventions at a time of constrained public finances is important. As well as achieving these aims an efficient waste policy helps to mitigate risks to longer-term sustainable growth, by helping to ensure that natural resources are not unsustainably used today, and contributing to GHG emission reduction targets. A Review of Waste Policies in a country should be done to ensure that the policies and interventions are fit for purpose to meet the challenges a country faces in seeking to create a more resource efficient economy. The economic analysis has to inform the work of the Review and consideration of different policies and intervention.

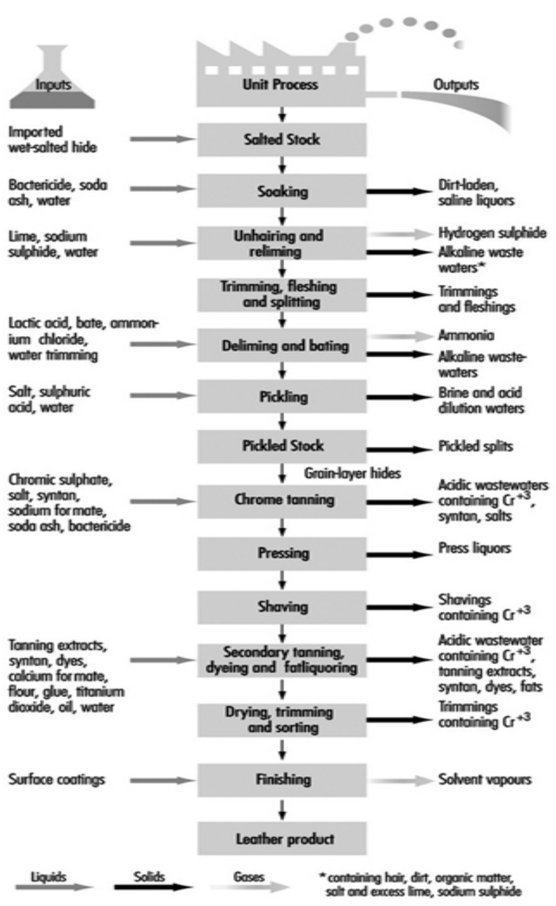
ENVIRONMENTAL IMPACT OF TANNERY WASTES

The treatment and processing of animal hides andskins can be a source of considerable environmental impact. Discharged wastewater contains pollutants from the hides, products from their decomposition and chemicals and various spent solutions used for hide preparation during the tanning process. Solid wastes and some atmospheric emissions also may arise. The major public concern over tanneries has traditionally been about odours and water pollution from untreated discharges. Other issues have arisen more recently from the increasing use of synthetic chemicals such as pesticides, solvents, dyes, finishing agents and new processing chemicals which introduce problems of toxicity and persistence.

Simple measures intended to control pollution can themselves create secondary cross-media environmental impacts such as groundwater pollution, soil contamination, sludge dumping and chemical poisoning.

Tanning technology that is now available, based on a lower chemical and water consumption, has less impact on the environment than traditional processes. However, many obstacles remain to its widespread application.

Environmental impacts & tannery operations



Pollution Control

Water pollution control

Untreated tannery wastes in surface waters can bring about a rapid deterioration of their physical, chemical and biological properties. Simple end-of-pipe effluent treatment processes can remove over 50% of suspended solids and biochemical oxygen demand (BOD) of effluent. More sophisticated measures are capable of higher levels of treatment.

As tannery effluents contain several chemical constituents that need to be treated, a sequence of treatment processes in turn must be used. Flow segregation is useful to allow separate treatment of concentrated waste streams.

Table below summarizes technological choices available for treatment of tannery effluents.

Technological choices for treatment of tannery effluents

Pre-treatment settling	Mechanical screening to remove coarse material Flow equalization (balancing)
Primary treatment	Sulphide removal from beamhouse effluents Chromium removal from tanning effluents Physical-chemical treatment for BOD removal and neutralization
Secondary treatment	Biological treatment Activated sludge (oxidation ditch) Activated sludge (conventional) Lagooning (aerated, facultative or anaerobic)
Tertiary treatment	Nitrification and denitrification
Sedimentation and sludge handling	Different shapes and dimensions of tanks and basins

Air pollution control

Air emissions fall into three broad groups: odours, solvent vapours from finishing operations and gas emissions from the incineration of wastes,biological decomposition of organic matter as well as sulphide and ammonia emissions from wastewaters are responsible for the characteristic objectionable odours arising from tanneries. The siting of installations has been an issue because of the odours that have historically been associated with tanneries. Reduction of these odours is more a question of operational maintenance than of technology.

Solvent and other vapours from the finishing operations vary with the type of chemicals used and the technical methods employed to reduce their generation and release. Up to 30% of the solvent used may be wasted through emissions, while modern processes are available to reduce this to around 3% in many cases.

The practice by many tanneries of incinerating solid wastes and off-cuts raises the importance of adopting good incinerator design and following careful operating practices.

Waste management

Treatment of sludge constitutes the largest disposal problem, apart from effluent. Sludges of organic composition, if free from chrome or sulphides, have value as a soil conditioner as well as a small fertilizer effect from nitrogenous compounds contained therein. These benefits are best realized by ploughing immediately after application. Agricultural use of chrome-containing soils has been a matter of controversy in various jurisdictions, where guidelines have determined acceptable applications.

Various markets exist for the conversion of trimmings and fleshings into by-products used for a variety of purposes, including the production of gelatin, glue, leatherboard, tallow grease and proteins for animal feed. Process effluents, subject to suitable treatment and quality control, are sometimes used for irrigation where water is in short supply and/or effluent disposal is severely restricted.

To avoid problems of leachate generation and odour, only solids and dewatered sludges should be disposed of at landfill sites. Care must be taken to ensure that tannery wastes do not react with other industrial residues, such as acidic wastes, which can react to create toxic hydrogen sulphide gas. Incineration under uncontrolled conditions may lead to unacceptable emissions and is not recommended.

Pollution Prevention

Improving production technologies to increase environmental performance can achieve a number of objectives, such as:

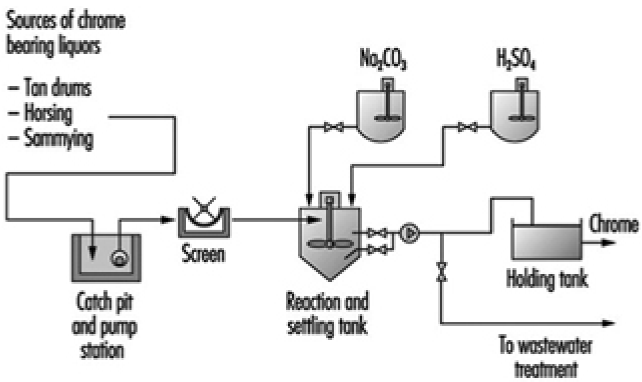
- Increasing the efficiency of chemical utilization
- Reducing water or energy consumption
- Recovering or recycling rejected materials.

Water consumption can vary considerably, ranging from less than 25 l/kg of raw hide to greater than 80 l/kg. Water use efficiency can be improved through the application of techniques such as increased volume control of processing waters, “batch” versus “running water” washes, low float modification of existing equipment; low float techniques using updated equipment, re-use of wastewater in less critical processes and recycling of individual process liquors.

Traditional soaking and unhairing account for over 50% of the BOD and chemical oxygen demand (COD) loads in typical tanning effluents. Various methods can be employed to substitute for sulphide, to recycle lime/sulphide liquors and to incorporate hair-saving techniques.

Reduction in chromium pollution can be achieved through measures to increase the levels of chrome that are fixed in the tanning bath and reduce the amounts that are "bled out" in subsequent processes. Other methods to reduce release of chromium are through direct recycling of used chrome liquors (which also reduces salinity of waste effluent) and the treatment of collected chrome-bearing liquors with alkali to precipitate the chromium as hydroxide, which can then be recycled. An illustration of a communal chrome recovery operation is shown in figure below

Flow chart for a communal plant for chrome recovery



The incoming effluent, after analysis, is treated to produce chrome hydroxide. This is redissolved, polished and subjected to further analysis before being passed back for use in the tanning process.
Source: UNEP 1991.

Where vegetable tanning is employed, preconditioning of hides can enhance the penetration and fixation of tans and contribute to decreased tannin concentrations in effluents. Other tanning agents such as titanium have been used as substitutes for chromium to produce salts of generally lower toxicity and to generate sludges that are inert and safer to handle.