Leather industry has grown by leas and bounds over the past decades as leather has become a material of choice in the world of high fashion. Concerns about environmental pollution from leather processing have lead to increasingly stricter laws and regulations. New bio-processing techniques offer new possibilities for leather manufacturers to protect the environment along with business bottomlines.

Leather making has been known to man since prehistoric times when hides and skins were used as protective wear and for other utility purposes. However, the understanding of the scientific principles behind leather making came much later. This resulted in newer processes and methodologies for making leather softer & fuller. Improvements in quality of leather led to its newer applications and widening appeal that integrated the manufacturer with the fashion markets of the world.

In India, leather industry occupies a prominent position and is one of the top foreign exchange earners for the country. Exports of leather products have grown to Rs. 14,000 crores in 2007-08 from Rs. 32 crores in 1965-66. Importantly, India has moved up the value chain and now primarily exports finished leather as against being an exporter of raw hides and skins earlier. It is not surprising that the turnover of leather industry now touches Rs. 30,000 crores, about 50% of this being exports. Overtime, Indian leather industry has carved a niche for itself in the competitive leather markets through quality of its manufacturing. Indian manufacturers now supply to some of the best brand names in the world such as Nike, Reebok, Florsheim, Harrods, Marks & Spencer, Deichmann, Pierre Cardin and so on. Leather industry is also employment intensive employing more than 2.5 million people in the country, of which 30% are women. For a snapshot on Indian leather industry also see figures on pg. 5.

Inddian leather industry is poised for a quantum jump in its annual exports (from current 3.5 bn USD to 7bn USD by 2011) by leveraging its core strengths in terms of availability of raw materials and human skills. Scale expansions in production capacities of finished leather and footwear are planned that aim at doubling finished leather production and achieve a fivefold increase in production of footwear. This scale expansion is expected to generate additional and significant employment opportunities in this sector.
On the technological front the industry has time and again met the challenge of abiding with environmental regulations deriving strength from its association with the Central Leather Research Institute, (CLRI), Chennai. Even then, as volumes and value of leather manufacturing expand, environmental considerations in leather processing and compliance with a progressively tightening pollution control regime attains unprecedented urgency and significance.

**Technological Challenge**

Leather manufacture involves chemical processing of a biological material, namely skin. Skin is perishable and is susceptible to degradation by microorganisms. In the course of conversion of skin into leather, large quantities of inorganic chemicals are employed to prepare skin for tanning during what are termed as beam house processes. Beam house operations aim at removal of unwanted materials including inter fibrillary matter and physical opening up the fabric structure of skin. This is done through use of large quantities of chemicals such as lime, sodium sulfide, ammonium salts, common salt and sulphuric acid. More than 80% of chemical pollution associated with leather processing all over the world is on account of chemicals employed in beam house operations. (See pg.6 for a schematic representation of input-output analysis).

The technological challenge is to replace the chemicals employed in beam house operations.
in leather making with biological alternatives. If such a paradigm shift is to be realized in commercial scale operations, it is necessary to ensure that a) only unwanted matrix components of skin are removed, b) the fibre structure of skin is opened up to required levels for further processing and c) the cost of processing leather through bioprocessing methodology matches favourably with current chemical-based methods. Since currently employed methods of leather manufacture lead to avoidable loss of high value matrix components in skin, bioprocessing as an alternative should also aim at higher recovery of these components.

The technological challenges that hinder the employment of bio-processing methodologies in leather manufacturing in place of chemical processing of skin have not been adequately addressed till date. Broadly speaking, the technical challenges faced by the industry in shifting to bioprocessing methodologies can be listed as under:

**Ambient Preservation Without Use of Common Salt or Drying:** Since skin is perishable it is preserved with common salt as soon as the raw skin is removed from a dead animal. The quantity of salt employed for short term preservation is large and almost equals the weight of raw skin. When the salted skin or hide is processed into leather, the first operation in a tannery is to remove the common salt applied for short term preservation which requires large quantities of water per kilogram of leather processed (see figure below). When discharged, this water causes addition of salinity to the soil which is a major environmental problem associated with leather making. It is understandable that replacement of common salt in short term preservation can offer significant environmental advantages. Preservation of skin without salting or drying under ambient conditions is therefore a major technological challenge in making leather manufacturing more environment friendly.

**Removal of Lime and Sodium Sulfide In Leather Processing:** Removal of hair and flesh from raw skin is an essential step in leather manufacturing process. This is accomplished by treatment of skin with a mixture of lime and sodium sulfide. Sodium sulfide breaks down the disulfide bonds in the hair protein (keratin) and aids in removal of hair. Treatment with lime and sulphide also leads to the removal of unwanted matrix components like proteoglycans, lipids, pigments etc. Lime causes swelling of skin by promoting reversible imbibing of large quantities of water through osmosis. Force generated on account of osmotic swelling of skin opens up the fibre structure of skin. Osmotic swelling also helps in consolidation of leather making substances which facilitates mechanical removal of flesh.
A bioprocessing methodology must aid in removal of hair and flesh on one hand, and open up the fiber structure of skin by selective digestion of proteoglycans, lipids and other unwanted matrix components on the other. While enzyme-assisted removal of hair has been found to be technologically feasible, removal of hair, flesh and all other unwanted matrix components in skin using only enzymes without the aid of chemicals has not yet been accomplished anywhere in the world. The technological challenge thus lies in removal of hair, flesh and all other unwanted matrix components with the aid of biological materials and complete avoidance of all inorganic chemicals employed currently by the industry.

Ready to Tan Pelt from Bioprocessing of Skin: Since the current technology employs lime and sulphide for removal of hair and flesh, an intermediate deliming operation using ammonium salts is necessary to mitigate toxic effects of hydrogen sulphide. Elimination of sodium sulphide in removal of hair also obviates the use of ammonium salts with large environmental benefits. Also, if the skins were not subjected to osmotic swelling as practiced in the commercial processes, an opportunity to process leather without alternation of pH (in the range of 12.5 to 2.5) is opened up with significant environmental advantages.

Few Millennium Indian Technology Leadership Initiative
To address these challenges, a knowledge network of 12 eminent research groups from different institutions was formed under the New Millennium Indian Technology Leadership Initiative (NMITLI) of the Council of Scientific and Industrial Research (CSIR). The technological challenges encountered in processing of leather without the aid of chemicals were posed to the partners in this network. In response, the network developed 18 technology leads and evaluated a total of 40 enzyme formulations to assess their technical feasibility in processing of leather.

Biological Alternatives for Ambient Short Term Preservation of Skin: The efforts of the knowledge network have led to the development of biological alternatives to use of common salt in short term preservation of skin. The approach adopted has been to identify and engineer the production of bacteriocin from micro organisms antagonistic to skin spoilage bacteria (see figure above). Capitalising on the technological leads from the field of microbial biotechnology, an opportunity for ambient preservation of skin based on biologicals has been opened up.

Cleaner and Greener Processing of Leather

Enzyme Formulations for Leather Processing: A total of eight enzyme formulations for removal of hair, four lipases for digestion of flesh and two commercially available amylases for enzymatic opening up of fibre structure without the use of lime and sodium sulphide have
been standardized. Complete elimination of several beam house chemicals namely, common salt, lime, sodium sulphide, ammonium salts and sulphuric acid from leather processing has been demonstrated as feasible.

Trials Completed
The concept of bioprocessing has been convincingly proved to a group of tanners and enzyme formulating companies. Leathers have been processed without the aid of chemicals in the beam house successfully and technical benefits with quality improvement have been quantified. Technologies for enzymes and other biological formulations have at present been standardized at levels of 300-500 Kg. per batch. Moreover, the formulations have been evaluated by the Central Leather Research Institute under both laboratory as well as user’s field conditions (see pictures above).

Quantification of Environmental Benefits
Beamhouse operations lead to generation of significant levels of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Dissolved Solids (TDS) on one hand, and solid wastes on the other. This results in environmental problems associated with disposal of solid and liquid wastes. BOD and COD generated during beam house operations are amenable to treatment. The amount of waste discharged from leather processing (per ton of raw material) includes about 700-750 Kg. of solid wastes, 40,000 litres of liquid wastes and 400-450 Kg. of total dissolved solids (salt). In the existing chemical-based leather processing technology, a large quantity of biomaterials having significant economic value are contaminated with chemicals and converted into solid wastes. In this context bioprocessing of leather offers a technological opportunity to achieve 2100 mg/Litre TDS and 100 Kg/MT solid waste norms with following potential environmental benefits:

- IBOD reduction by not less than 50%.
- ICOD reduction by not less than 50%
- A TDS reduction by not less than 40%
- Sulfide reduction by 100%

Way Forward
Efforts focussing on application of biotechnological approaches in processing of leather as outlined above and anchored under the NMITLI program of the CSIR, have led to technological breakthroughs on a global platform. The project presents a successful case of first principle in science leading to viable and breakthrough technologies for use by a tradition bound industry like leather.
However, since these technological breakthroughs involve a paradigm shift in manufacturing approaches, it is necessary to prove the technology developed on a credible scale and also customize the application of generic methods of leather making for different raw material stock as well as various end uses of leather. Enzyme formulations would need to be differently prepared for use with cow, buffalo, goat and sheep based raw materials. Application conditions for biological materials would also need to be fine tuned for making shoe uppers, garments, gloves and industrial leathers.

To achieve the above mentioned last mile goals, a new Public-Private Partnership is now being designed to prove technologies at credible scales under industrial conditions.